FINAL
Total Maximum Daily Load (TMDL)

for

Organic Enrichment/Dissolved Oxygen
Patton Creek AL/03150202-030_03

Alabama Department of Environmental Management
Water Quality Branch
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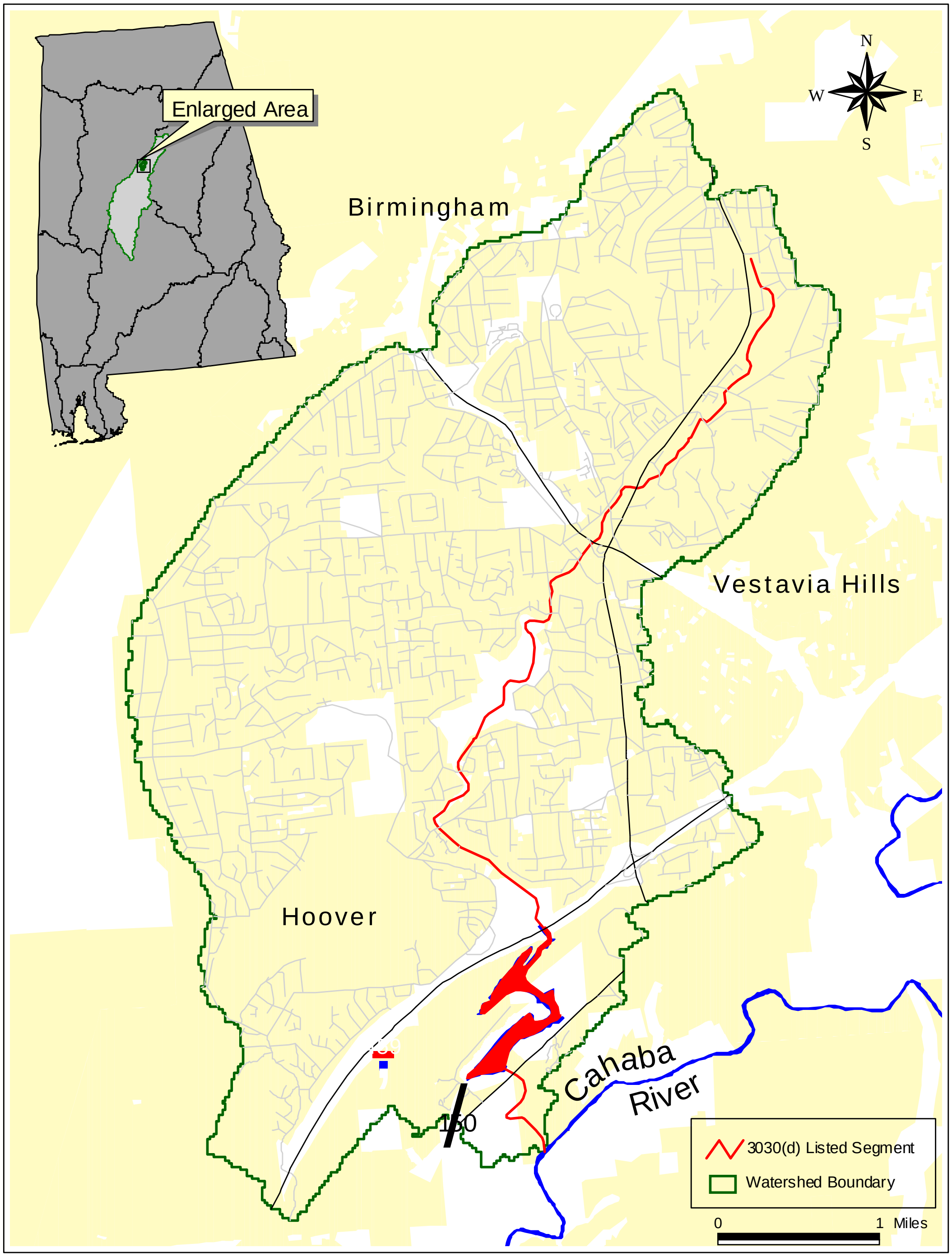

List of Abbreviations

ADEM	Alabama Department of Environmental Management
BMP	Best Management Practices
CBOD	Carbonaceous Biochemical Oxygen Demand
CFS	Cubic Feet per Second
CWP	Clean Water Partnership
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
FSA	Farm Services Agency
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Stormwater System
NBOD	Nitrogenous Biochemical Oxygen Demand
NCDC	National Climatic Data Center
NHD	National Hydrography Database
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source Pollution
NRCS	Natural Resources Conservation Service
OE	Organic Enrichment
OEO	ADEM Office of Education and Outreach
RF3	Reach File 3
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USF&WS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation

1.0 Executive Summary

Patton Creek, a part of the Cahaba River Basin, is located in Jefferson County and is just south of the city of Birmingham in Hoover and Vestavia Hills. It is a small tributary to the Cahaba River and has been on Alabama's §303(d) list since 1996 for organic enrichment/dissolved oxygen (OE/DO). Table 1-1 summarizes the listing information related to TMDL development.

Table 1-1 1996-§ 303(d) Listed Segment of Patton Creek in the Cahaba River Basin

Waterbody ID	Waterbody	Uses	Causes	Sources	Size	Downstream/Upstream Location
(AL/03150202-030_03)	Patton Creek	Fish & Wildlife	OE/DO	Urban Runoff/Storm Sewers	5.0 miles	Cahaba River/Its Source

The following report addresses the results of the TMDL analysis for OE/DO for Patton Creek. The Patton Creek watershed comprises 17 $miles^2$ of drainage area and has a Fish and Wildlife (F&W) use classification. The land use/cover characteristics of the watershed are primarily forested and residential. In accordance with the water quality criteria for the State of Alabama, OE/DO numeric targets are 5.0 mg/L at the mid-depth level if the depth is less than 10 feet and at the 5-foot level is the depth is greater than 10 feet.

The data analysis and source assessment identified low DO levels in the Patton Creek watershed associated with low flows, high levels of sediment oxygen demand (SOD) in the impoundment, and nutrient loads from leaking septic tanks and urban runoff. The ADEM Spreadsheet Water Quality Model (SWQM) was used to determine the DO scenarios for critical conditions for Patton Creek, listed segment AL/03150202-030_03. The TMDL is presented in Table 1-2.

The pollutants shown in the TMDL table for the listed segment includes ultimate carbonaceous biochemical oxygen demand ($CBOD_U$) and nitrogenous biochemical oxygen demand ($NBOD_U$). The TMDL for Patton Creek includes reductions necessary to reduce long-term SOD within the system to meet water quality standards for DO. For the purposes of this TMDL, a critical low flow exhibited during the summer month of August was utilized. Compliance under critical summer conditions assures that standards are met throughout the year.

The wasteload allocation (WLA) of the TMDL represents the contributions from point source discharges, including the storm water sewer system. The Patton Creek watershed lies within a Phase I Municipal Separate Storm Sewer System (MS4). Since no facilities are currently permitted to discharge oxygen-consuming wastes directly to Patton Creek, the only National Pollutant Discharge Elimination System (NPDES) permit in the watershed is the MS4 Phase I permit. Therefore, the WLA represents loads from land use activities in the watershed that are regulated under the MS4 Phase I Permit.

Table 1-2 Maximum Allowable $NBOD_u$ and $CBOD_u$ Loads for Patton Creek

Constituent	**Existing Load (lb/day)**	**TMDL (lb/day)**	**Load Reduction**	
	WLA_{MS4} + LA	**WLA_{MS4} + LA**	**WLA_{MS4}**	**LA**
$NBOD_U$	76.8	26.4	66%	66%
$CBOD_U$	25.5	19.5	24%	24%

NOTE: The load reductions are expressed as both WLA_{MS4} and LA percent reductions because the entire Patton Creek watershed is contained within the boundaries of the Jefferson County MS4 Phase I Permit (ALS000001).

2.0 Basis for the §303(d) Listing

2.1 Introduction

Section §303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987 and USEPA's Water Quality Planning and Management Regulations [(Title 40 of the Code of Federal Regulations (CFR), Part 130)] require states to identify waterbodies which are not meeting water quality standards applicable to their designated use classifications. The identified waters are prioritized based on severity of pollution with respect to designated use classifications. Total maximum daily loads (TMDLs) for all pollutants causing violation of applicable water quality standards are established for each identified water. Such loads are established at levels necessary to implement the applicable water quality standards with seasonal variations and margins of safety. The TMDL process establishes the allowable loading of pollutants, or other quantifiable parameters for a waterbody, based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water-quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA, 1991).

The State of Alabama has identified the Patton Creek watershed as being impaired by organic enrichment/dissolved oxygen (OE/DO). The listing was reported on the 1996 §303(d) list of impaired waters as shown in Table 1-1. The TMDL developed for the Patton Creek watershed is consistent with a phased-approach: estimates are made of needed pollutant reductions, load reduction controls will be implemented, and water quality will be monitored for plan effectiveness. Flexibility is built into the plan so that load reduction targets and control actions can be reviewed and updated if monitoring indicates continuing water quality problems.

2.2 Problem Definition

Patton Creek was listed as impaired by OE/DO due to violations of the State's water quality criteria for DO. DO concentrations less than 5.0 mg/L are caused by historic and anthropogenic loads of oxygen consuming waste to the creek and a small impoundment at the downstream end of the creek before the confluence of the Cahaba River. Historically, a wastewater treatment facility discharged to the system but ceased operation in 1996. Anthropogenic sources of oxygen consuming waste are attributed to urban runoff and leaking septic systems in the watershed.

The purpose of this TMDL is to establish the acceptable loading of organic material from all sources, such that the State of Alabama water quality criteria for DO are not violated in Patton Creek.

Water Quality Criterion Violation:	Dissolved Oxygen
Pollutant of Concern:	Organic Enrichment/Dissolved Oxygen
Water Use Classification (multiple):	Fish and Wildlife

Usage of waters in the Fish and Wildlife classification is described in ADEM Admin. Code R. 335-6-10-.09(5)(a), (b), (c), and (d).

(a) Best usage of waters:

Fishing, propagation of fish, aquatic life, and wildlife, and any other usage except for swimming and water-contact sports or as a source of water supply for drinking or food processing purposes.

(b) Conditions related to best usage:

The waters will be suitable for fish, aquatic life and wildlife propagation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propagation of shrimp and crabs.

(c) Other usage of waters:

It is recognized that the waters may be used for incidental water contact and recreation during June through September, except that water contact is strongly discouraged in the vicinity of discharges or other conditions beyond the control of the Department or the Alabama Department of Public Health.

(d) Conditions related to other usage:

The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted criteria of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports.

(e) Specific criteria:

4. (i) For a diversified warm water biota, including game fish, daily dissolved oxygen concentrations shall not be less than 5 mg/L at all times; except under extreme conditions due to natural causes, it may range between 5 mg/L and 4 mg/L, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels.

3.0 Technical Basis for TMDL Development

3.1 Applicable Water Quality Criterion

The minimum dissolved oxygen concentration in a stream classified for Fish and Wildlife use is 5.0 mg/L. The target is established at a depth of 5 feet in waters 10 feet or greater in depth; for those waters less than 10 feet in depth, dissolved oxygen criteria are applied at mid-depth. This TMDL specifies NBODu and CBODu reductions to reduce the oxygen demanding sources in the stream and also to reduce the SOD in the impoundment to meet the DO criteria.

3.2 Source Assessment

The Patton Creek watershed is a 17 square mile watershed in the Hoover and Vestavia Hills suburbs of Birmingham, Alabama. In 1996 a Jefferson County Environmental Services Department (ESD) wastewater treatment facility discontinued discharging to the creek. At the time of this TMDL there are no direct discharges to the creek. However, the entire watershed is within a MS4 area. Therefore, all sources of urban runoff will be considered as stormwater wasteloads.

Jefferson County, the City of Birmingham and 22 other municipalities are included in one MS4 permit regulated by the NPDES program (ALS000001). During rain events sediment and other compounds, including oxygen-consuming waste, from urban areas are transported to the stream by road drainage systems and storm drains. The potential sources of loading are therefore numerous and have been identified based on an evaluation of available landuse/cover (e.g., urban high density or forested land). A source assessment was used as the basis of development of the model and ultimate analysis of the TMDL allocations.

A landuse map of the Patton Creek watershed is presented in Figure 3-1 with landuse percentages listed in Table 3-1. The predominant landuse within the watershed is forest and residential with 55.3 percent and 32 percent, respectively. Each landuse type has the potential to contribute to the organic loading in the watershed due to organic material on the land surface that potentially can be washed off into the receiving waters. The dissolved oxygen deficit in Patton Creek can be attributed to two major water quality processes: (1) oxygen consuming loads that are delivered to the creek measured by BOD (5-day) and ammonia (NH3) and (2) deposition of organic matter in the impoundment that exerts an oxygen demand as the matter decays over time called sediment oxygen demand (SOD).

Table 3-1 Percent Landuse for the Patton Creek Watershed

Cataloging Unit	Forest	Residential	Urban	Open Water	Other
Patton Creek (AL/03150202-030_03)	55.3%	32%	3.4%	0.5%	8.8%

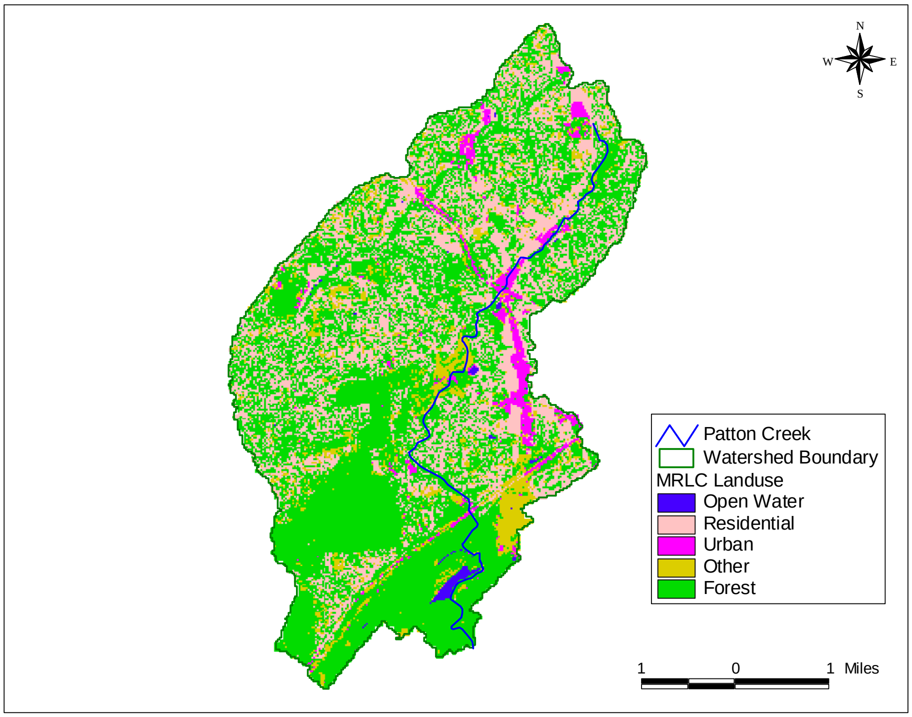

Figure 3-1 Patton Creek Landuse Activities

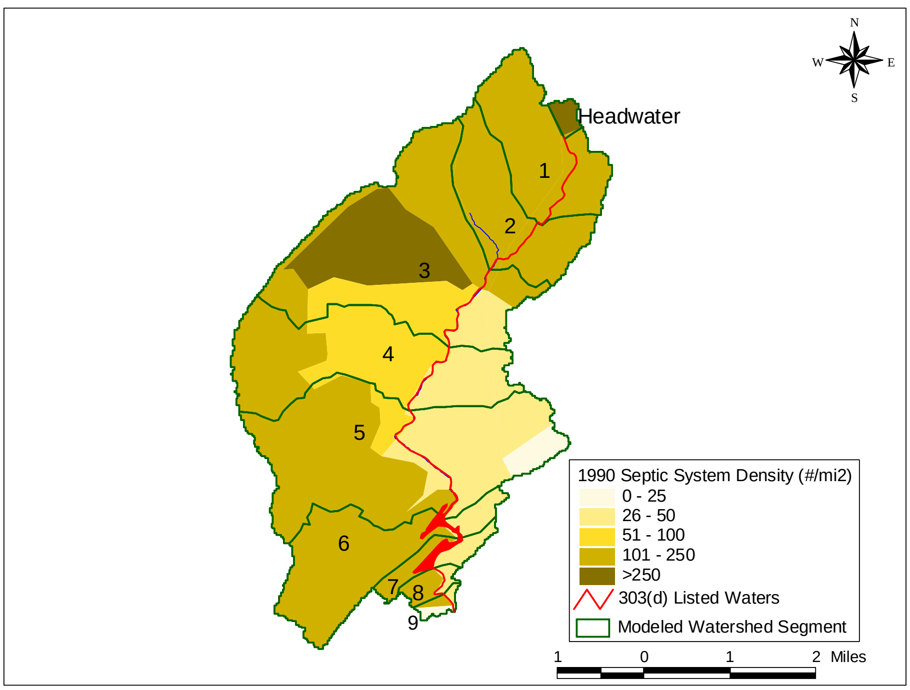

Figure 3-2 1990 Density of Septic Systems in the Patton Creek Watershed with SWQM Segments Delineated

An evaluation of the density of septic systems was also conducted to consider the possibility of oxygen consuming wastes from leaking septic systems in the watershed. In 1990 the US census reported the type of sewage facility used by households by census tract (USCensus, 2003). The number of septic systems was distributed evenly over each tract in the watershed and the density distribution based on the census tract is presented in Figure 3-2. Areas in the north and western portions of the watershed have a high distribution of septic systems. The high distribution was considered in the ammonia calibration of the SWQM used in TMDL development.

3.3 Data Availability and Analysis

A wide range of data and information were used to characterize the watershed and the instream conditions. The categories of data used include census tract data described previously, physiographic data that describe the physical conditions of the watershed and instream water quality monitoring data.

ADEM has collected chemical and *in situ* data at various locations on Patton Creek since 1995. The most intensive of these studies were conducted during 2002 and 2003. These data are necessary to characterize loading inputs in the watershed. The following presents the data sources and their use in TMDL development.

3.3.1 Physiographic Data

Physiographic data include watershed topography and landuse activities. These data were used to simulate flows and water quality in Patton Creek. Digital elevation maps (DEMs) in conjunction with the national hydrography database reach network (NHD) were used to establish watershed boundaries and flow paths. Finally, multi-resolution land coverage (MRLC) provided the landuse distribution as shown in the figure in the previous section.

3.3.2 Water Quality Data

In 1995, ADEM began monitoring Patton Creek just upstream of its confluence with the Cahaba River and downstream of a small impoundment at PA1A illustrated in Figure 3-3. In addition to PA1A, ADEM has collected water quality data at five other locations, shown in Figure 3-3. The stations illustrated were monitored as part of the §303(d) rotating basin program in 2002 then again in 2003. These data were collected over several months in both years and even in the summer months so that the water quality could be represented during dry and wet seasons. These data were the focus of the source assessment, model inputs, and calibration. The data in 2003 were collected under higher flow conditions due to more precipitation during these months. Figure 3-4 is evident of the higher flow conditions in 2003 versus 2002 and the increase in DO violations during a dry time period in 2002.

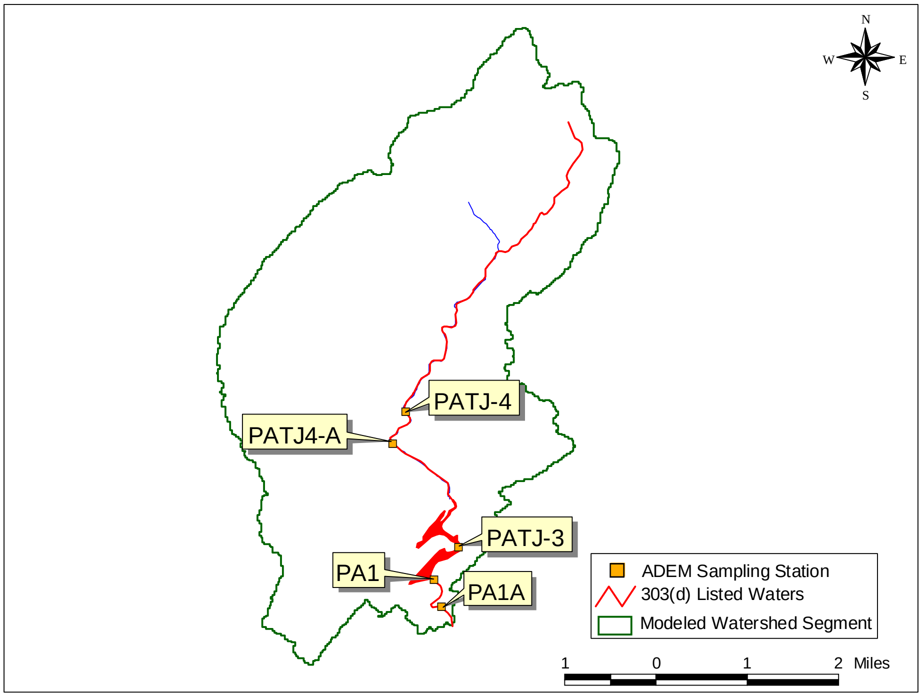

Figure 3-3 ADEM Monitoring Stations on Patton Creek

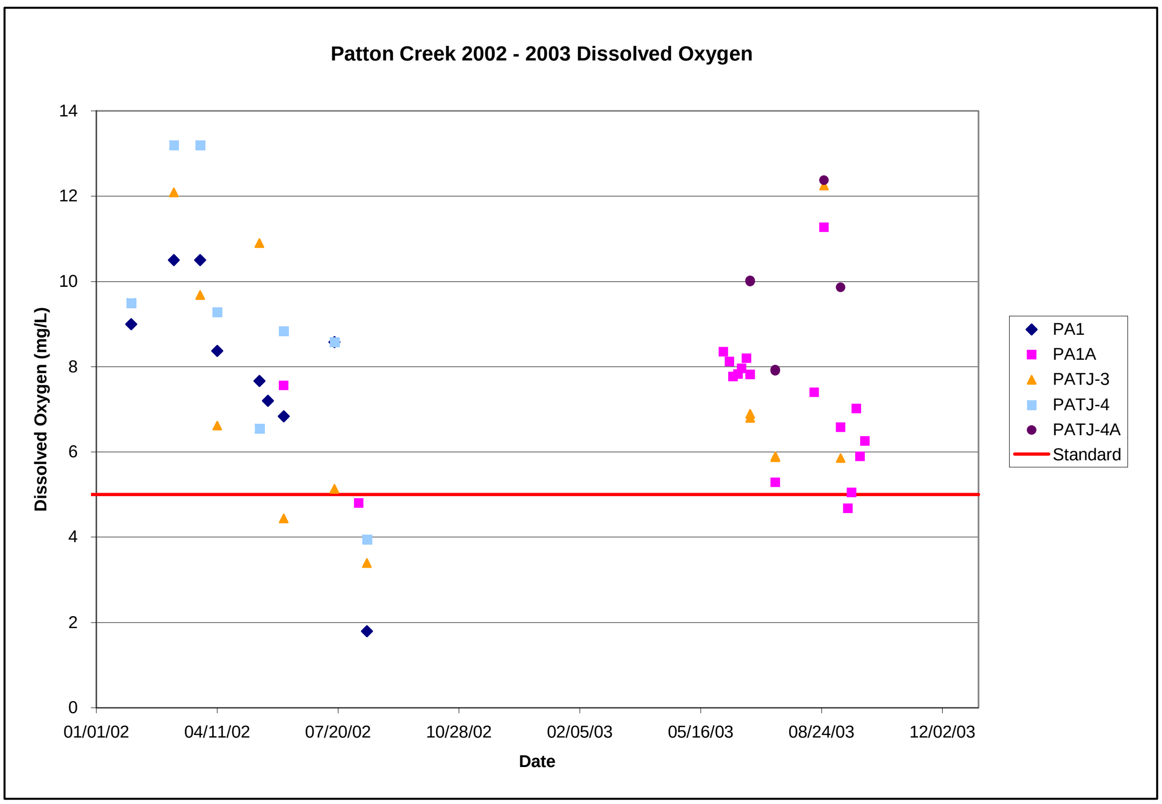

Figure 3-4 Patton Creek Dissolved Oxygen in 2002 and 2003

Data collected by ADEM include flow measurements, DO, and nutrient sampling. These data were plotted to establish trends in water quality. Prior to 1996, a wastewater treatment facility was permitted to discharge in Patton Creek. The presence of the wastewater discharge can be seen in the total phosphorus samples collected by ADEM at PA1A in 1995 and 2002-2003, Figure 3-5. Changes in creek nutrient quality cannot be seen in the other parameters collected before and after removal of the point source.

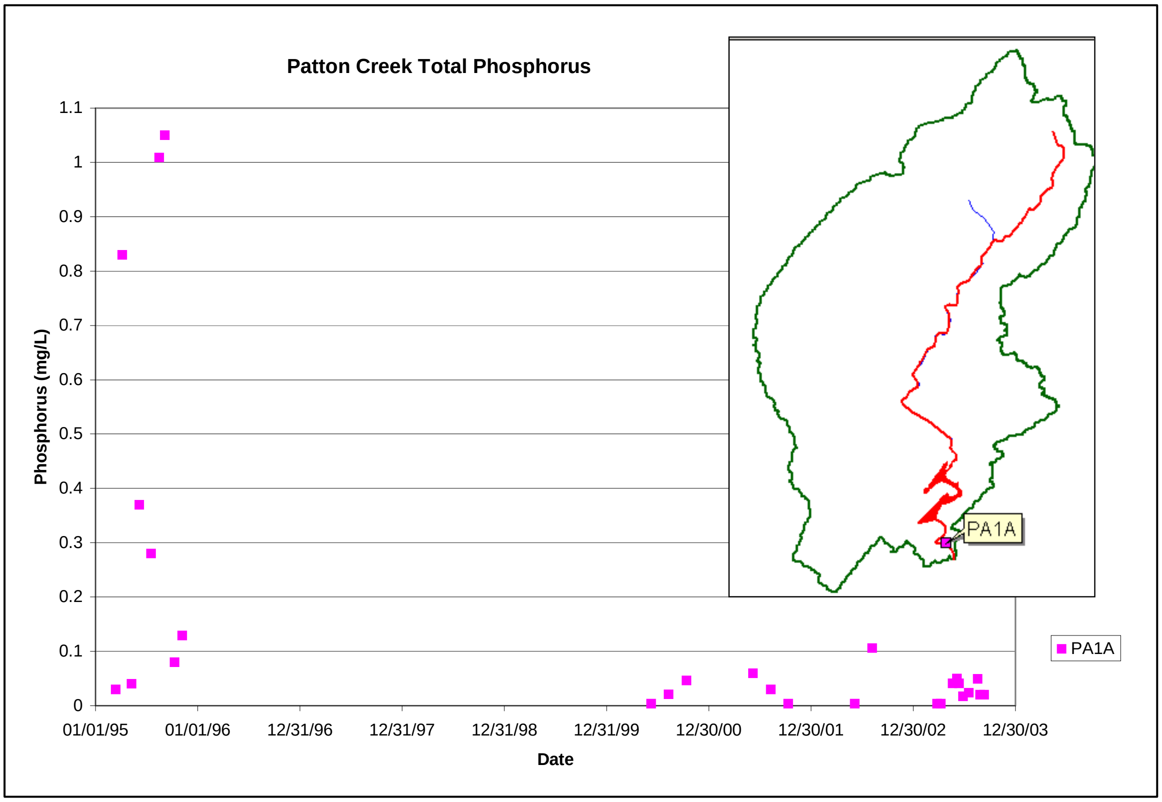

Figure 3-5 Patton Creek Total Phosphorous

In addition to data collected by ADEM, the USGS and Jefferson County have collected data on Patton Creek. The data collected by USGS included flow measurements, DO, and nutrients for varying, inconsistent time periods from 1998 through 2001. The Jefferson County data included nutrient samples collected in 1999 and winter of 2000. The location of sampling stations is illustrated in Figure 3-6.

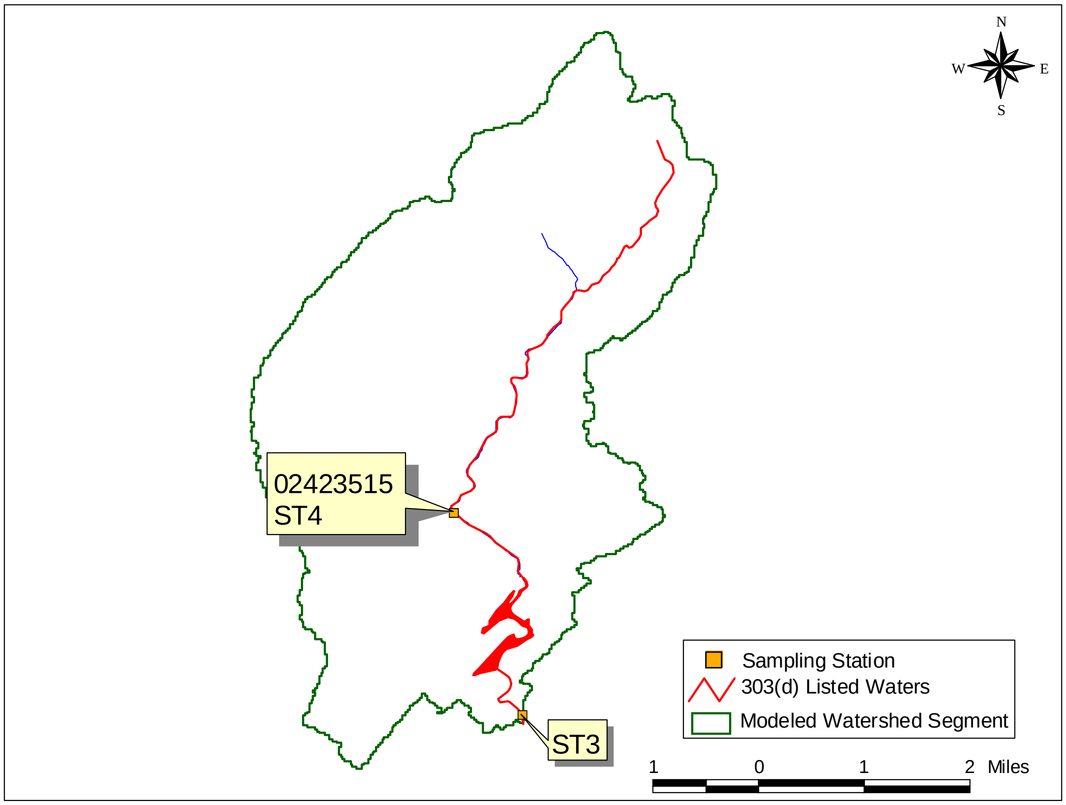

Figure 3-6 USGS and Jefferson County Sampling Stations on Patton Creek

4.0 Model Development

Establishing the relationship between instream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. In this section, the numerical modeling techniques developed to simulate the loading of organic material and nutrients, and the resulting instream response of DO, are presented. For the TMDL the ADEM Spreadsheet Water Quality Model (SWQM) was used to relate DO concentrations in the stream to Carbonaceous Biochemical Demand (CBOD), Nitrogenous Biochemical Oxygen Demand (NBOD), Sediment Oxygen Demand (SOD) and reaeration.

Hydrologic response and pollutant loading model calibrations must occur to determine the watershed loads to the receiving waters. Loads washed into the system will pass through and/or react during dry periods if the loads still remain in the water column. In addition, build up of organic material in the listed reach can increase sediment oxygen demand that exerts itself during low flow periods.

4.1 Watershed Water Quality Modeling –SWQM

A steady state model, SWQM, was used to represent the source-response linkage in the watershed. The model was selected for OE/DO TMDL development based on the availability of data, seasonal variations in DO concentrations, and low flow conditions in Patton Creek. Analysis of monitored data, review of literature, and past modeling experience were used to establish inputs to the model.

SWQM is based on the Streeter-Phelps DO deficit equation with modifications to account for oxygen demand resulting from nitrification of ammonia (nitrogenous biochemical oxygen demand) and organic demand fund in the waterbody sediment. The equation below shows the Streeter-Phelps relationship with additional components to account for nitrification and SOD:

$$(1)\quad D = \frac{K_1 L_0}{K_2 - K_1}\left(e^{-K_1 t} - e^{-K_2 t}\right) + \frac{K_3 N_0}{K_2 - K_3}\left(e^{-K_3 t} - e^{-K_2 t}\right) + \frac{SOD}{K_2 H}\left(1 - e^{-K_2 t}\right) + D_0 e^{-K_2 t}$$

where: D = DO deficit at time t, mg/l
L_0 = initial CBOD, mg/l
N_0 = initial NBOD, mg/l (NBOD = NH_3-N x 4.57)
D_0 = initial DO deficit, mg/l
K_1 = CBOD decay rate, 1/day
K_2 = reaeration rate, 1/day
K_3 = nitrification rate, 1/day
SOD=sediment oxygen demand, g O_2/ft^2/day
H=average stream depth, ft
t = time, days

The CBOD concentration, expressed as L_0 in the above equation, is the ultimate carbonaceous biochemical oxygen demand ($CBOD_U$). The CBOD concentration remaining at any time, t, can be expressed by the following first-order equation:

(2) $L = L_u e^{-K_1 t}$

where: L = CBOD remaining at any time, t, mg/l
L_u = $CBOD_U$, mg/l = Lo
(Eqn 1)
K_1 = CBOD decay rate, 1/day
t = time, days

In the presence of nitrifying bacteria, ammonia is oxidized first to nitrite, then to nitrate. The oxidation reaction is assumed to be first order and would have the form shown in the Equation (3):

(3) $N = N_0 e^{-K_3 t}$

where: N = NBOD remaining at any time, t, mg/l
N_0 = initial NBOD, mg/l
K_3 = nitrification rate, 1/day
t = time, days

The conversion of organic nitrogen to ammonia is assumed to follow first-order kinetics and is represented by Equation (4):

(4) $NH_3 - N = ORG\left(1 - e^{-K_4 t}\right)$

where: NH_3-N = ammonia nitrogen produced by hydrolysis of organic nitrogen, mg/l
ORG = initial organic nitrogen concentration, mg/l
K_4 = organic nitrogen hydrolysis rate, 1/day
t = time, days

Oxygen demand by benthic sediments and organisms can represent a significant portion of oxygen consumption in surface water systems. Benthic deposits at a given location in an aquatic system are the result of the transportation and deposition of organic material. The material may be from historic sources or sources outside the system, such as wastewater particulate CBOD or leaf litter, or it may be generated inside the system as occurs with plant growth. In addition to oxygen demand caused by decay of organic matter, the indigenous invertebrate population can generate significant oxygen demand through respiration. The sum of oxygen demand due to organic matter decay plus demand from invertebrate respiration is equal to the SOD. SOD is averaged over the water column depth, as indicated by the third term (to the right of the equal sign) in Equation (1).

The process by which oxygen enters a stream is known as reaeration. Equation (1) shows the net effect on DO concentration of the simultaneous processes of deoxygenation through the decay of carbonaceous organic matter, nitrification of ammonia, SOD and reaeration. The resulting pattern in DO concentration versus distance downstream from a waste source is known as the DO sag curve.

Numerous equations for estimating a stream's reaeration rate have been developed and many are presented in *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling*, 2nd edition, USEPA. Reaeration rates in the SWQM can be either entered directly or computed using the formula developed by E.C. Tsivoglou and shown in Equation (5).

(5) $K_2 = C(Slope)(Velocity)$

where: K_2 = reaeration rate at 20°C, 1/day
C = Tsivoglou Coefficient
C = 1.8 when stream flow < 10 cfs
C = 1.3 when stream flow > 10 cfs and < 25 cfs
C = 0.88 when stream flow > 25 cfs
Slope = water surface slope, feet/mile
Velocity = water velocity, feet/second

Another commonly used method for estimating a stream's reaeration rate is the O'Conner-Dobbins formulation shown in Equation (6). This formulation generally works best for streams with a depth of greater than 5 feet and a slope of less than 2 feet/mile.

(6) $K_2 = \frac{12.9U^{0.5}}{H^{1.5}}$

where: K_2 = reaeration rate at 20°C, 1/day
U = stream velocity, feet/second
H = stream depth, feet

Temperature affects the rate at which reactions proceed. Reaction rates are generally expressed with units of per day at 20°C. If the reactions are occurring at a temperature other than 20°C, then the reaction rates must be corrected for the new temperature. The most commonly used expression to adjust reaction rates for temperature is the modified Arrhenius relationship shown in Equation (7):

(7) $K_{T_2} = (K_{20°C})\Theta^{(T_2 - 20)}$

where: K_{T2} = reaction rate at the new temperature, 1/day
$K_{20°C}$ = reaction rate at 20°C, 1/day

The Θ values for each of the reaction rates shown in Equation (1) vary slightly from reference to reference but those used in the SWQM are listed in Table 4-1.

Table 4-1 SWQM Parameters Used in Model Calibration and TMDL Allocation Scenarios

Parameter in SWQM	Definition	Value Used in Model Calibration and TMDL	Units
K_d	CBOD Decay Rate	0.1	1/day
K_{NH3}	Nitrification rate	0.1	1/day
K_{TON}	TON Hydrolosis Rate	0.05	1/day
K_a	Reaeration Rate	0.6 to 2.06	1/day

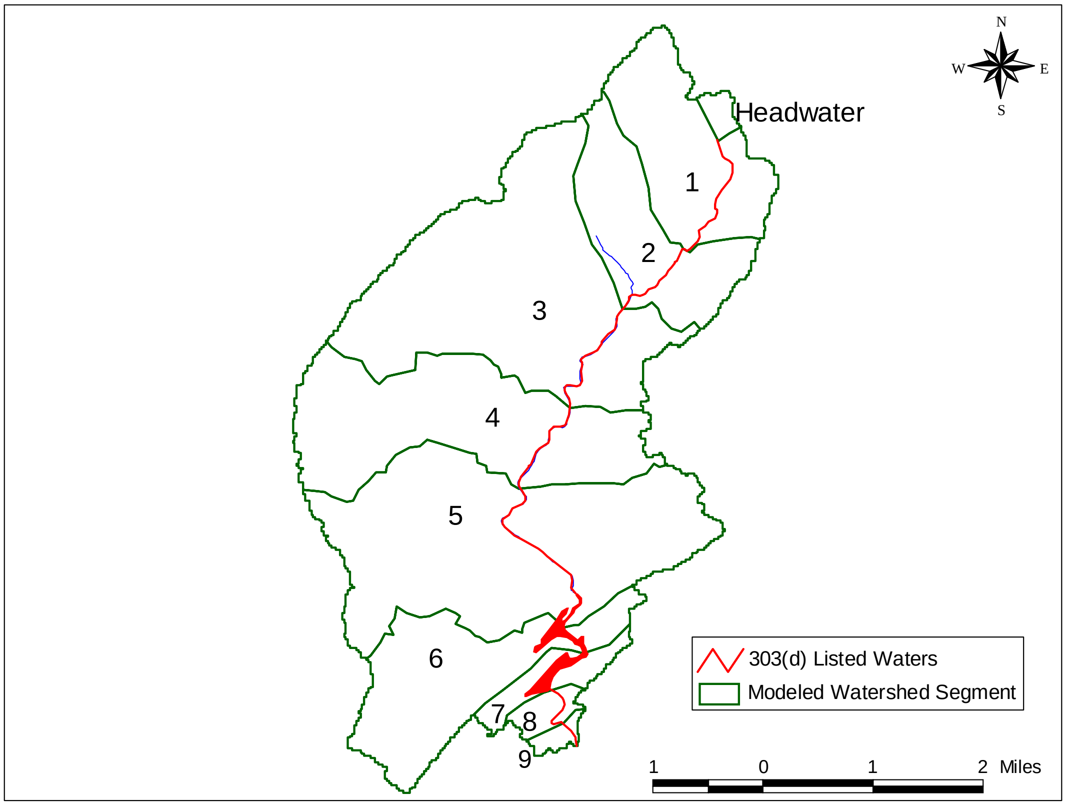

Figure 4-1 Patton Creek Segments in SWQM

The model was calibrated to low flow conditions using data collected during low flow conditions in August 2002. Rates for CBOD decay, nitrification, and total organic nitrogen (TON) hydrolosis were consistent in each of the modeled segments. Reaeration rates were calculated in most of the segments but input in segments to represent conditions in the impoundment and just upstream of the impoundment, segments 5, 6, and 7. Figure 4-1 shows segments delineated for the SWQM.

SOD rates were also input into the model and varied by segment. Table 4-2 represents the SOD rates used to calibrate the Patton Creek SWQM. The model uses the units of $gmO_2/ft^2/day$ but the conversion to the conventional SOD $gmO_2/m^2/day$ are shown for the reader. The rates in the impoundment of Patton Creek are believed to be much higher than in the upper segment as sediment settles out of the water column.

Table 4-2 Sediment Oxygen Demand Calibrated on Patton Creek

Segment #	SOD, gm-O_2/ft^2/day	SOD, gm-O_2/m^2/day
1	0.010	0.11
2	0.010	0.11
3	0.010	0.11
4	0.050	0.54
5	0.100	1.08
6	0.250	2.69
7	0.250	2.69
8	0.010	0.11
9	0.010	0.11

The modeled DO calibration and TMDL scenario are illustrated in Figures 4-2 and 4-3, respectively. Dramatic changes in longitudinal water quality concentrations can be seen, a small impoundment on Patton Creek holds water between mile 6.0 and 7.0. Other calibration plots are shown in Appendix B. TMDL plots are shown in Appendix C.

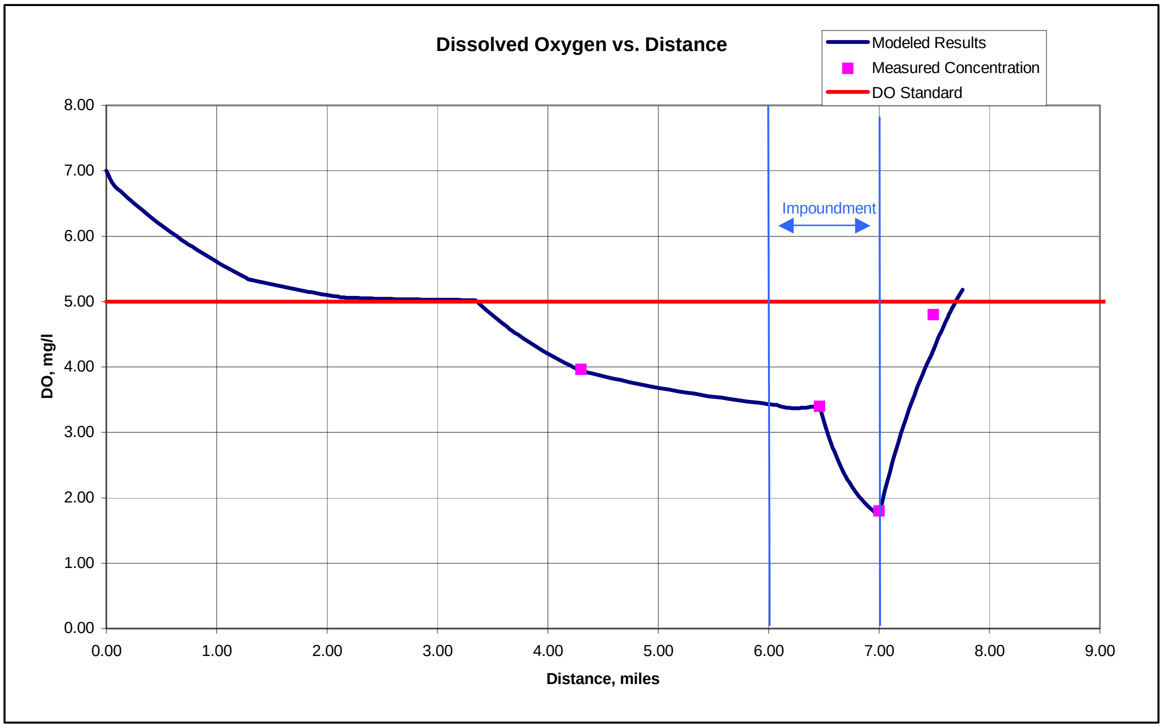

Figure 4-2 Patton Creek SWQM Dissolved Oxygen Calibration

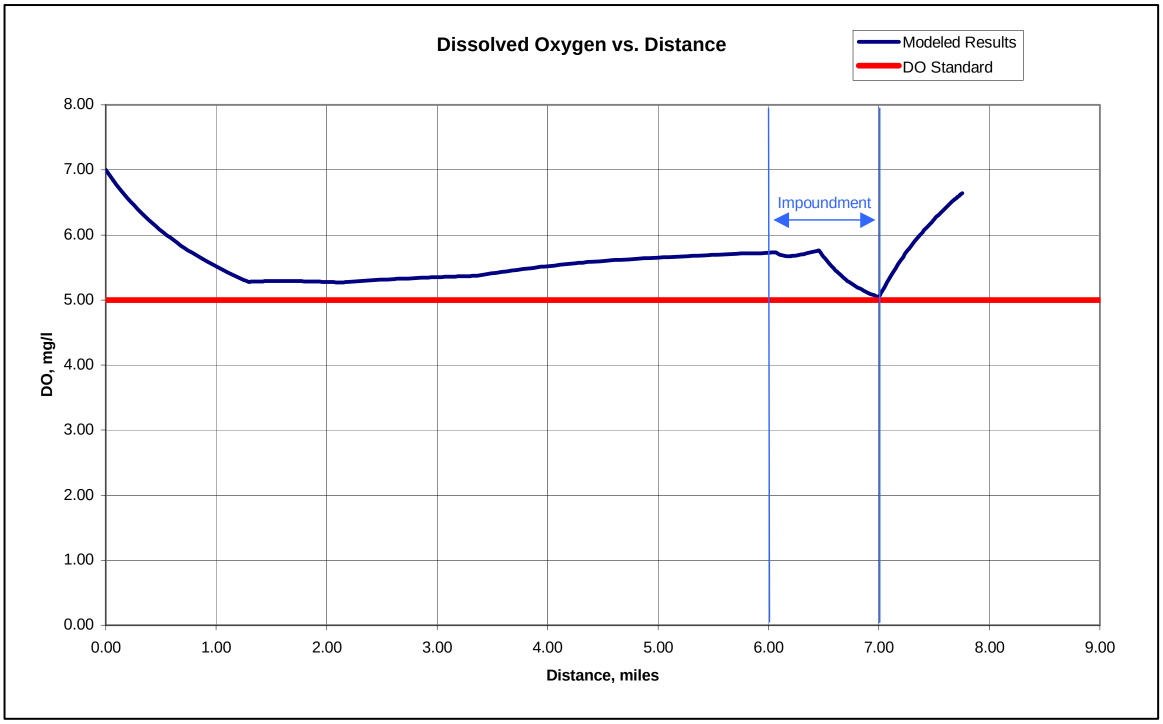

Figure 4-3 Patton Creek SWQM Dissolved Oxygen TMDL Scenario

The TMDL scenario shown in Figure 4-3, represents a load reduction to meet the water quality criterion of 5.0 mg/L. The $CBOD_u$ (BOD), $NBOD_u$ (NH3), and SOD were reduced until the water column dissolved oxygen in the model met the 5.0 mg/L target. It is well-documented that a reduction in CBOD and NBOD loads will result in an improvement to the SOD exhibited by the sediments. This is especially true for an impoundment that tends to capture and concentrate all of the upstream loads from the watershed. For the purposes of this TMDL, the SOD was reduced in the model to a value of 0.12 $gmO_2/ft^2/day$ (equal to 1.25 $gmO_2/m^2/day$) in the impoundment to represent a reduced oxygen consumption due to settling and decay of organic matter in the impoundment. After many SOD measurements and DO TMDL developments in the southeast (in particular where SOD measurements and modeling has occurred such as the Flint Creek, Alabama and southern four basins in Georgia by EPA Region 4), the 1.25 $gmO_2/m^2/day$ represents an achievable SOD of a mixed land use to meet the water quality standards of DO. Once the model was updated with the reduced SOD, the $CBOD_u$ and $NBOD_u$ loads were reduced to meet the 5.0 mg/L target.

5.0 Development of Total Maximum Daily Load

The TMDL is the total amount of a pollutant load that can enter a waterbody (the loading capacity) and still attain the applicable water quality standard. A TMDL is expressed as WLA for point source discharges from facilities and activities regulated by the NPDES permit program and Load Allocation (LA) for all nonpoint sources. The TMDL must also incorporate an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

5.1 Numeric Targets for TMDL

EPA regulations define loading, or assimilative capacity, as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 CFR Part 130.2(f)).

Using the DO water quality criterion of 5.0 mg/L, a TMDL model analysis was performed through a critical summer period to determine the loading capacity for the watershed. This was accomplished through a conservative model aimed at meeting the DO target limit by varying watershed source contributions. The simulations reflect the effects of urban loads on DO as well as loads from forested areas. The final acceptable simulation represents the TMDL (and loading capacity of the waterbody).

5.2 Critical Conditions

Data analysis shows that the critical conditions for OE/DO are during summer low flow periods. The low DO conditions within the Patton Creek watershed correspond to summer periods of low flow and high temperature. For the purpose of this TMDL, a low flow period month in August 2002 was used to develop the critical conditions. From examination of the data a representative condition was extracted from the data to represent the calibration conditions and the critical conditions.

5.3 Margin of Safety (MOS)

The MOS for the TMDL was incorporated implicitly through the use of conservative modeling assumptions including low stream flows persist through the critical summer months. An implicit MOS is also assumed because of the removal of the wastewater facility. It is expected that there is and will continue to be an improvement of the SOD in the impoundment due to the removal of the plant in 1996. Since this improvement of SOD by removal of anthropogenic sources is a longterm process, it is expected that the SOD would improve even more without this TMDL. The load reductions required by this TMDL will decrease the oxygen demanding loads to the creek, decrease SOD even more, thereby improving water quality in the stream.

5.4 Seasonal Variation

Seasonal variation was considered by examining the historical data. All of the impairments occurred during low flow conditions. Other periods, during higher flows were examined with no DO concentrations below 5.0 mg/L, resulting in a higher assimilative capacity.

5.5 Wasteload Allocations

Patton Creek is within a MS4 permitted area therefore what was traditionally thought of as a nonpoint source (NPS) of pollution from urban runoff is considered under an NPDES permit. There are no facilities permitted under the NPDES program permitted to discharge directly to Patton Creek. The TMDL allocations presented in this report will consider the necessary watershed wasteloads to meet water quality standards for DO.

5.6 TMDL Results

Table 5-1 presents the existing loads, the TMDL scenarios and the associated percent load reduction in NBODu & CBODu loads necessary for Patton Creek to attain water quality standards. The loads are expressed as $CBOD_U$ and $NBOD_U$. Since the entire Patton Creek watershed is located within the Jefferson County MS4 Phase I NPDES Permit (ALS000001), the loads and reductions are expressed as wasteload allocation (WLA_{MS4}) and load allocation (LA). Although, Patton Creek watershed lies within the defined boundaries of the MS4 Permit, there may be areas of the Patton Creek watershed that are not regulated under the MS4 NPDES permit, therefore a LA reduction needs to be expressed.

Table 5-1 Maximum Allowable $NBOD_u$ and $CBOD_u$ Loads for Patton Creek

Constituent	**Existing Load (lb/day)**	**TMDL (lb/day)**	**Load Reduction**	
	WLA_{MS4} + LA	**WLA_{MS4} + LA**	**WLA_{MS4}**	**LA**
$NBOD_U$	76.8	26.4	66%	66%
$CBOD_U$	25.5	19.5	24%	24%

NOTE: The load reductions are expressed as both WLA_{MS4} and LA percent reductions because the entire Patton Creek watershed is contained within the boundaries of the Jefferson County MS4 Phase I Permit (ALS000001).

6.0 Follow-up Monitoring

This TMDL is consistent with an adaptive management approach: allowable loads have been identified using the best available data and information; load reduction goals have been established; future water quality will be monitored for plan effectiveness and need for future revisions. Flexibility is built into the plan so that load reductions and control actions can be reviewed and updated when future monitoring indicates continuing water quality problems or improvement. An effective water quality monitoring program is a key component of a TMDL process that incorporates adaptive management, for it provides vital information concerning the effectiveness of control measures being implemented as well as provides the necessary data to address known data gaps and uncertainties.

ADEM has adopted a basin approach to water quality management; an approach that divides Alabama's fourteen major river basins into five groups. Each year, the ADEM water quality resources are concentrated in one of the basin groups. One goal is to continue to monitor §303(d) listed waters. This monitoring will occur in each basin according to the schedule listed below.

Table 7-1 Monitoring Schedule for Alabama

River Basin Group	Schedule
Choctawhatchee, Chipola, Perdido-Escambia and Chattahoochee	2004
Tallapoosa, Alabama and Coosa	2005
Escatawpa, Lower Tombigbee, Upper Tombigbee, Mobile	2006
Cahaba, Black Warrior	2007
Tennessee	2008

Monitoring will help further characterize water quality conditions resulting from the implementation of this TMDL in the watershed.

7.0 Public Participation

As part of the public participation process, this TMDL was placed on public notice and made available for review and comment. The public notice was prepared and published in the four major daily newspapers in Montgomery, Huntsville, Birmingham, and Mobile, as well as submitted to persons who have requested to be on ADEM's postal and electronic mailing distributions. In addition, the public notice and subject TMDL was made available on ADEM's Website: www.adem.state.al.us. The public can also request paper or electronic copies of the TMDL by contacting Mr. Chris Johnson at 334-271-

7827 or clj@adem.state.al.us. The public was given an opportunity to review the TMDL and submit comments to the Department in writing. At the end of the public review period, all written comments received during the public notice period became part of the administrative record. ADEM considered all comments received by the public prior to finalization of this TMDL and subsequent submission to EPA Region 4 for final review and approval.

8.0 References

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Appendix A Data Used In TMDL

Table A-1 ADEM Monitoring Data Used in TMDL Development

Station	Date	Time	Water TEMP(C)	DO	pH	Flow	BOD-5 (mg/l)	NO2/NO3 (mg/l)	NH3 (mg/l)	TKN (mg/l)	Total-P (mg/l)	DRP (mg/l)	Ortho-P (mg/l)
PA1	10/14/98	10:00	21.1	5.48	7.0								
PA1	06/02/99	9:30	24.8	5.91	7.22								
PA1	08/05/99	10:00	30.3	3.86	7.5								
PA1	10/13/99	10:00	21.6	4.24	7.0								
PA1	08/09/00	9:45	30.0	4.4	6.6								
PA1	01/30/02	10:11	12.0	9.00	6.60	35.50	0.5	0.664	0.05	0.17	0.06		0.002
PA1	03/06/02	9:20	14.2	10.50	6.88		2.9	0.375	0.015	<0.15	0.04		<0.004
PA1	03/28/02	9:20	14.0	10.50	6.80		0.7	0.384	0.06	0.78	0.047		<0.004
PA1	04/11/02	10:20	19.0	8.37	6.92		1.1	0.347	0.119	<0.15	0.037		0.003
PA1	05/16/02	9:42	22.0	7.67	7.20	5.10	4.3	0.141	0.072	0.59	0.052		0.006
PA1	05/23/02	12:15	22.0	7.20	7.72	3.10							
PA1	06/05/02	11:00	28.7	6.84	7.39	4.10	1.7	0.177	0.045	1.75	0.057		0.009
PA1	07/17/02	9:53	24.0	8.58	7.40		1.6	0.502	0.015	0.557	0.031		0.007
PA1	08/13/02	10:15	28.0	1.80	7.60		1.5	0.228	0.454	1.16	0.083		0.04
PA1	08/13/02						2.5	0.232	0.439	0.941	0.084		0.038
PA1A	03/15/95	10:25	16.0	9.30	7.20		1.7	0.47		0.2	0.03		
PA1A	04/06/95	9:55	19.0	7.80	7.40		2.2	0.14		0.2	0.83		
PA1A	05/10/95	9:30	24.0	6.80	7.50		2.8	0.26		0.3	0.04		
PA1A	06/07/95	10:15	27.8	5.70	7.10		1.7	0.13		0.3	0.37		
PA1A	07/19/95	10:20	30.0	3.50	7.10		0.9	0.23		0.4	0.28		
PA1A	08/16/95	9:50	30.3	4.10	7.10		0.7	0.294		0.3	1.009		
PA1A	09/06/95	10:15	25.4	4.00	7.70		3.1	0.23		0.3	1.05		
PA1A	10/11/95	11:00	20.7	8.50	6.90		1.4	0.75		0.2	0.08		
PA1A	11/07/95	10:50	15.2	9.50	6.60		2.4	0.414		0.2	0.129		
PA1A	06/07/00	10:00	24.0	5.60	6.90		1.9	0.174	<0.015		<0.004		
PA1A	08/09/00	9:45	30.0	4.40	6.60		1.2	0.354	<0.015		0.021		
PA1A	10/11/00	11:00	15.3	8.12	7.84		1.9	0.216	<0.015		0.046		
PA1A	06/06/01	10:00	25.2	5.93	8.00		2.2	0.342	<0.015		0.06		
PA1A	08/08/01	10:00	25.5	8.04	7.30		1.5	0.39	0.33		0.03		
PA1A	10/10/01	11:15	19.2	8.11	7.71	2.5	0.4	0.053	<0.015		<0.004		
PA1A	06/05/02	10:15	27.9	7.56	6.73	7.0	1.5	0.152	<0.015		<0.004		
PA1A	08/06/02	11:00	31.0	4.80	7.52	1.1	2.4	0.321	<0.015		0.106		
PA-1A	3/26/2003	11:30					1.6	0.297	0.024	0.433	<0.004	<0.004	
PA-1A	4/8/2003	11:30					0.6	0.59	0.094	<0.15	<0.004	<0.004	
PA-1A	5/20/2003	10:50					0.9	0.659	0.032	<0.15	0.041	<0.004	
PA-1A	6/4/2003	12:45	23.6	8.35	7.28		2.7	0.474	<0.015	0.674	0.05		
PA-1A	6/9/2003	1100	26.6	8.12	7.15	15.1							
PA-1A	6/11/2003	11:15						0.253	<0.015	<0.15	0.041	<0.004	
PA-1A	6/12/2003	9:15	25.8	7.77	7.11	19.3							
PA-1A	6/16/2003	10:10	25.8	7.83	7.21	22.9							
PA-1A	6/19/2003	8:45	22.6	7.96	6.76								
PA-1A	6/23/2003	10:45	25.0	8.2	7.86	24.6							
PA-1A	6/26/2003	10:30	27.9	7.82	8	13.9	0.8	0.395	<0.015	<0.15	0.017	<0.004	
PA-1A	7/17/2003	13:00	30.8	5.29	7.12	6.3	0.5	0.213	<0.015	0.44	0.024	0.003	
PA-1A	8/18/2003	9:45	26.7	7.4	7.6			0.43	0.049	0.558	0.049		
PA-1A	8/26/2003	9:45	29.2	11.3	7.3	8.9		0.3	<0.015	0.553	<0.02	0.01	
PA-1A	9/9/2003	11:45	27.3	6.6	7.1	1.3		0.439	<0.015	0.446	<0.02	0.014	
PA-1A	9/15/2003	10:45	25.7	4.7	7.1	1.6							
PA-1A	9/18/2003	10:20	26.0	5.1	7.4	0.9							

Station	Date	Time	Water TEMP(C)	DO	pH	Flow	BOD-5 (mg/l)	NO2/NO3 (mg/l)	NH3 (mg/l)	TKN (mg/l)	Total-P (mg/l)	DRP (mg/l)	Ortho-P (mg/l)
PA-1A	9/22/2003	11:00	24.4	7.0	7.2	13.3							
PA-1A	9/25/2003	10:45	23.7	5.9	7.3	5							
PA-1A	9/29/2003	10:10	22.3	6.3	7.3	3.2							
PATJ-3	03/06/02	10:00	7.3	12.09	6.67		2.4	0.362	<0.015	<0.15	0.05		0.01
PATJ-3	03/28/02	9:50	12.2	9.68	6.62		0.6	1.13	<0.015	1.08	0.049		0.004
PATJ-3	04/11/02	11:07	19.0	6.62	8.06		0.7	0.372	0.072	<0.15	0.035		0.005
PATJ-3	05/16/02	8:50	19.0	10.90	7.15		2.9	0.269	0.093	0.135	0.033		0.005
PATJ-3	06/05/02	11:50	26.0	4.44	7.16		1.9	0.574	0.265	0.905	0.043		0.007
PATJ-3	07/17/02	10:10	25.9	5.14	7.50		2.3	0.734	0.295	0.553	0.032		0.022
PATJ-3	08/13/02	11:00	24.8	3.40	7.70		3.5	0.031	0.14	0.718	0.048		0.022
PATJ-3	08/13/02	11:00					3.5	0.035	0.102	0.214	0.048		0.024
PATJ-3	3/26/2003	10:15					0.7	0.326	<0.015	<0.15	<0.004	0.004	
PATJ-3	4/8/2003	9:45					5	0.663	<0.015	<0.15	<0.004	0.004	
PATJ-3	5/20/2003	10:00					0.5	0.721	0.02	<0.15	<0.004	0.004	
PATJ-3	6/11/2003	11:15						0.325	<0.015	<0.15	0.021	0.004	
PATJ-3	6/26/2003	9:20	24.2	6.8	7.6		0.5	0.524	<0.015	<0.15	<0.004	0.004	
PATJ-3	7/17/2003	11:45	26.5	5.88	7.27		0.7	0.198	0.029	0.38	0.025	0.004	
PATJ-3	8/26/2003	8:45	26.5	12.3	7.1			0.214	<0.015	0.52	<0.02	0.004	
PATJ-3	9/9/2003	11:45	23.8	5.9	6.7			0.153	<0.015	0.317	<0.02	0.004	
PATJ-4	01/30/02	9:10	12.0	9.50	6.50		0.8	0.709	<0.015	0.09	0.08		0.004
PATJ-4	03/06/02	8:30	10.4	13.20	7.14	11.80	2.4	0.532	0.04	0.26	0.04		0.004
PATJ-4	03/28/02	8:30	10.4	13.20	7.14		0.9	0.501	<0.015	0.27	0.042		0.01
PATJ-4	04/11/02	9:30	17.0	9.28	7.07	7.60	0.5	0.375	<0.015	<0.15	0.026		0.008
PATJ-4	05/16/02	8:25	16.4	6.55	7.40	2.10	1.6	0.345	<0.015	0.303	0.024		0.013
PATJ-4	06/05/02	10:00	23.9	8.84	7.70	1.50	1.2	0.248	<0.015	0.554	0.06		0.023
PATJ-4	07/17/02	9:22	24.0	8.58	7.40		1.9	0.43	<0.015	0.383	0.026		0.014
PATJ-4	08/13/02	9:25	25.3	3.96	7.60		1.5	0.037	<0.015	0.554	0.05		0.02
PATJ-4	08/13/02	9:25					1.4	0.039	<0.015	0.501	0.049		0.305
PATJ-4A	3/26/2003	13:00					1.2	0.415	<0.015	<0.15	<0.004	0.004	
PATJ-4A	4/8/2003	9:50					0.7	0.387	0.061	<0.15	0.07	0.023	
PATJ-4A	4/8/2003	12:30					0.2	0.755	<0.015	<0.15	<0.004	0.004	
PATJ-4A	5/20/2003	11:30					0.5	0.806	0.029	<0.15	<0.004	0.004	
PATJ-4A	6/11/2003	12:15						0.377	<0.015	<0.15	<0.004	0.004	
PATJ-4A	6/26/2003	11:10	23.9	10.02	8.35	6.6	1.2	0.597	<0.015	0.348	<0.004	0.014	
PATJ-4A	7/17/2003	13:50	27.7	7.93	7.99	6.5	0.7	0.397	<0.015	0.353	0.05	0.023	
PATJ-4A	8/26/2003	10:20	26.4	12.4	7.6	6.5		0.262	<0.015	0.753	<0.02	0.004	
PATJ-4A	9/9/2003	11:45	25.7	9.9	7.8	1.2		0.046	<0.015	0.512	<0.02	0.004	

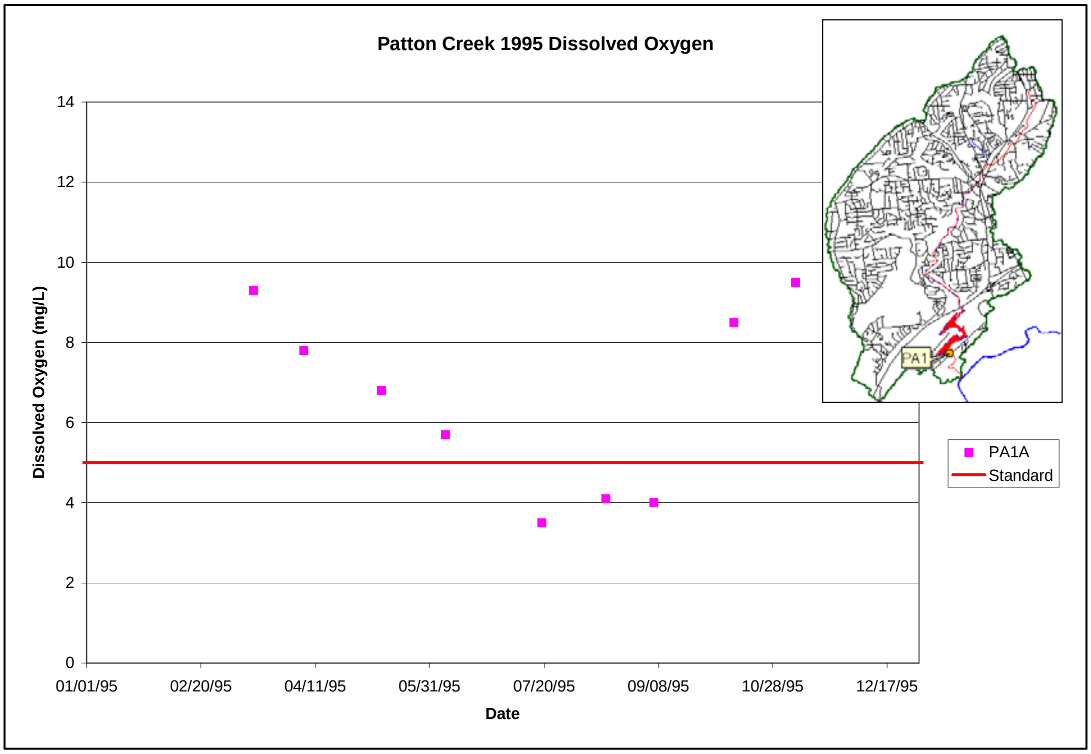

Figure A-1 Dissolved Oxygen Measured in 1995

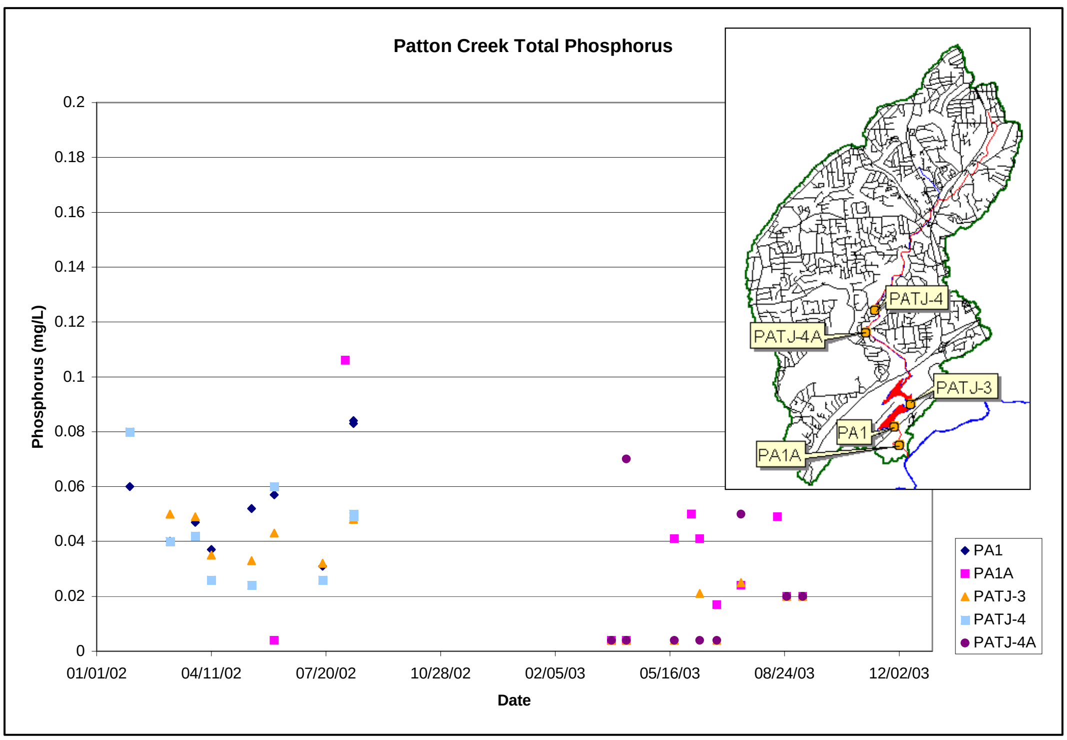

Figure A-2 Total Phosphorus Measured in 2002 and 2003

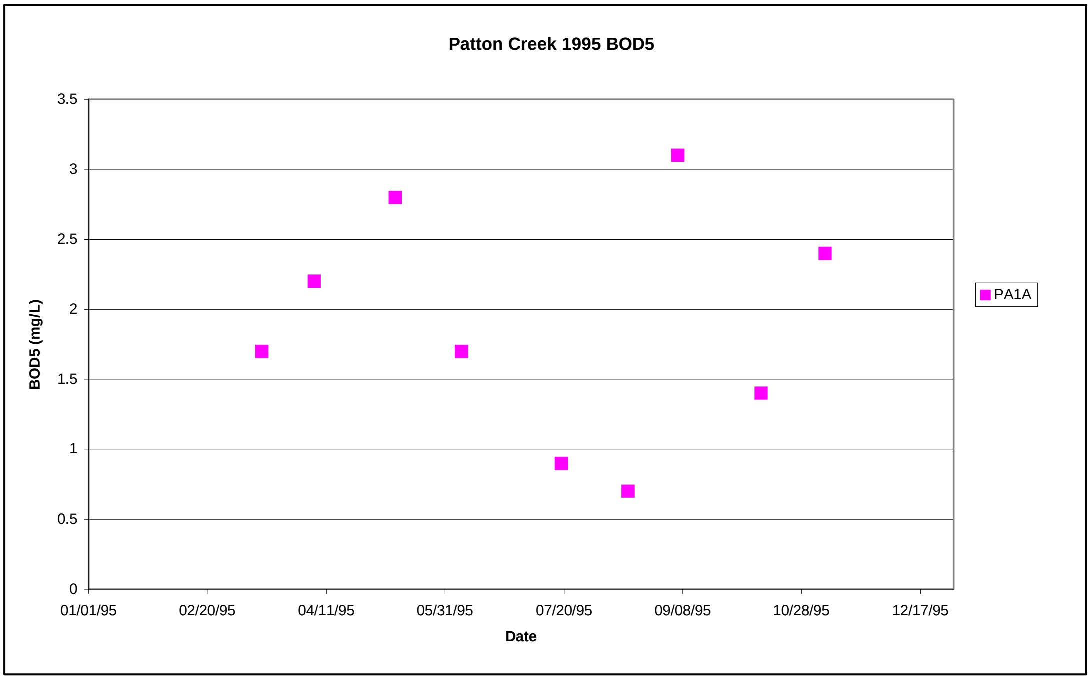

Figure A-3 BOD_5 Measured in 1995

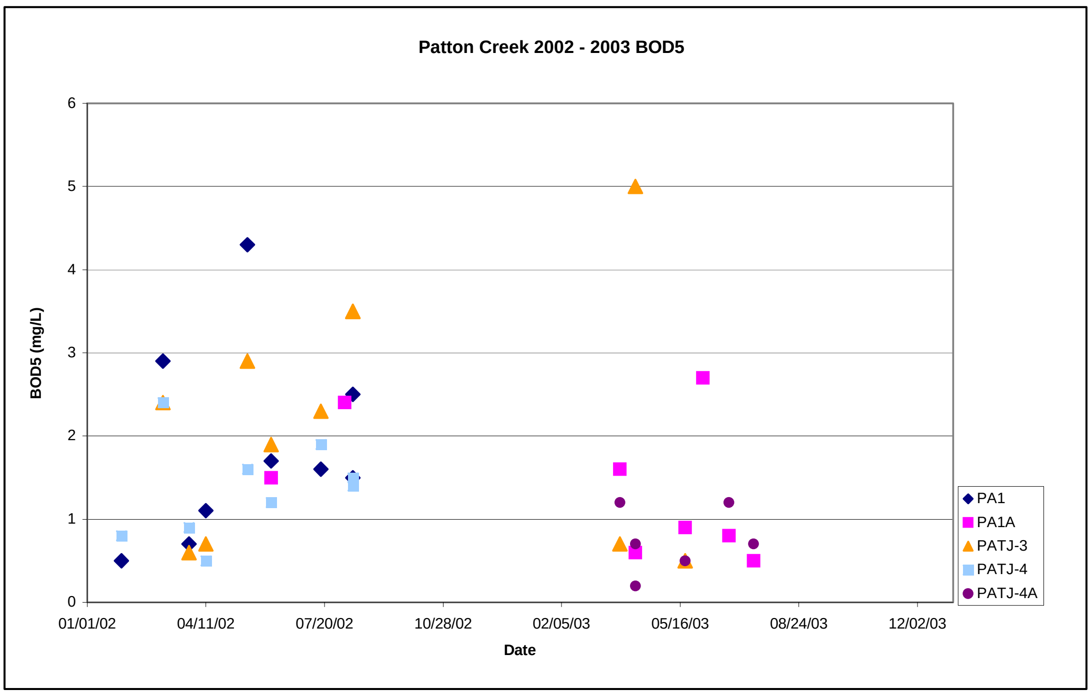

Figure A-4 BOD_5 Measured in 2002 and 2003

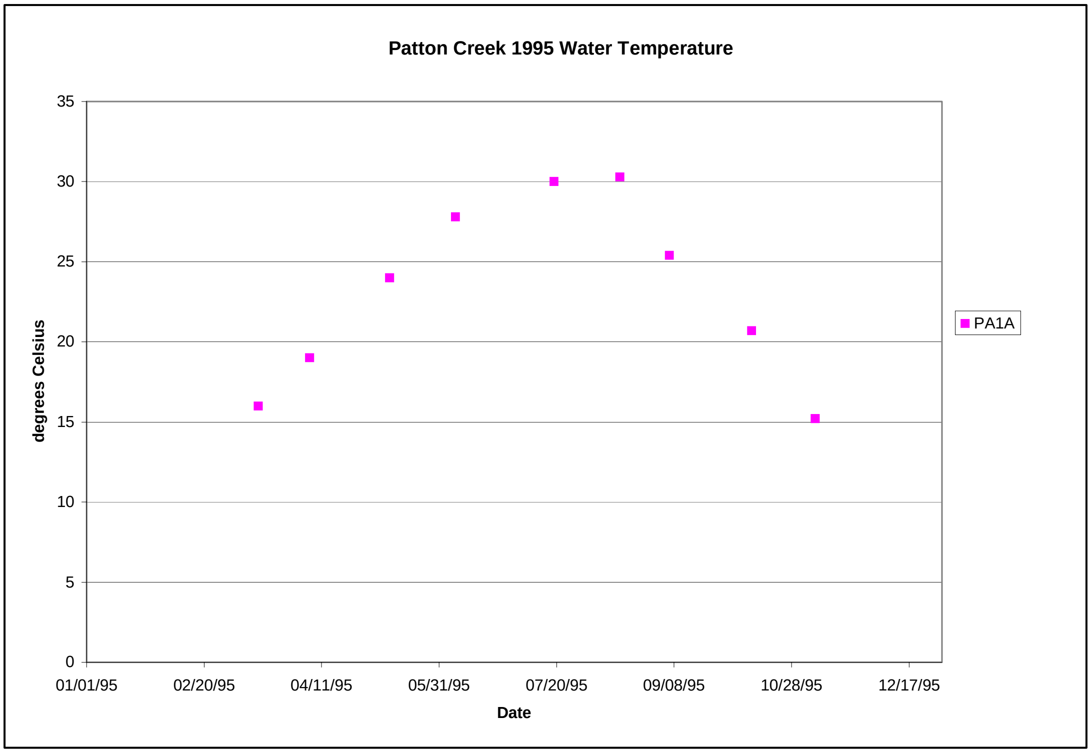

Figure A-5 Water Temperature Measured in 1995

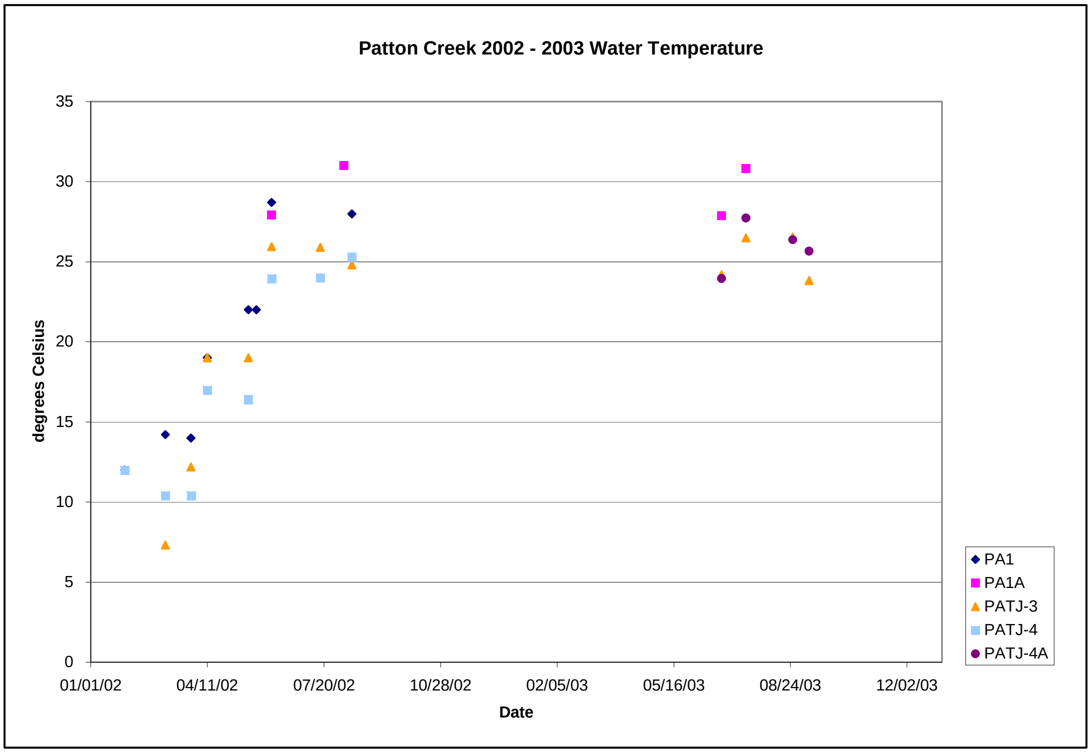

Figure A-6 Water Temperature Measured in 2002 and 2003

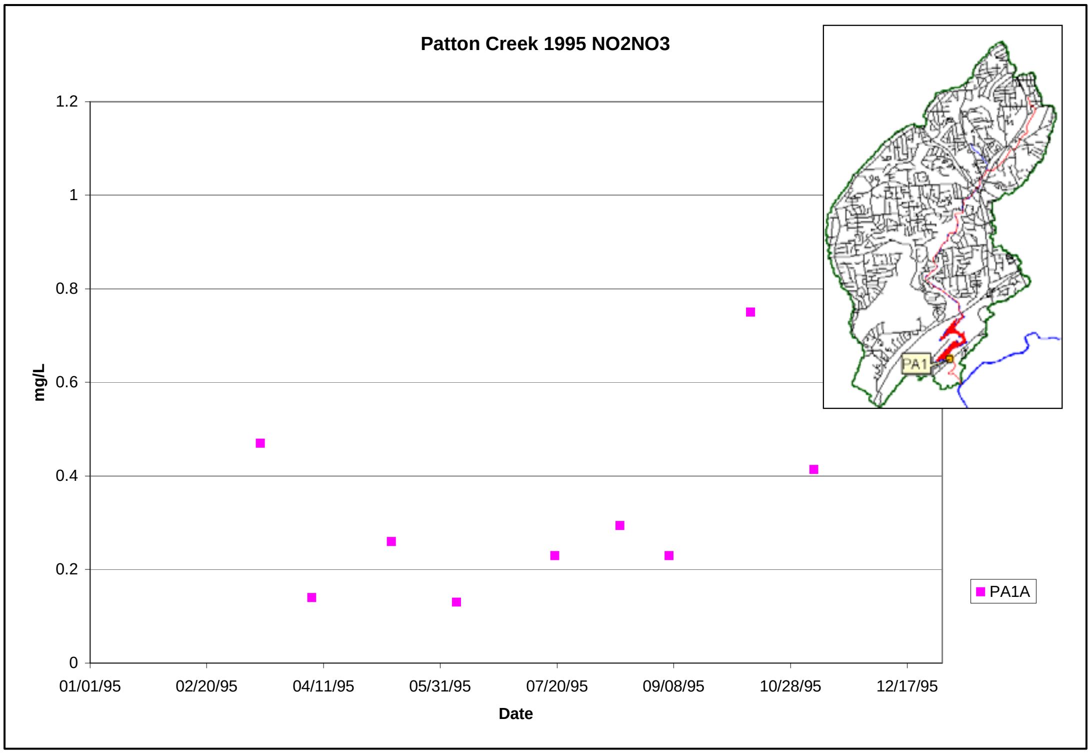

Figure A-4 Nitrite Plus Nitrate as Nitrogen (NO2NO3) Measured in 1995

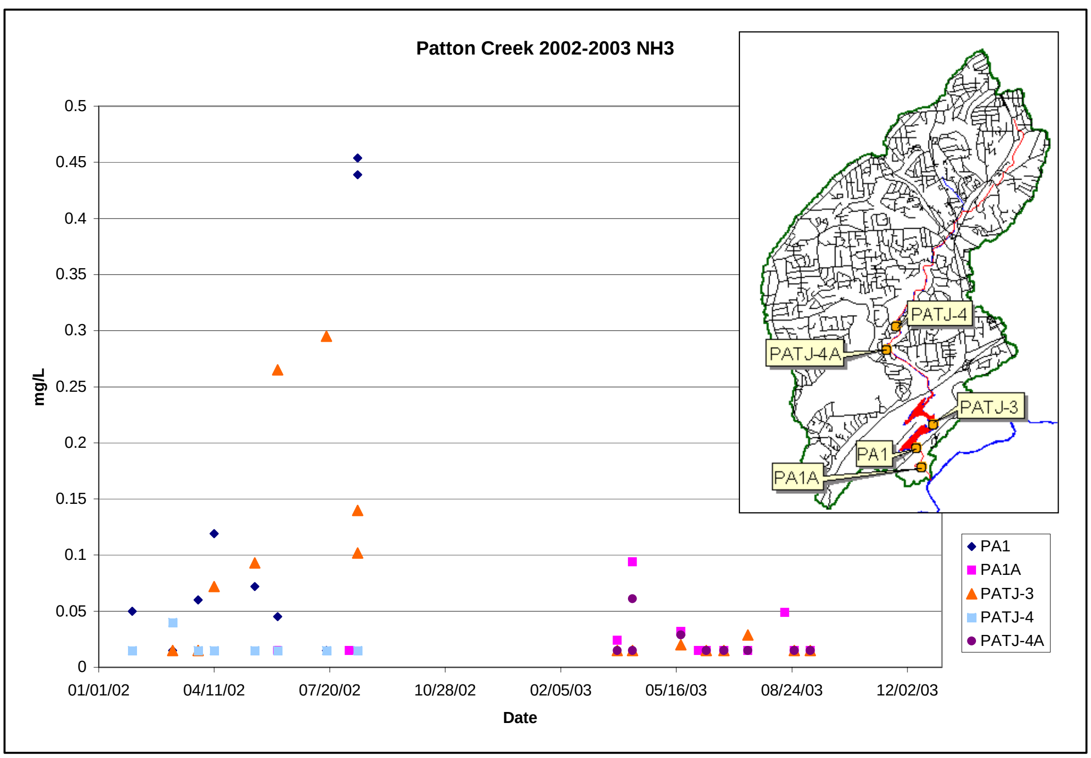

Figure A-5 Nitrite Plus Nitrate as Nitrogen (NO2NO3) Measured in 2002 and 2003

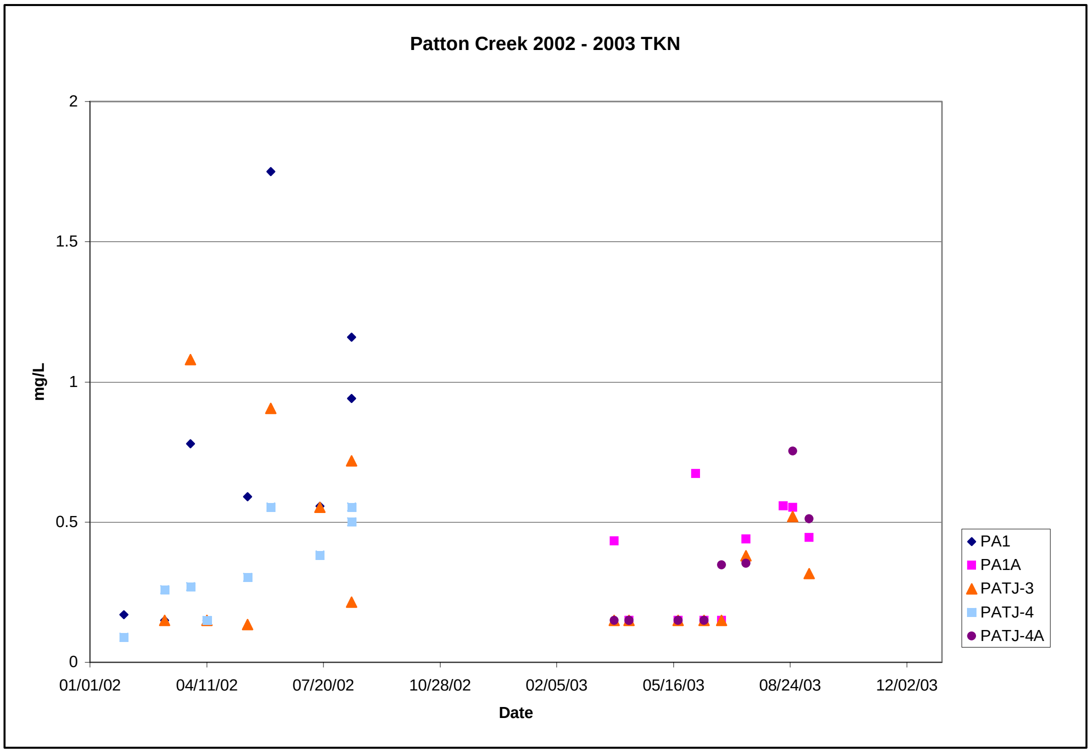

Figure A-6 Total Kjeldahl Nitrogen (TKN) Measured in 2002 and 2003

Appendix B Model Calibration Plots

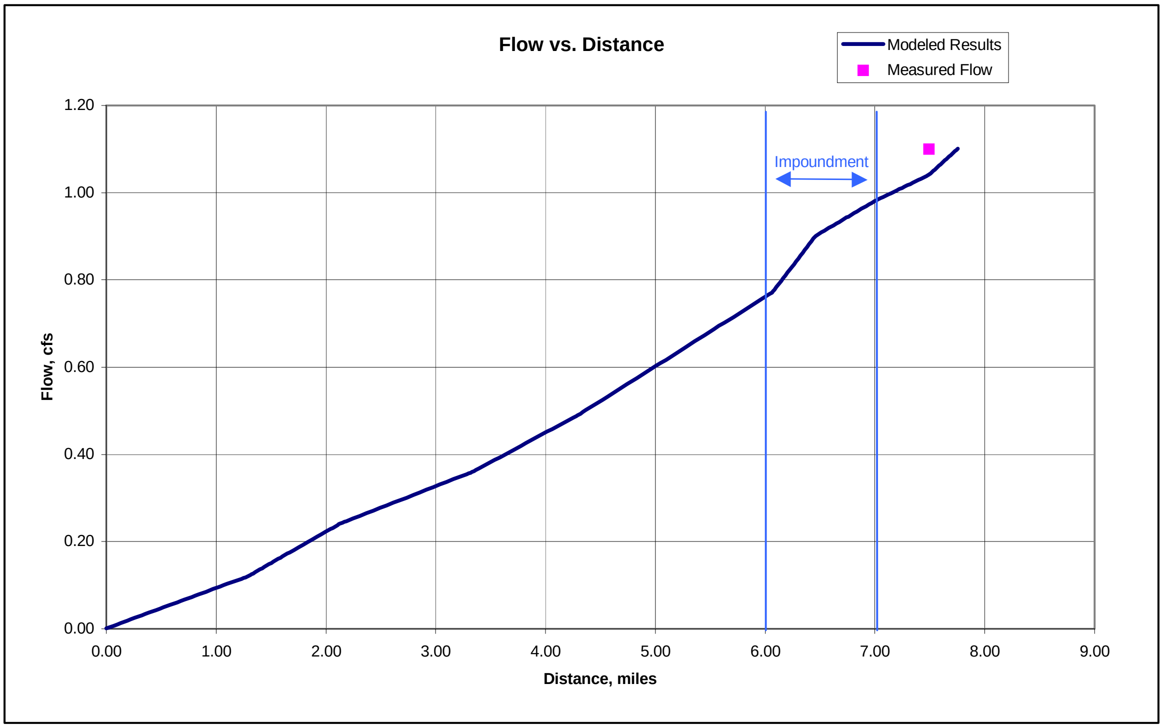

Figure B-1 SWQM Calibrated Flow on Patton Creek

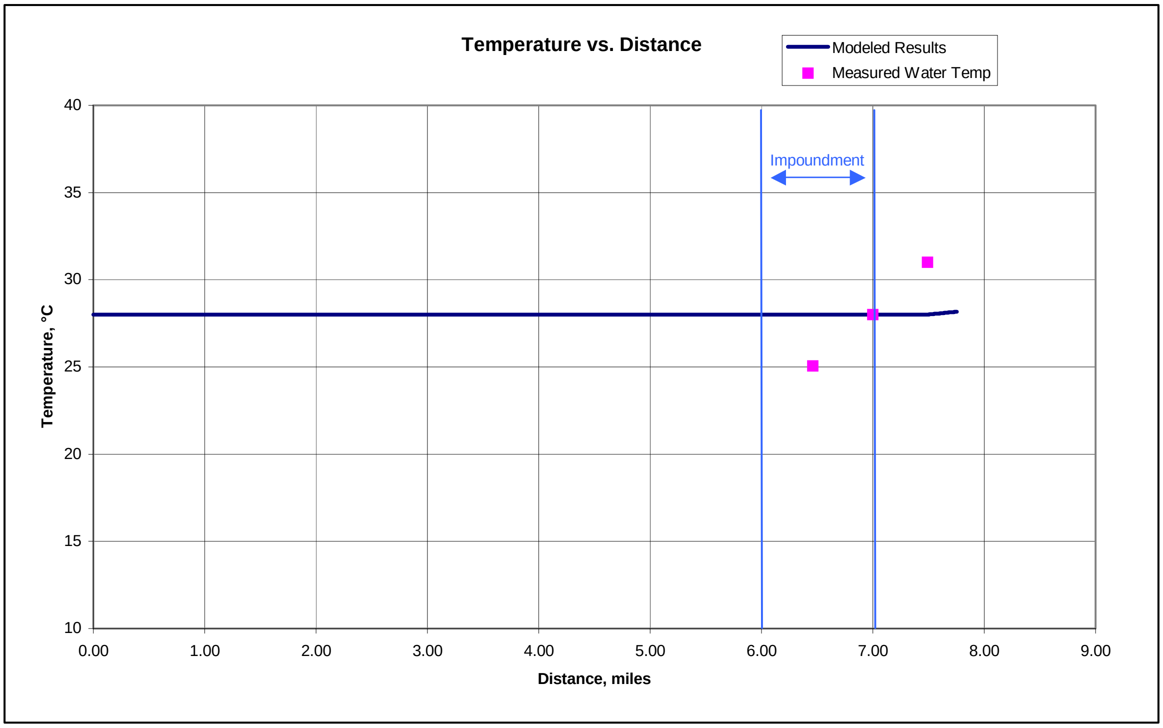

Figure B-2 SWQM Calibrated Water Temperature on Patton Creek

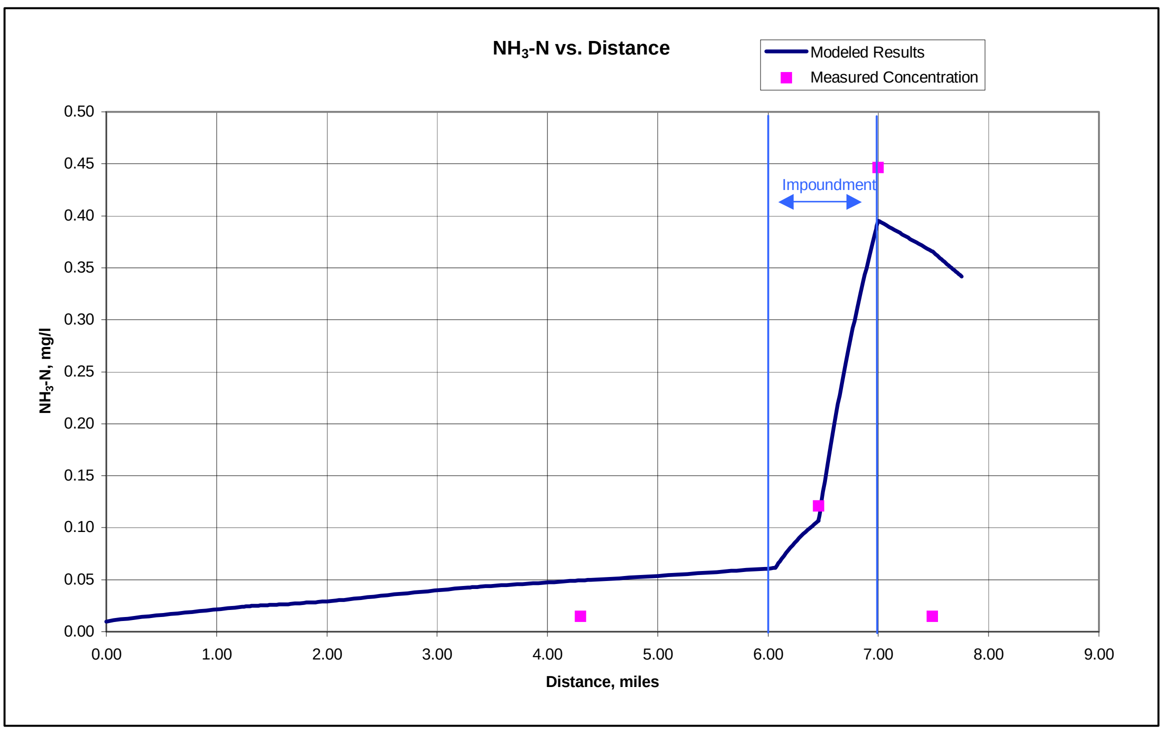

Figure B-3 SWQM Calibrated NH_3 as Nitrogen on Patton Creek

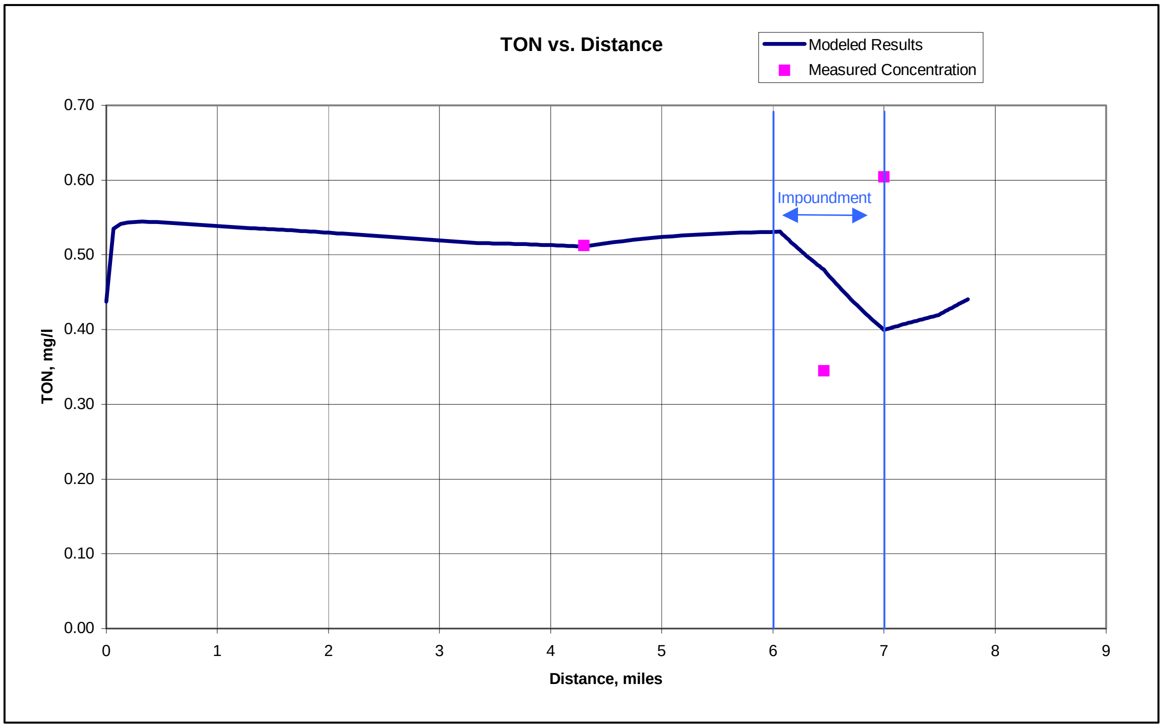

Figure B-4 SWQM Calibrated Total Organic Nitrogen on Patton Creek

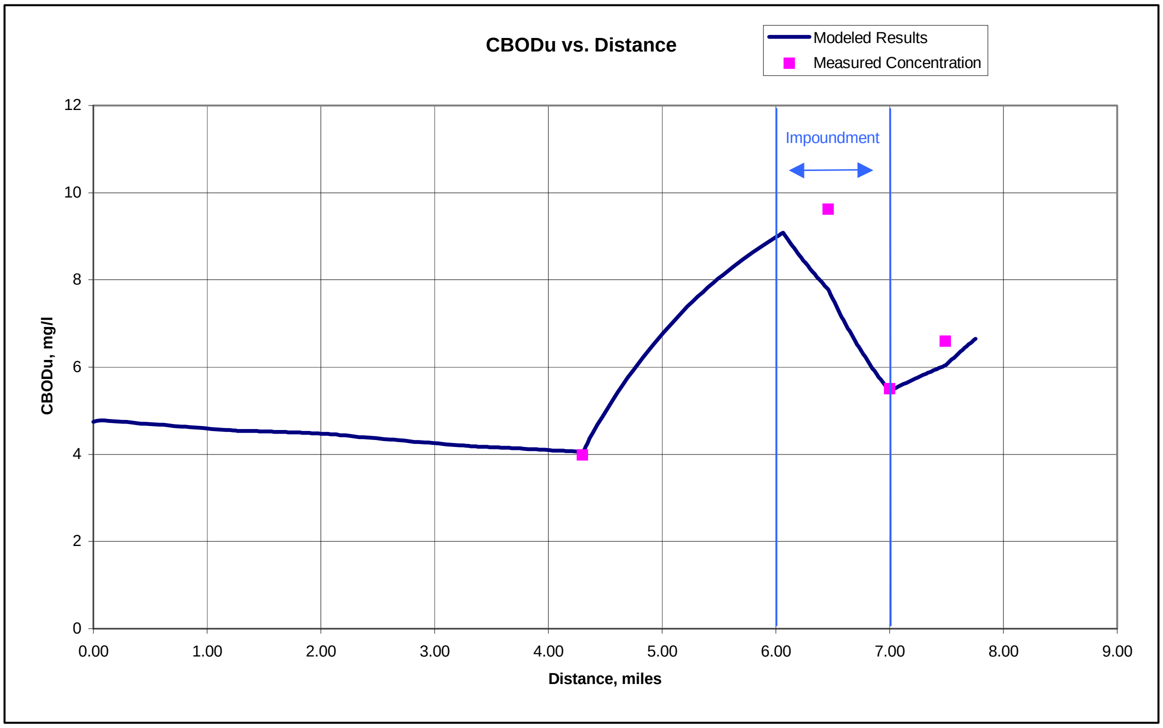

Figure B-5 SWQM Calibrated $CBOD_U$ on Patton Creek

Appendix C TMDL Scenario Plots

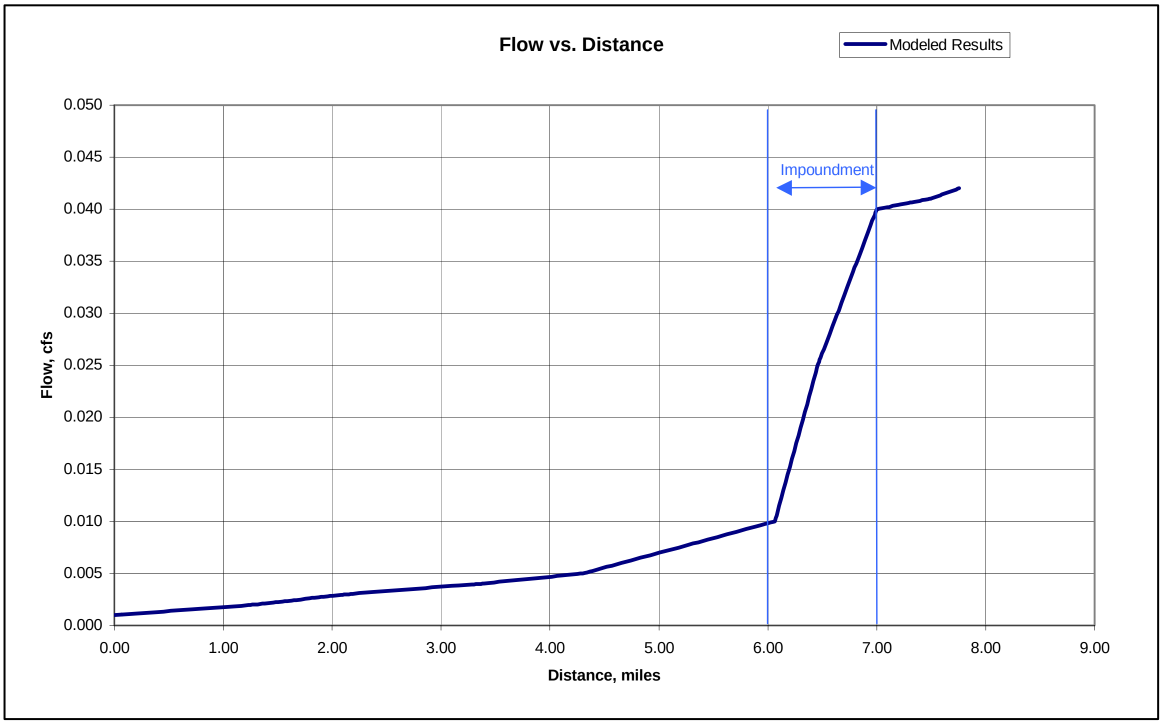

Figure C-1 SWQM TMDL Flow on Patton Creek

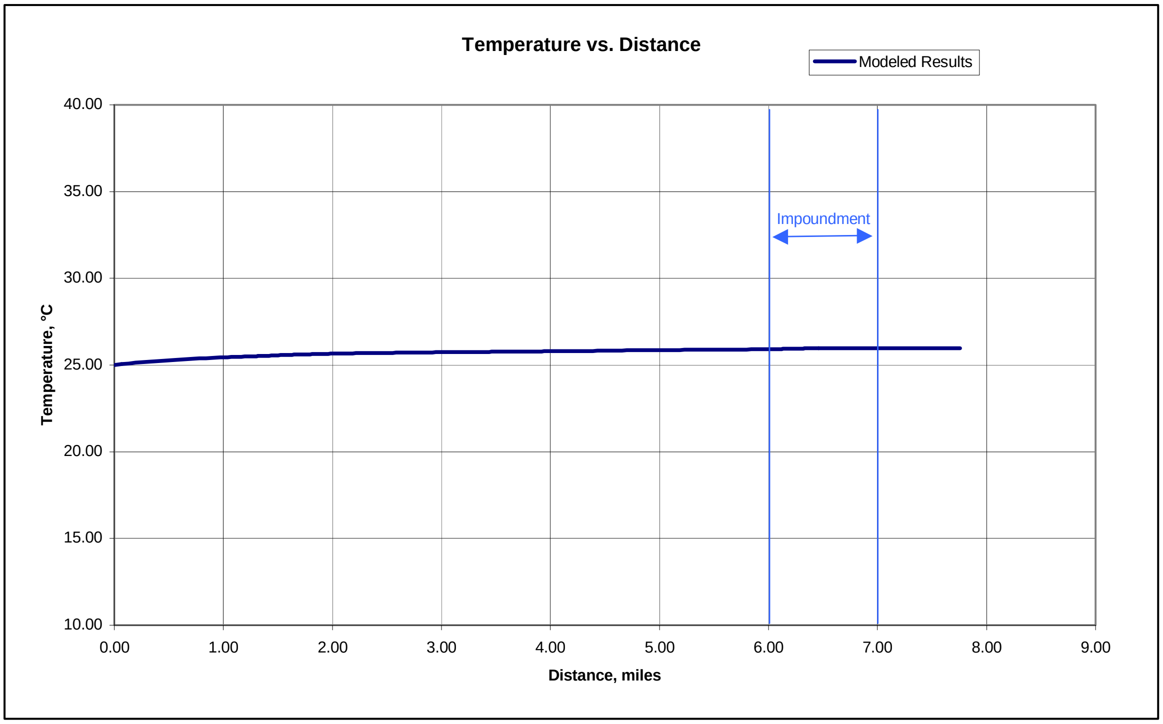

Figure C-2 SWQM TMDL Water Temperature on Patton Creek

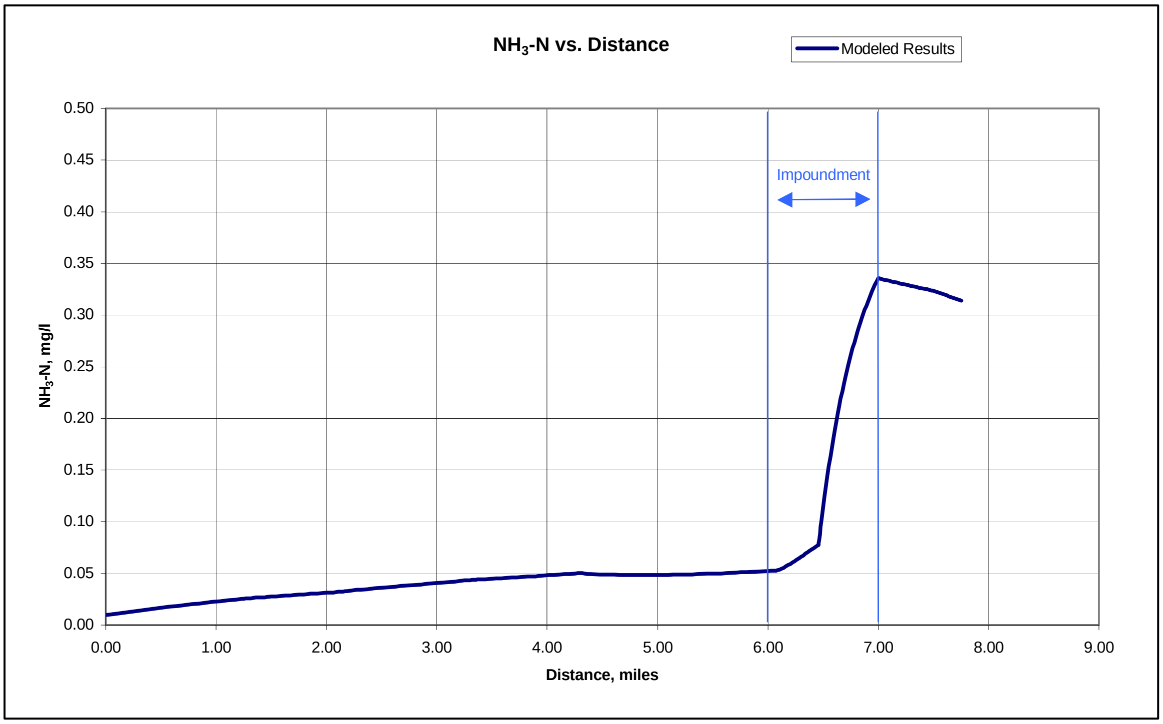

Figure C-3 SWQM TMDL NH_3 as Nitrogen on Patton Creek

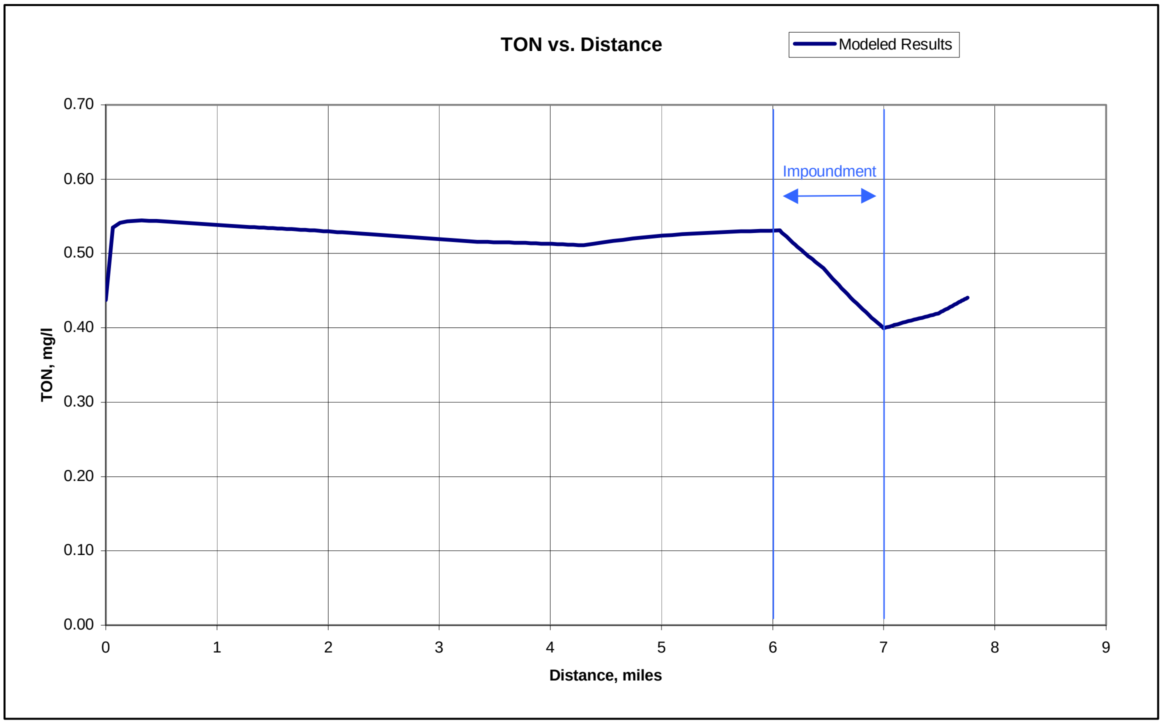

Figure C-4 SWQM TMDL Total Organic Nitrogen on Patton Creek

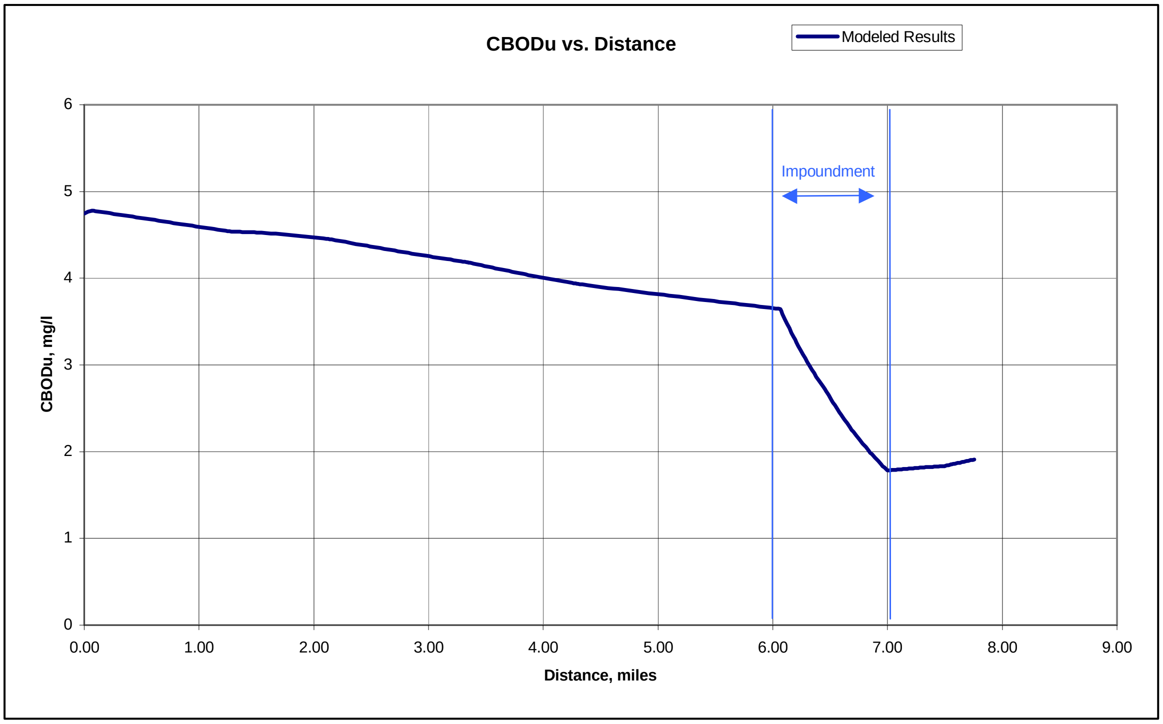

Figure C-5 SWQM TMDL $CBOD_U$ on Patton Creek