Total Maximum Daily Loads of Nitrogen and Phosphorus for Fairlee Creek

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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
CWA	Clean Water Act
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
EUTRO5	Eutrophication Module of WASP5
FA	Future Allocation
FCEM	Fairlee Creek 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	Nonpoint 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 can receive without violating water quality standards.

The Fairlee Creek was identified on the State's 1996 list of WQLSs as impaired by nutrients (nitrogen and phosphorus). This report proposes the establishment of two TMDLs for the Fairlee Creek: one for nitrogen and one for phosphorus.

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

EXECUTIVE SUMMARY

This document establishes Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus in the Fairlee Creek. Fairlee Creek drains directly to the Chesapeake Bay, and is part of the Upper Eastern Shore Tributary Strategy Basin. The creek is impaired by the nutrients nitrogen and phosphorus, which 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 standards at levels whereby the designated uses for the Fairlee Creek will be met. The TMDL was determined using the WASP5 water quality model. Total loading caps for nitrogen and phosphorus entering the Fairlee Creek are established for average 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 654 lb/month, and the low flow TMDL for phosphorus is 77 lb/month. These TMDLs apply during the period May 1 through October 31. The annual TMDL for nitrogen is 83,420 lb/yr, and the annual TMDL for phosphorus load is 6,310 lb/yr. Allowable loads have been allocated between point and nonpoint sources. The estimated annual nonpoint source loads for the TMDLs are based on land uses projected to the year 2000. The annual point source loads make up the balance of the allocation. The low flow nonpoint 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.

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 the Tributary Strategies 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 margin of safety (MOS) for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a WQLS can receive and still meet water quality standards. The Fairlee Creek was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment**.** It was listed as being impaired by nutrients. This document establishes TMDLs for the nutrients nitrogen and phosphorus in Fairlee Creek.

Fairlee Creek was identified as being impaired by nutrients due to signs of eutrophication, and low dissolved oxygen. Eutrophication, the overenrichment of aquatic systems by excessive inputs of nitrogen and phosphorus**,** was evidenced in Fairlee Creek by recurrent seasonal algal blooms. Land development as well as the addition of point source discharges can increase the rate of eutrophication to problematic levels. Highly eutrophic waters will characteristically have fewer species present, and particularly high concentrations of algae. Due to the algae, dissolved oxygen levels are likely to fluctuate between day and night, which can cause fish kills. The estuarine portion of Fairlee Creek is classified as a Use II water and all free flowing portions are classified as Use I waters. Code of Maryland Regulations (COMAR) 26.08.02. High concentrations of algae and wide fluctuations in dissolved oxygen can interfere with the designated uses for Fairlee Creek, and therefore cause a violation of the water quality standards of the State. For these reasons, this document will address high levels of nitrogen and phosphorus to control chlorophyll *a* concentrations (a surrogate for algal blooms) and to maintain dissolved oxygen standards.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Fairlee Creek, is located in Kent County, Maryland (Figure 1). It drains directly to the Chesapeake Bay roughly three miles due east of Pooles Island. The Creek is approximately 5.2 miles in length, from its confluence with the Bay to the upper reaches of the headwaters. The Fairlee Creek watershed has an area of approximately 8,470 acres or 13.2 square miles. The predominant land use in the watershed, based on 1990 Maryland Office of Planning information, (Figures 2 and 3) is mixed agriculture (5,520 acres or 65%), with other areas being under forest (2,540 acres or 30%) and urban (410 acres or 5%).

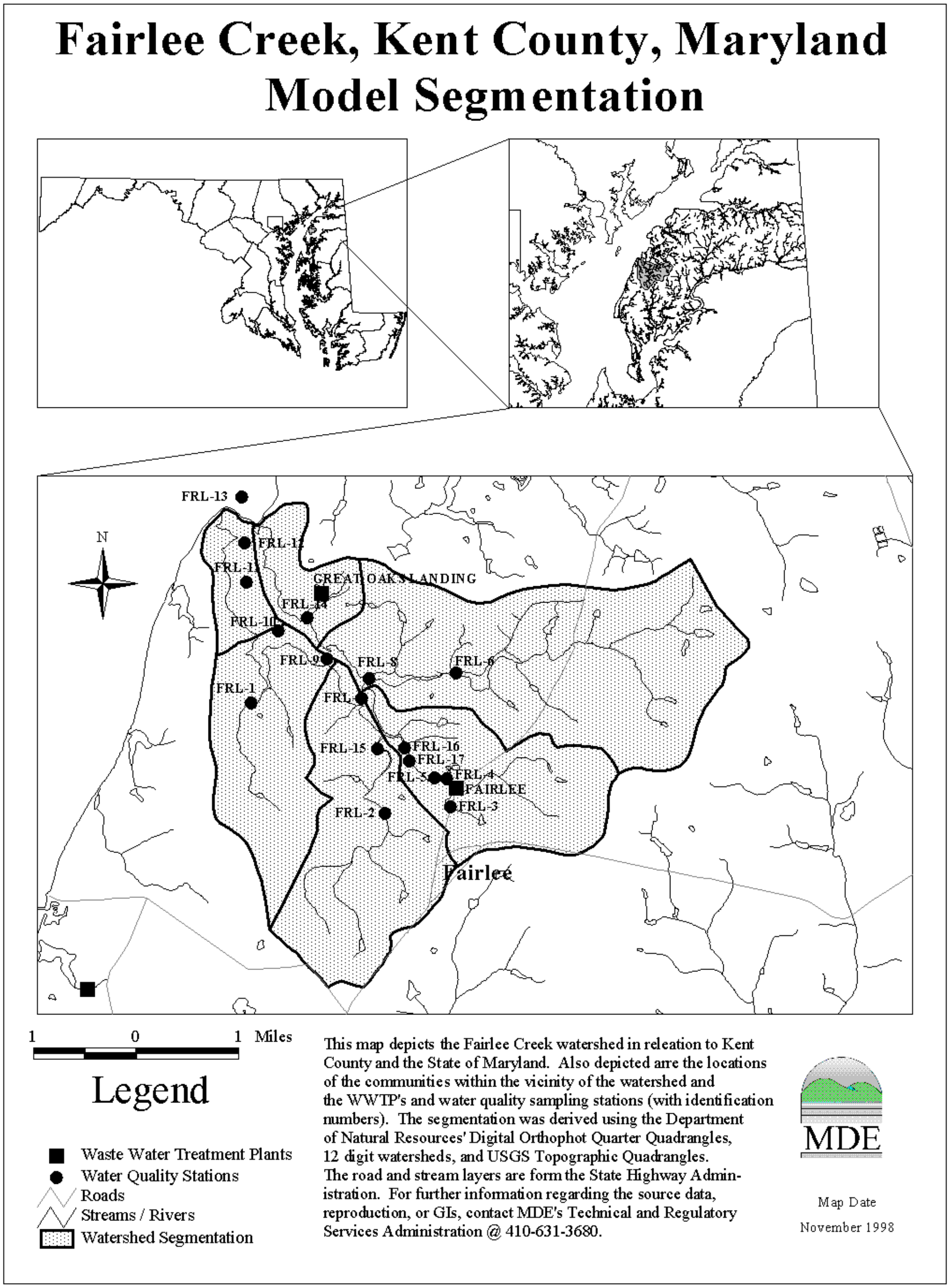

Figure 1: Location Map of the Fairlee Creek Drainage Basin within Maryland

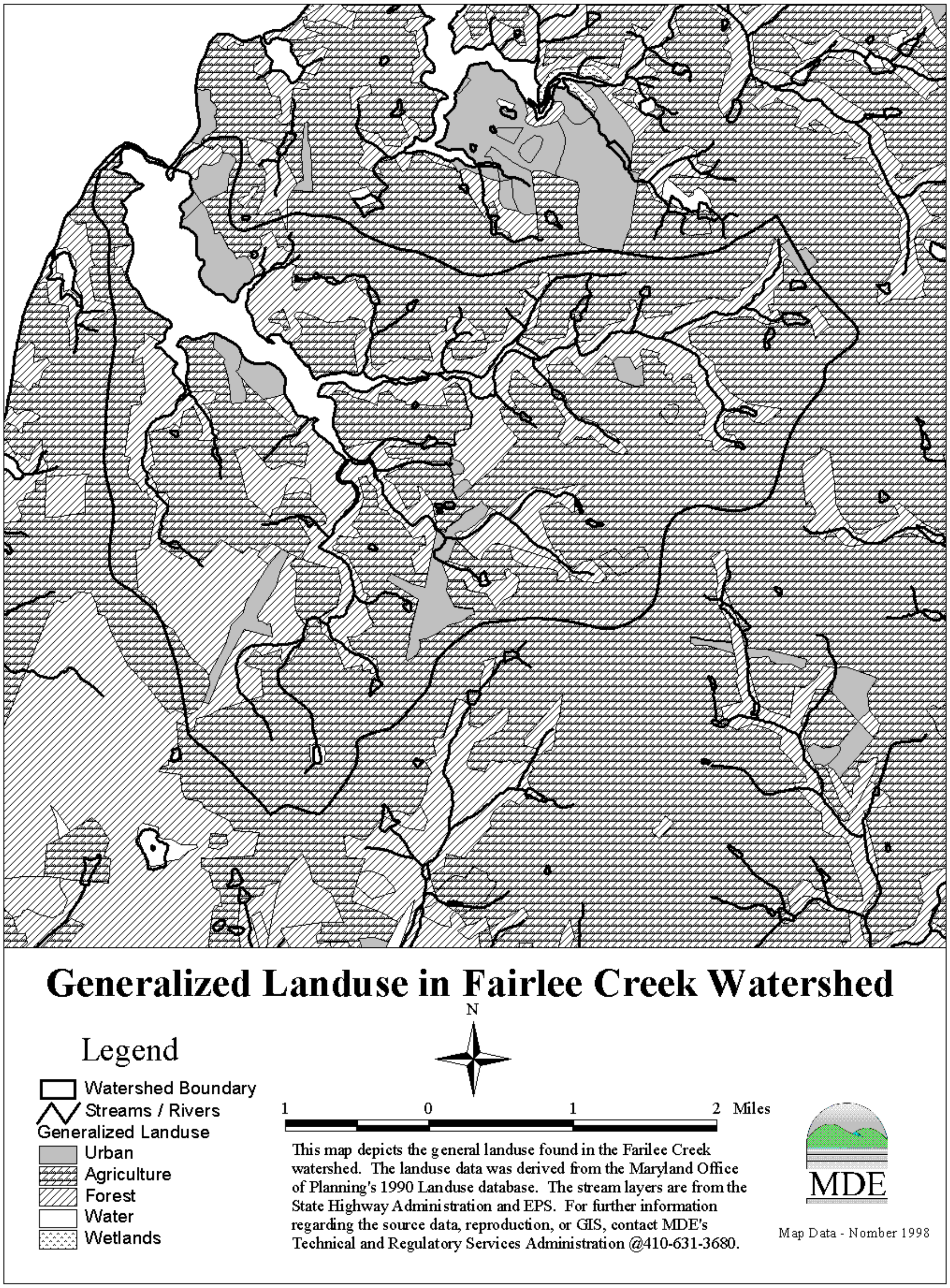

Figure 2: Predominant Land Use in the Fairlee Creek Drainage Basin

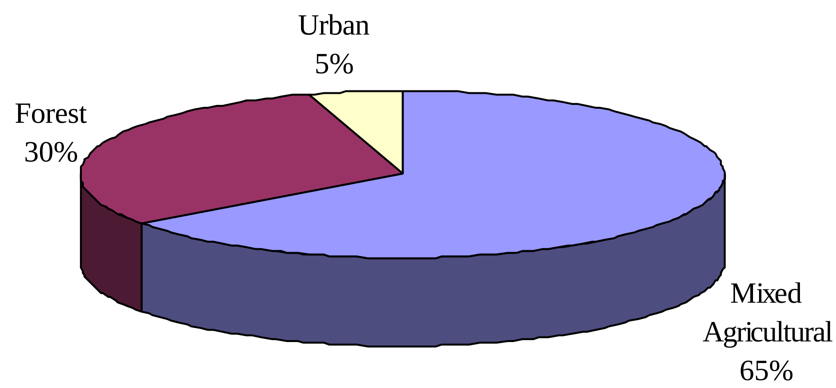

Figure 3: Estimated 1990 Land Use in the Fairlee Creek Drainage Basin

Fairlee Creek is tidal throughout its navigable reach, which extends from the highly depositional delta area at its mouth for approximately 2.2 miles upstream to an area known as Goose Hollow. Above the limit of navigability of most powerboats, Fairlee Creek's mainstem bifurcates into separate branches, with one traveling due south and the other continuing along the centerline of the Creek towards the southeast. Numerous beaver dams are located on both of the upper free flowing branches, which dramatically reduces creek velocities in these branches. Depths of the river range from about 1 foot in the headwaters to greater than 5 feet in the tidal zone prior to the creek's confluence with the Chesapeake Bay.

In the Fairlee Creek watershed, the estimated total nitrogen load is 90,154 lb/yr, and the total phosphorus load is 6,543 lb/yr, for the year 1991 (Figure 4). The existing nonpoint source loads were determined using land use loading coefficients. The land use information was based on 1990 Maryland Office of Planning data. The total nonpoint source load was calculated by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficients. The loading coefficients were based on the results of the Chesapeake Bay Model (U.S. EPA, 1991), which was a continuous simulation model. The Chesapeake Bay Program nutrient loading rates account for atmospheric deposition[1], loads from septic tanks, and loads coming from urban development, agriculture, and forest land. The total nitrogen load coming from nonpoint sources is 88,526 lb/yr, and the total nonpoint source phosphorus load is 6,355 lb/yr.

The point source flows came from the discharge monitoring reports stored in MDE's point source database. However, because both of the WWTPs (Wastewater Treatment Plants), Fairlee and Great Oak Landing, have such small discharges, neither are required to report nitrogen or phosphorus concentrations. So, to calculate the loads, WWTP effluent concentration were

1 Atmospheric deposition directly to the water's surface was not taken into account. The surface area of the water in the Fairlee Creek Basin only accounts for a small amount of the total surface area of the watershed. And, the majority of the water surface, the estuary, is located downstream from the impairment. Thus, the contribution from atmospheric deposition directly to the water's surface was considered insignificant.

estimated using measured water quality effluent data from July and August of 1991. The July and August data was selected because it was the most reliable field data which was readily available. When used in conjunction with the actual plant flows the estimated concentrations give a reasonable estimate of the yearly loads. The total nitrogen load coming from point sources is 1,628 lb/yr, and the total nitrogen point source load is 188 lb/yr. The year 1991 was used because this is the year for which all relevant water quality data was measured.

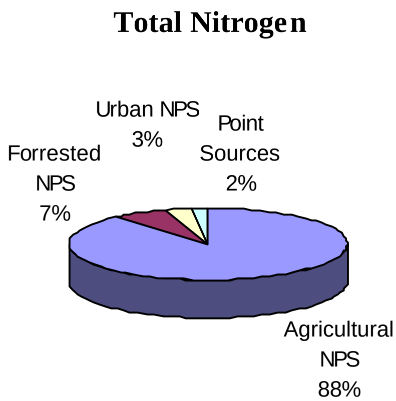

Figure 4: 1991 Nitrogen and Phosphorus Point and Nonpoint Source Loadings

2.2 Water Quality Characterization

The water quality of four physical parameters, chlorophyll *a*, inorganic phosphorus, ammonia, and dissolved oxygen, were examined to determine the extent of the impairment in Fairlee Creek. Four water quality surveys were conducted in the Fairlee Creek watershed in July and August of 1991. Figure 1 identifies the locations of the water chemistry sampled during each survey. The months of July and August represent critical conditions for the Fairlee Creek. This is because in July and August 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 water quality data from 1991 was used because it was comprehensive and also readily available.

Figure 5 presents a longitudinal profile of chlorophyll *a* data sampled during the 1991 field surveys. The sampling region covers the entire tidal portion of the Fairlee Creek from its confluence with the Chesapeake Bay (Station FRL-13), and includes free-flowing stations in the southeast tributary leading up to and above the Fairlee WWTP. Table 1 states the location (in miles from Fairlee Creek's mouth) of all the water quality stations. As the data indicates, ambient chlorophyll *a* concentrations for the first 2.5 miles are all below 50 µg/l. However, the levels are much greater above 2.5 miles, where mean values are about 80 µg/l, with a maximum concentration of over 200 µg/l.

Dissolved oxygen concentrations along the longitudinal profile are depicted in Figure 6. As the data indicates, above station FRL-7 (2.623 miles) the dissolved oxygen levels fall below the standard of 5 mg/l. In the tidal portion of the creek, dissolved oxygen concentrations are well above the standard.

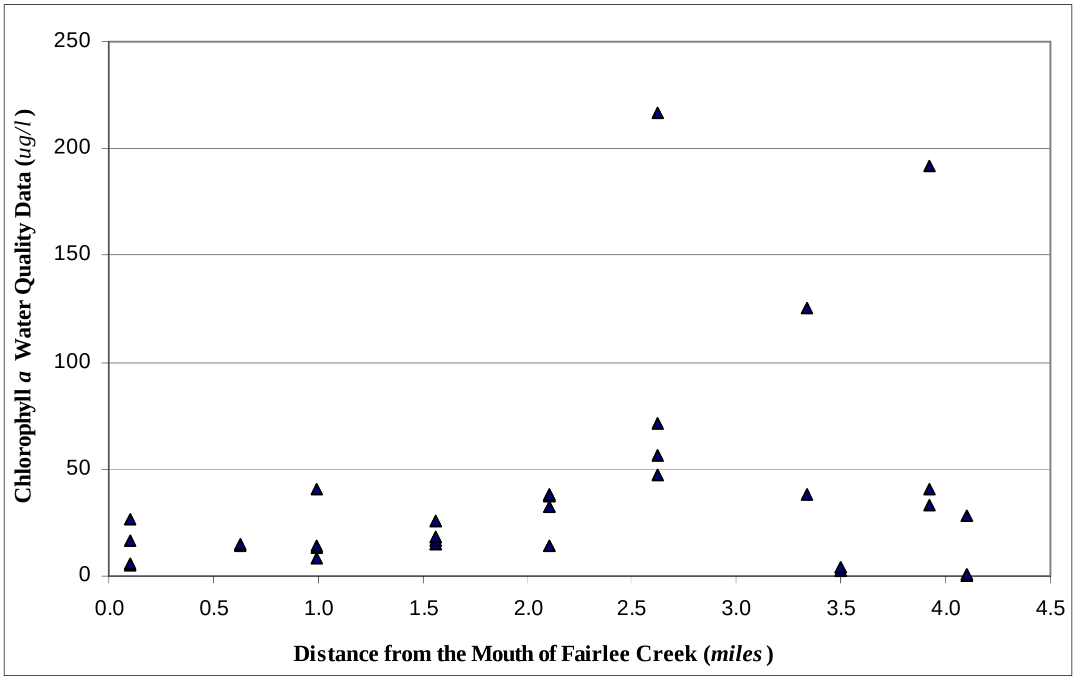

Figure 5: Longitudinal Profile of Chlorophyll *a* Data

Table 1: Location of Water Quality Stations

Water Quality Station	Miles from Mouth of Fairlee Creek
FRL-13	0.099
FRL-12	0.628
FRL-11	0.994
FRL-10	1.566
FRL-9	2.107
FRL-7	2.623
FRL-16	3.337
FRL-17	3.499
FRL-5	3.922
FRL-4	4.102

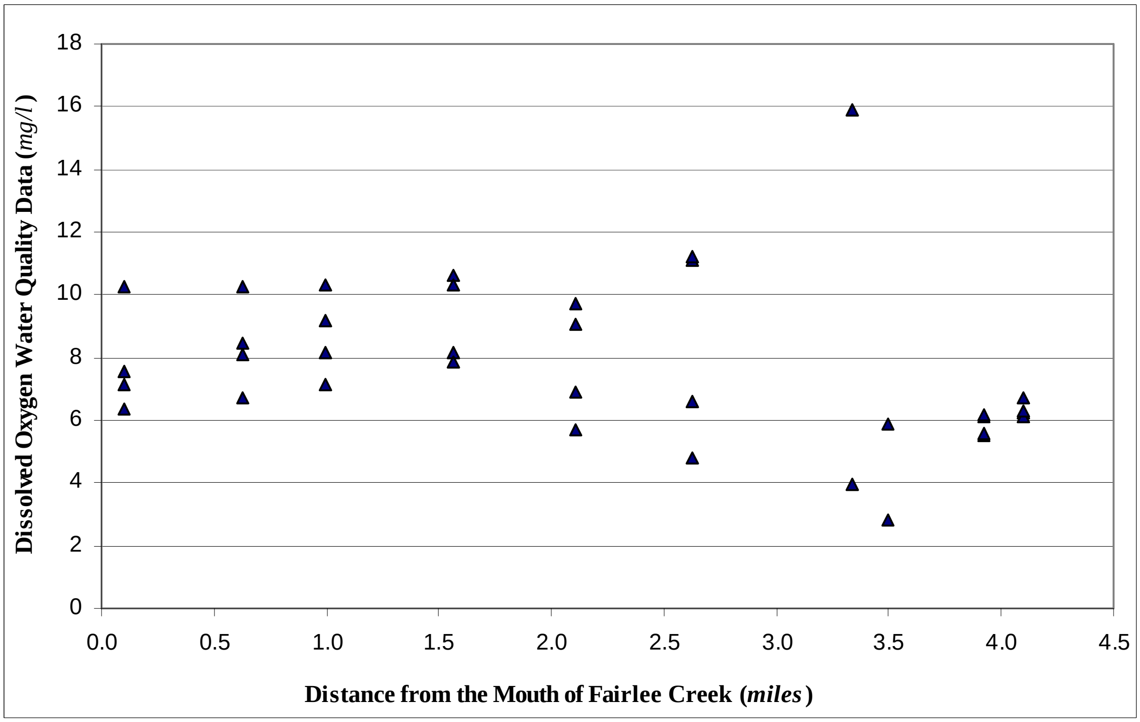

Figure 6: Longitudinal Profile of Dissolved Oxygen Data

The ammonia levels along the longitudinal profile are depicted in Figure 7. In the tidal portion of Fairlee Creek, ammonia levels are generally less than 0.05 mg/l. However, the concentration of ammonia increases rapidly in the free-flowing southeast tributary, with peak values in the immediate vicinity of the Fairlee WWTP outfall exceeding 0.2 mg/l at station FRL-5.

Figure 8 presents a longitudinal profile of inorganic phosphorus as indicated by ortho-phosphate levels measured in samples collected in 1991. They are similar to that of ammonia, with concentrations in the tidal portion measured at or near the level of detection (0.01 mg/l), with elevated levels near the outfall of the Fairlee WWTP with a maximum concentration of greater than 0.09 mg/l.

2.3 Water Quality Impairment

The Fairlee Creek system is impaired by an overenrichment of nutrients. Nitrogen and phosphorus loadings from both point and nonpoint sources have resulted in higher than acceptable chlorophyll *a* concentrations and dissolved oxygen concentrations below the standard of 5 mg/l. Mean summer concentrations of chlorophyll *a* in the upper reaches of the southeast branch of Fairlee Creek range between 50-150 µg/l, with nuisance algal bloom levels periodically reaching 250 µg/l. Mean summer concentrations of dissolved oxygen in the same region of Fairlee Creek range between 4-10 mg/l, with severe depletion resulting in concentrations low as 2.5 mg/l.

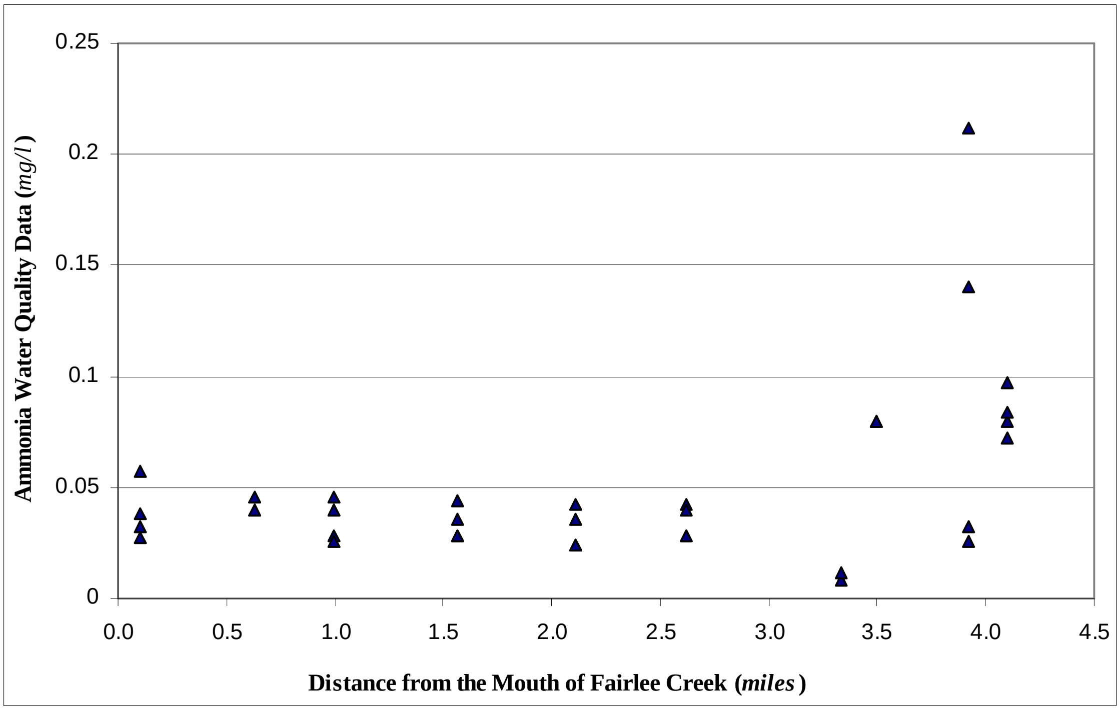

Figure 7: Longitudinal Profile of Ammonia Data

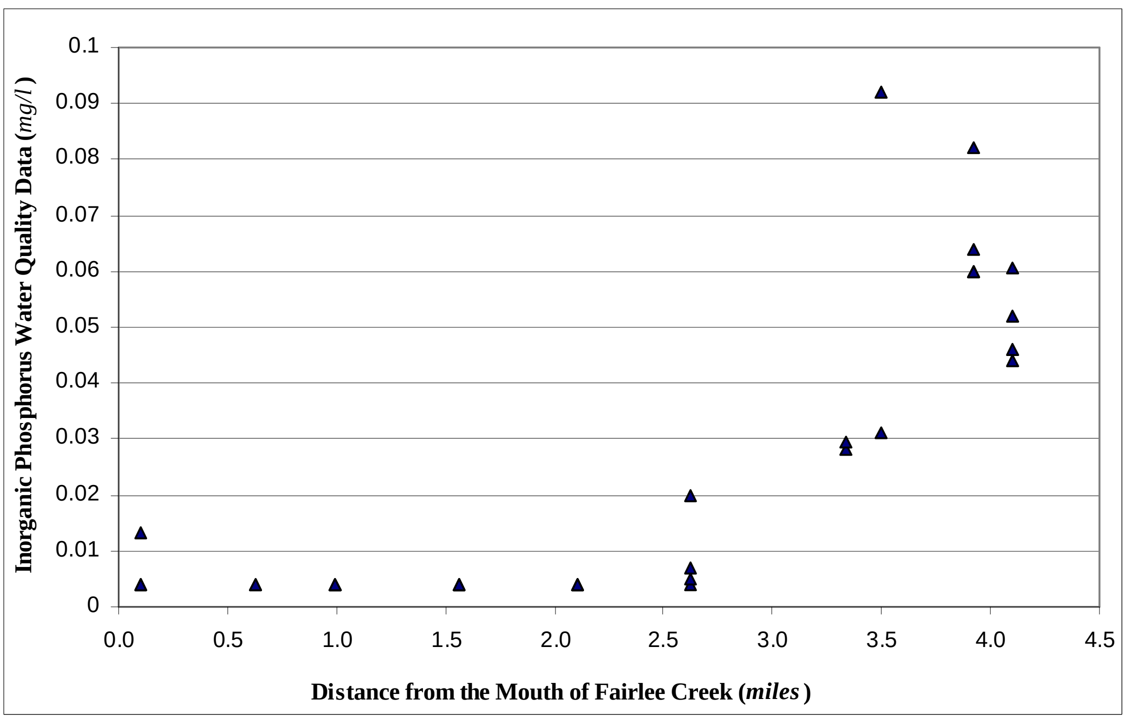

Figure 8: Longitudinal Profile of Inorganic Phosphorus Data

3.0 TARGETED WATER QUALITY GOAL

The objective of the TMDLs for nitrogen and phosphorus for the Fairlee Creek is to reduce nutrient inputs to a level that will ensure the maintenance of the dissolved oxygen standards and reduce frequency and magnitude of algal blooms. Specifically, the TMDLs for nitrogen and phosphorus for the Fairlee Creek are intended to:

1. Assure that a minimum dissolved oxygen level of 5 mg/l is maintained throughout the Fairlee Creek system, and,

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

The dissolved oxygen level is based on specific numeric criteria for Use I & II waters set forth in the Code of Maryland Regulations 28.08.02. The chlorophyll *a* water quality level is based on the designated use of Fairlee Creek, and guidelines set forth by Thomann and Mueller (1987) and by the EPA *Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part* (1997).

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the nutrient TMDLs and total loading allocations for point sources and nonpoint sources were developed for the Fairlee Creek. The first section describes the modeling framework for simulating nutrient loads, hydrology, and water quality responses. The second and third sections summarize the scenarios that were explored using the model. The assessment investigates water quality responses assuming different stream flow and nutrient loading conditions. The fourth and fifth sections present the modeling results in terms of TMDLs, and allocate the TMDLs between point sources and nonpoint 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 Fairlee Creek TMDLs was WASP5. 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 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling

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2 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.

(CEAM) in Athens, GA (Ambrose *et al.*, 1988). EUTRO5 is the component of WASP5 that simulates eutrophication, incorporating eight water quality constituents in the water column and the sediment bed.

The spatial domain of the Fairlee Creek Eutrophication Model (FCEM) extends from the confluence of the Fairlee Creek and the Chesapeake Bay for about 3.4 miles along the mainstem and southeast tributary of Fairlee Creek. Three tributaries, other than the southeast tributary, that drain into Fairlee Creek are also included in the modeling domain. Fairlee WWTP discharges into the southeast tributary, and Great Oak Landing WWTP discharges into a tributary closer to the mouth of the creek, called Great Oak Landing Cove in this document.

Freshwater flows and nonpoint source loadings are taken into consideration by dividing the drainage basin into 6 subwatersheds (Figure 9) and assuming that these flows and loadings are direct inputs to the FCEM, with the exception of the three tributaries. Figure 9 also shows the water quality segmentation used for the FCEM.

The FCEM inputs, including nonpoint 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 FCEM was calibrated using the water quality monitoring data collected during July and August 1991. The results of this calibration for chlorophyll *a* and dissolved oxygen are shown in Figure 10, and the complete details are presented in Appendix A. As can be seen, the calibration of the model captured the peak chlorophyll *a* concentrations, and did well in capturing the trend in the dissolved oxygen concentrations.

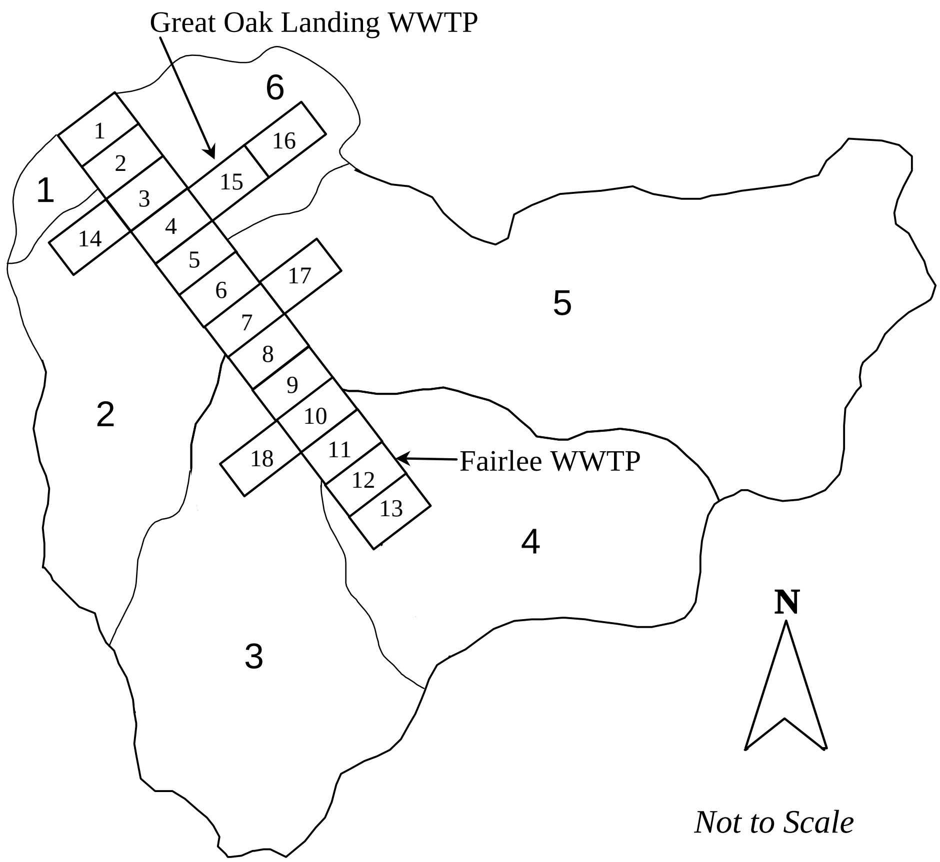

Figure 9: The 6 Subwatersheds of the Fairlee Creek Drainage Basin

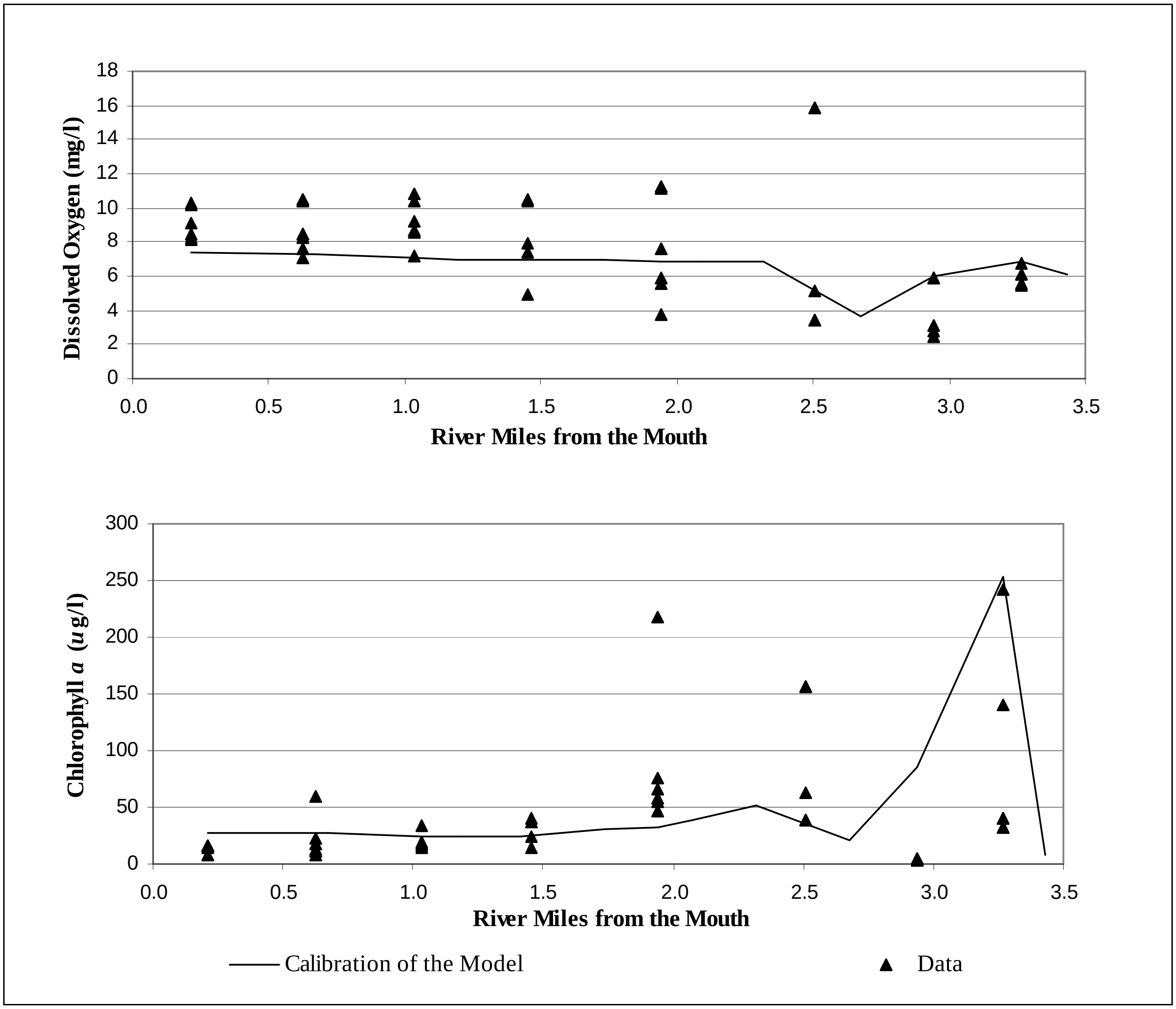

Figure 10: Results of the Calibration of the Model for Chlorophyll *a* and Dissolved Oxygen

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. The total point and nonpoint source nutrient loads were established to achieve the water quality goal of maintaining a dissolved oxygen concentration standard of 5 mg/l and reducing chlorophyll *a* concentration to 50 μg/l.

The nutrient loading scenarios are grouped according to *base case* and *future conditions*. The base case conditions represent the nutrient loads and water quality status in 1991. The year 1991 was used because data was available for both low flow and average flow conditions, and all point sources were operating in that year. This choice of base line year does not affect the outcome of the TMDL, which depends on projections calculated by the model**.** The future conditions represent the system after the Fairlee WWTP has removed its discharge from Fairlee Creek. The future conditions also project the maximum allowable nutrient loads the system can incorporate without incurring an impairment. The final conditions include a margin of safety intended to account for estimation uncertainties in a manner that is environmentally conservative.

For both point and nonpoint 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 creek.

The first scenario represents the base case conditions of the stream at low flow, 1.56 cfs, and warm water temperatures (above 70 ^{0}F). There are no flow gages in Fairlee Creek watershed. Flow was determined using a nearby United States Geological Survey (USGS) flow gage in Morgan Creek (01493500). Morgan Creek was chosen because it is relatively the same size as the Fairlee Creek watershed, and the two are located close together. The flow from Morgan Creek was then apportioned to the 6 watersheds in Fairlee Creek based on relative drainage area size. For the first scenario, the 7-day consecutive lowest flow expected to occur every 10 years, known as the 7Q10 flow, was used. The total nonpoint source (NPS) loads were computed using 1991 base-flow field data. The nonpoint source loads reflect atmospheric deposition, loads from septic tanks, and other nonpoint sources loads coming off the land. The total point source loads were actual effluent loads measured during the 1991 water quality surveys.

The second scenario represents the base case conditions of the stream at average flow, 11.1 cfs total flow in the basin. The total nonpoint source loads were calculated using the same methodology described in the beginning of the document for the 1991 loads**.** They were based on average loading rates that are consistent with the Chesapeake Bay Program loading rates (U.S. EPA, 1991), and account for both atmospheric deposition and loads from septic tanks. The total point source loads were average loading values taken from 1991 discharge monitoring reports, and the 1991 water quality surveys (DMRs).

In 1996 Fairlee WWTP stopped discharging to Fairlee Creek. Previous modeling of the Fairlee Creek system had determined that the nutrient reductions necessary at the Fairlee WWTP to achieve water quality standards in the river would be too costly to implement. The loads that used to be received by Fairlee WWTP, are now diverted to Tolchester WWTP. No follow up data has been taken in Fairlee Creek in 1998. In the next two scenarios, the model was used to predict the water quality response in the Creek without the Fairlee WWTP discharging to see if a water quality violation was still occurring.

The third scenario represented the future conditions, without the Fairlee WWTP, for the case of low stream flow. The total nonpoint source flows were the same as for scenario 1. Nonpoint source loads were simulated as 1991 summer base flow nutrient concentrations plus a 5% margin of safety (MOS). The 1991 base flow nonpoint source loading was selected because it was the most reliable field data which was readily available. Because the 1991 loads represent base-flow loads attributable to mostly groundwater recharge, it is not expected that the loads will have changed significantly between 1991 and 1998. Total point source loads for the summer low flow critical conditions made up the balance of the total allowable load. It was assumed that the Fairlee WWTP was not discharging to the Creek. Details of this modeling activity are described further in the technical memorandum entitled *Significant Nutrient Point Sources in the Fairlee Creek Watershed.*

The fourth scenario represented future conditions, without the Fairlee WWTP, for the case of average stream flow. The total nonpoint source loads reflect estimated year 2000 loads for both nitrogen and phosphorus. The year 2000 nonpoint source loads were calculated using the same methodology described in the beginning of the document, for the 1991 loads. The year 2000 loading rates were based on the results of the Chesapeake Bay Model (U.S. EPA, 1991), and accounted for loads from both atmospheric deposition and septic tanks. It was estimated from Maryland Department of Agriculture's (MDA's) agricultural BMP database, and reduction factors from the Tributary Strategies Technical Appendix, that a 10% reduction in nitrogen loads and a 9% reduction in phosphorus loads has already been achieved in the Fairlee Creek watershed. These reductions were subtracted from the nonpoint source loads entering the system, for more detailed information see Appendix A. A 3% margin of safety was also added to the nonpoint source loads. Total point source loads for the average annual conditions made up the balance of the total allowable load. It was assumed that the Fairlee WWTP was not discharging to the Creek. Details are described further in the technical memorandum entitled *Significant Nutrient Point Sources in the Fairlee Creek Watershed.* The loads used in all the model scenario runs are shown in Table 2.

Table 2: Point and Nonpoint Source Loads used in the model Scenario Runs

Scenario	**Point Source**			**Nonpoint Source**			**MOS**	
#	Flow	Nitrogen	Phosphorus	Flow	Nitrogen	Phosphorus	Nitrogen	Phosphorus
	mgd	*lb/day*	*lb/day*	*cfs*	*lb/day*	*lb/day*	*lb/day*	*lb/day*
1	0.065	4.43	0.535	1.56	14.8	1.53	N/A	N/A
2	0.065	4.43	0.535	11.0	243	17.4	N/A	N/A
3	0.014	0.7	0.37	1.56	14.8	1.53	0.45	0.05
4	0.014	0.7	0.37	11.0	218	15.8	7.26	0.52

4.4 Scenario Results

Base Case Scenarios:

1. *Low Flow:* Assumes low stream flow conditions. Assumes the 1991 low flow nonpoint source loads, and 1991 average July and August point source loads for the point sources.

2. *Average Annual Flow:* Assumes average stream flow conditions. Assumes the 1991 average annual nonpoint source loads, and 1991 average annual point source loads for the point sources.

The first scenario represents the base case for summer low flow conditions when water quality is impaired by high chlorophyll *a* levels, and low dissolved oxygen concentrations. 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 can be seen in Figure 10. Figure 10 also shows the dissolved oxygen levels for these scenarios. It can be seen that the dissolved oxygen level falls below the standard of 5 mg/l in scenario one.

Future Condition Scenarios:

3. *Low Flow:* Assumes low stream flow conditions. Assumes 1991 summer low flow nonpoint 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. Assume year 2000 nonpoint source loads with nitrogen reduced by 10% and phosphorus by 9%, plus a 3% margin of safety added to both of the computed loads. Assumes that point source loads for the average annual conditions make up the balance of the total allowable load.

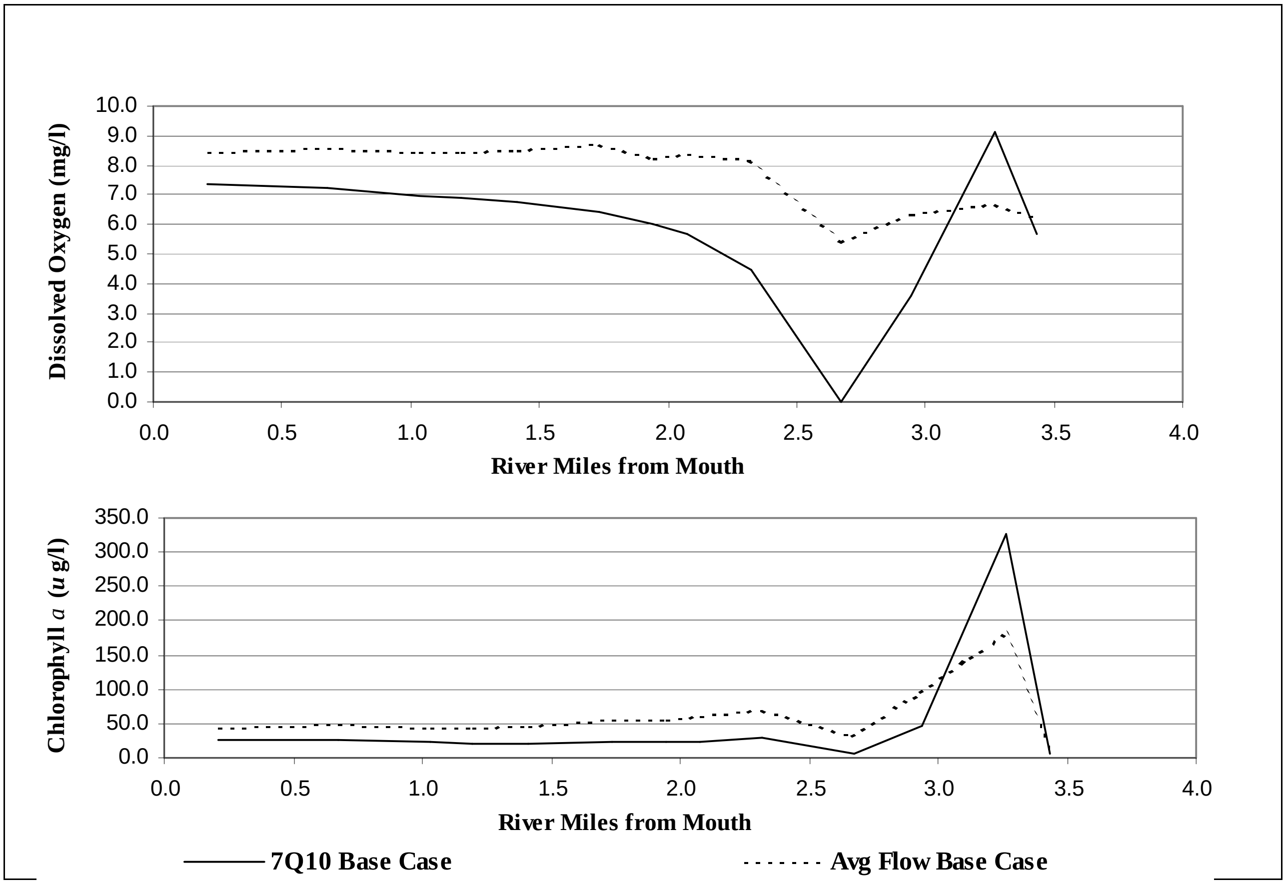

Figure 10: Model Results for the Base Case Scenarios for Chlorophyll *a* and Dissolved Oxygen

The FCEM 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. The photosynthetic process centers about the chlorophyll containing algae, which utilize radiant energy from the sun to convert water and carbon dioxide into glucose, and release oxygen. Because the photosynthetic process is dependent on solar radiant energy, the production of oxygen proceeds only during daylight hours. Concurrently with this production, however, the algae require oxygen for respiration, which can be considered to proceed continuously. Minimum values of dissolved oxygen usually occur in the early morning predawn hours when the algae have been without light for the longest period of time. Maximum values of dissolved oxygen usually occur in the early afternoon. The diurnal range of dissolved oxygen (maximum minus minimum) may be large when excessive algae is present and if the daily mean level of dissolved oxygen is low, minimum values of dissolved oxygen during a day may approach zero.

The diurnal dissolved oxygen variation due to photosynthesis and respiration can be estimated based on the amount of chlorophyll *a* in the water. For both model scenarios 3 and 4, where there is the greatest potential for a diurnal dissolved oxygen problem, the variation due to photosynthesis and respiration was calculated and subtracted from the average dissolved oxygen values produced by the model (Thomman and Mueller, 1987). For a more detailed explanation see Appendix A.

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 Fairlee Creek. The fourth scenario shows that water quality standards for both chlorophyll *a* and dissolved oxygen are achieved along the entire length of the creek during average flow conditions. The results from scenarios 3 and 4 also showed that water quality is protected for the full length of the Fairlee Creek and the three tributaries that were modeled. The results from these two scenarios can be seen in Figure 11. Table 3 shows the model results for dissolved oxygen and chlorophyll *a* for Great Oak Landing Cove, and as can be seen the water quality for both parameters is met. These two scenarios provide the justification for the TMDL presented below.

It would appear that as the flow increases the chlorophyll *a* problem worsens, except between river miles 3.0 and 3.4. However, the model results reflect extreme conditions. The fourth model scenario was run at steady-state conditions for 35 days with summer temperatures (above 70 ^{o}F). It is unlikely that average flow conditions would occur for that length of time during summer conditions. It is therefore unlikely that the Creek would receive the heavy loadings in the summer that were assumed in this model scenario.

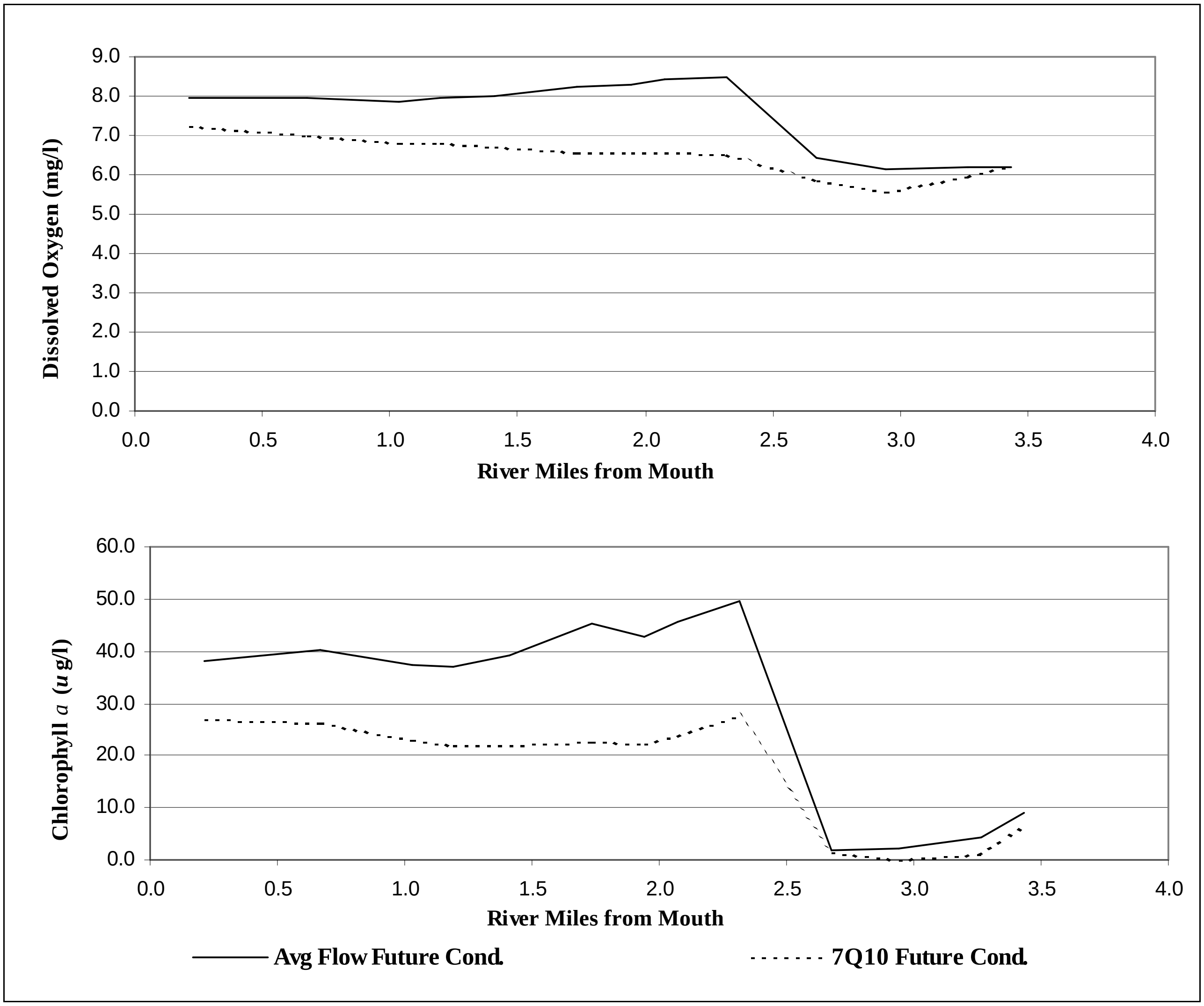

Figure 11: Model Results for Future Condition Scenarios for Chlorophyll *a* and Dissolved Oxygen

Table 3: Water Quality in Great Oak Landing Cove

Scenario	Dissolved Oxygen *mg/l*	Chlorophyll *a* *ug/l*
7Q10 Base Case		
Upper Cove	6.78	9.1
Lower Cove	7.33	20.5
Avg Flow Base Case		
Upper Cove	8.23	18.8
Lower Cove	7.50	27.0
7Q10 Future Cond.		
Upper Cove	6.80	10.6
Lower Cove	7.07	20.7
Avg Flow Future Cond.		
Upper Cove	6.71	4.3
Lower Cove	7.88	16.6

4.5 TMDL Loading Caps

The critical seasons for excessive algal growth in Fairlee Creek are during low flow conditions in the summer, and during 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. During average flow conditions, the increased nonpoint 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[3]:

NITROGEN TMDL **654 *lbs/month***

PHOSPHORUS TMDL **77 *lbs/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 Creek 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. Model scenario 4 showed that with the nutrient reductions expected in the basin, the water quality standards would be maintained for both chlorophyll *a* and dissolved oxygen. The resultant annual TMDLs for nitrogen and phosphorous are:

3 This TMDL applies only if the Fairlee WWTP discharge is removed from Fairlee Creek.

NITROGEN TMDL 83,420 *lbs/year*

PHOSPHOROUS TMDL 6,310 *lbs/year*

Because the TMDLs set limits on nitrogen, and because of the way the model simulated nitrogen, it is not necessary to also include a TMDL for nitrogenous biochemical oxygen demand (NBOD), to protect the dissolved oxygen standards in the river. It was also deemed unnecessary to include TMDLs for carbonaceous biochemical oxygen demand (CBOD), because the NPDES permits reflect limits that are protective of dissolved oxygen standards in the river.

4.6 Load Allocations Between Point Sources and Nonpoint Sources

The allocations described in this section demonstrate how the subject TMDLs can be implemented to achieve water quality standards in Fairlee Creek. Specifically, these allocations show, that the sum of nutrient loadings to Fairlee Creek from existing and nonpoint sources or anticipated 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 nonpoint 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 or require a reduction in loading from nonpoint sources below actual year 2000 loading rates. Maryland 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.

This section describes possible allocations for both the low flow and average annual cases. Note that the overall point source allocations set forth in Table 4 (summer low flow) and Table 6 (average annual) combine current loads and future allocations ("FAs"). However, allocations to existing point source discharges and FAs are identified separately in Table 9 (Summary of Low Flow TMDLs for Nitrogen and Phosphorus) and Table 10 (Summary of Annual TMDLs for Nitrogen and Phosphorus).

<u>Low Flow Allocations</u>:

The nonpoint source load allocations (LA) for nitrogen and phosphorus for the summer low flow critical conditions are represented as the base flow loads and flows as seen in 1991. The choice of 1991 base-flow nonpoint source loading was selected because reliable field data was readily available. Because the 1991 loads represent base-flow loads attributable to mostly groundwater recharge, it is not expected that the loads will change significantly. The nonpoint source loads that were assumed in the model account for both "natural" and human-induced components. Ideally one would separate the two, but in these cases adequate data was not available to do so.

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 Nutrient Point Sources in the Fairlee Creek Watershed.* The nonpoint source and point source nitrogen and phosphorus allocations for summer critical low flow conditions are shown in Table 4.

Table 4: Point Source and Nonpoint Source Summer Low Flow Load Allocations

	Total Nitrogen *(lb/month)*	**Total Phosphorus *(lb/month)***
Nonpoint Source	523	47
Point Source	105	28

Annual Allocations:

The annual nonpoint source nitrogen and phosphorus load allocations are represented as estimated year 2000 loads, assuming a 10% reduction in nitrogen loads and a 9% reduction in phosphorus loads, both due to agricultural BMPs that have already implemented. The background concentrations are included in the nonpoint source loads. As was discussed in the "Scenario Descriptions" section of this document the year 2000 loads were based on loading rates from the Chesapeake Bay Model (U.S. EPA, 1991).

Point source load allocations for the annual flow conditions made up the balance of the total allowable load. This point source load allocation was adopted from results of model scenario 4. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *Significant Nutrient Point Sources in the Fairlee Creek Watershed.* Table 5 shows the load allocations to point and nonpoint sources respectively, for nitrogen and phosphorus for the annual TMDL.

Table 5: Point Source and Nonpoint Source Annual Load Allocations

	Total Nitrogen *(lb/yr)*	**Total Phosphorus *(lb/yr)***
Nonpoint Source	79,490	5,780
Point Source	1,280	340

4.7 Future Allocations and Margins of Safety

Future allocations represent surplus assimilative loading capacity that is either currently available, or projected to be available due to planned implementation of environmental controls. The future allocations for point sources for nitrogen and phosphorus have been computed as the difference between the current estimated loads from the WWTP and maximum allowable load.

The summer low flow nitrogen and phosphorus Future Allocations are given in Table 6. The annual nitrogen and phosphorus Future Allocations are given in Table 7.

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 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 3% of the nonpoint source loads for nitrogen and phosphorus for the annual TMDL. Similarly, a 5% MOS was included in computing the low flow TMDLs. These explicit nitrogen and phosphorus margins of safety are summarized in Table 6 and Table 7.

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 well below 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. Finally, under low stream flow conditions, the nonpoint source contribution is a fairly stable concentration associated with the stream’s base flow. Thus, the margin of safety depends most on the point source contribution, the control of it is much more certain than nonpoint sources. Hence, another implicit safety factor will be provided by the NPDES permits, 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 35 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 6: Summer Critical Low Flow Margins of Safety and Future Allocations

	Total Nitrogen *(lb/month)*	**Total Phosphorus *(lb/month)***
Margins of Safety	26	2
Future Allocations	84	17

Table 7: Annual Margins of Safety and Future Allocations

	Total Nitrogen *(lb/yr)*	**Total Phosphorus *(lb/yr)***
Margins of Safety	2,650	190
Future Allocations	1,020	200

4.8 Summary of Total Maximum Daily Loads

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

For Nitrogen (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**	**+**	**FA**
654	**=**	**523**	**+**	**21**	**+**	**26**	**+**	**84**

For Phosphorus (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**	**+**	**FA**
77	**=**	**47**	**+**	**11**	**+**	**2**	**+**	**17**

The annual TMDLs for Fairlee Creek, equated with illustrative allocations, are:

For Nitrogen (*lb/yr*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**	**+**	**FA**
83,420	**=**	**79,490**	**+**	**260**	**+**	**2,650**	**+**	**1,020**

For Phosphorus (*lb/yr*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**	**+**	**FA**
6,310	**=**	**5,780**	**+**	**140**	**+**	**190**	**+**	**200**

Where:

TMDL = Total Maximum Daily Load
LA = Nonpoint 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 18.8 lb/day of nitrogen and 2.5 lb/day of phosphorus. And, on average the annual TMDLs will result in loads of approximately 229 lb/day of nitrogen and 17 lb/day of phosphorus.

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the nitrogen and phosphorus TMDLs will be achieved and maintained. For both TMDLs, and especially the annual TMDLs which involve more significant nonpoint 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 by 2004. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 1996 and 1998 approved by EPA. The State has given a high-priority for funding assessment and restoration activities to these watersheds.

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

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