Upper Merrimack and Pemigewasset River Study

Field Program 2009-2012

Monitoring Data Report

December 2012

US Army Corps of Engineers ®
New England District

New Hampshire Department of Environmental Services

New Hampshire Southern Planning Commission
SNHPC

CDM Smith

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Abbreviations

$CBOD_5$: 5-day carbonaceous biological oxygen demand

$CBOD_{20}$: 20-day carbonaceous biological oxygen demand

cfs: cubic feet per second

cfsm: cubic feet per second per square mile

D/S: downstream

DO: Dissolved oxygen

EPA NERL: US EPA New England Regional Laboratory

EPA: US Environmental Protection Agency

g O_2/m^2 per day: grams of oxygen per square meter per day (SOD units)

mg/L: milligrams per liter

mgd: million gallons per day

mg P/m^2 per day: milligrams of phosphorus per square meter per day (p-flux units)

MOR: monthly operating report

mpn: most probable number

NHDES: New Hampshire Department of Environmental Services

P-flux: sediment phosphorus flux

PSNH: Public Service of New Hampshire

QAPP: Quality Assurance Project Plan

SMAST: School for Marine Science and Technology at the University of Massachusetts-Dartmouth

SOD: Sediment oxygen demand

U/S: upstream

ug/L: micrograms per liter

USGS: United States Geological Survey

7Q10: 7-day average flow with a 10-year return period

Section 1
Background

1.1 Upper Merrimack and Pemigewasset River Study

The Upper Merrimack and Pemigewasset River Study is a jointly funded cost-sharing effort by the federal government, through the United States Army Corps of Engineers (USACE), the New Hampshire Department of Environmental Services (NHDES), and various communities in the watershed.

Over the past several decades, significant improvements have been made to the water quality of the Merrimack River. However there are remaining water quality, quantity, and fish and wildlife habitat issues. Recently the USACE, with sponsors in Massachusetts and New Hampshire, completed work on the lower Merrimack River to compare the relative contributions and impacts of pollution from nonpoint sources and combined sewer overflows, and to compare alternative bacteria abatement strategies in the watershed.

The previous study area focused on the impacts of bacteria and nutrients in the portion of the river from Hooksett, NH downstream to its confluence with the Atlantic Ocean in Newburyport, MA. The purpose of this new effort is to extend the evaluation of instream water quality in the mainstem Pemigewasset and Merrimack Rivers upstream to Lincoln, NH, close to the headwaters. One of the goals is to create a time dependent model of flow and water quality of the Upper Merrimack and Pemigewasset Rivers that can be used to guide the following activities and decisions:

- The model will be used as a tool to identify the sources of the dissolved oxygen deficit in reaches of the river that are listed on the New Hampshire 303(d) list of impaired waters, and plan for the expected needs of several wastewater treatment facilities for updated discharge permits,

- Assess the water quality and quantity impacts of potential future increases in water withdrawals from the mainstem Merrimack by communities south of Concord, NH.

- Potentially evaluate alternative usage of USACE reservoirs in the watershed to lessen impacts of treated wastewater discharges and/or water supply withdrawals.

The performance of the model will be tested against data collected from the mainstem Pemigewasset and Merrimack Rivers, and their primary tributaries in New Hampshire. This document presents the results and findings of the first year of data collection, spanning June 2009 through July 2010.

1.2 Sampling Program Overview

A field sampling program was developed as part of the Upper Merrimack and Pemigewasset River Study. The primary objective of the field sampling program is to provide an accurate and representative picture of the current water quality conditions at specific sampling stations along the mainstem, with particular emphasis on impounded reaches, as well as the mouths of major tributaries. Data collected under this task will be used as input to the existing water quality and hydrologic/hydraulic models which will be extended upstream under subsequent tasks of the Upper Merrimack and Pemigewasset River Study. These models will serve as the basis for future planning and regulatory decisions in the basin.

The field sampling program consists of the following components:

- Impoundment studies
- Continuous dissolved oxygen and temperature monitoring
- Low-flow water quality surveys
- High-flow water quality survey
- Sediment Oxygen Demand and Nutrient Flux monitoring

Maps showing the approximate locations of sampling and data recording are shown in subsequent sections of this report; detailed location maps can be found in Appendix A. It should be noted that throughout this study the NHDES definition of impoundment has been applied to river segments within the study area. Specifically, river segments behind dams recognized by the NHDES Dan Bureau are considered impoundments, regardless of dam height.

The approved Field Sampling Plan (February 2008), QAPP (November 2008), QAPP Addendum 1 and Standard Operating Procedure Compendium (August 2009) served as the governing documents for the implementation of the sampling program. Deviations from the approved documents will be noted for each event in subsequent sections of this report.

All activities were performed by members of the CDM team, which is comprised of CDM and its subcontractors:

- Normandeau Associates, Inc. of Bedford, NH
- University of Massachusetts School for Marine Science and Technology (SMAST) of New Bedford, MA
- MWH Laboratories of Monrovia, CA
- Eastern Analytical Laboratory of Concord, NH
- US EPA New England Regional Laboratory of Chelmsford, MA

1.2.1 Data Quality Objectives

Based on the sampling program objectives and the proposed data usage for the Upper Merrimack and Pemigewasset River Study, the following Data Quality Objectives (DQOs) were established for the sampling program:

- Collect water quality, sediment and impoundment data sufficient for extending the existing water quality and hydrologic/hydraulic models from Manchester, NH to Lincoln, NH.

- Develop a comprehensive data base of water quality data with which to characterize the impacts of point source loads and non-point source loads on dissolved oxygen and chlorophyll-a levels in the Upper Merrimack and Pemigewasset Rivers in New Hampshire.

These DQOs, along with the other quality objectives and criteria specified in the approved QAPP, will be used to assess the usability of the data in subsequent sections of this report.

1.2.2 Study Area

For the purposes of the field sampling program, the study area is the mainstem Pemigewasset and Merrimack Rivers south of Lincoln, NH to the New Hampshire-Massachusetts state line in Nashua, NH. The reach of the Merrimack River downstream of Hooksett, NH was included in the Merrimack River Watershed Assessment Study completed by CDM in 2005, thus the intention of water quality monitoring in that reach is to supplement the data collected as part of the previous study and provide continuity.

Six dams are included in the study area, as follows:

- Ayers Island Dam in Bristol/New Hampton

- Franklin Falls Dam in Franklin

- Eastman Falls Dam in Franklin

- Garvins Falls Dam in Concord/Bow

- Hooksett Dam in Hooksett

- Amoskeag Dam in Manchester

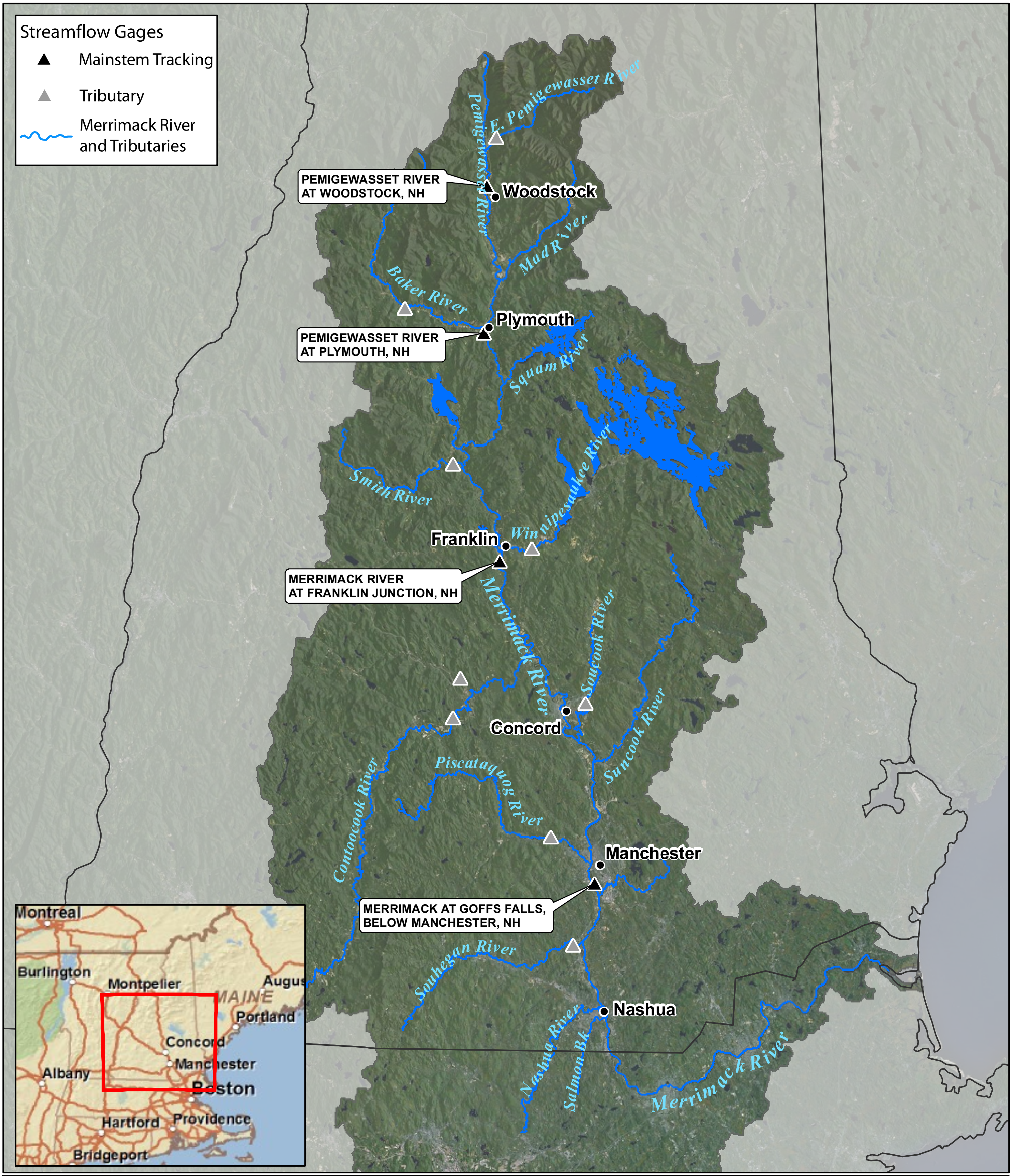
Franklin Falls Dam is owned and operated by USACE and is used primarily for flood control purposes while the other dams are owned and operated by Public Service Company of New Hampshire (PSNH) and are used for hydroelectric power generation.

In addition to the mainstem sampling locations, 16 major tributaries have been identified within the study area. Impacts of the tributary sub-basins will be evaluated as part of this field sampling program by collecting water quality samples at the mouths of these key tributaries. Table 1-1 lists the tributaries to the mainstem Upper Merrimack and Pemigewasset River that are to be included in the model along, with the location of the confluence with the mainstem.

Table 1-1: Key Tributaries to the Upper Merrimack and Pemigewasset Rivers

Tributary	Location of Confluence
East Branch Pemigewasset	Woodstock, NH
Mad River	Campton, NH
Baker River	Plymouth, NH
Squam River	New Hampton, NH
Newfound River	Bristol, NH
Smith River	Bristol/Hill, NH
Chance Pond Brook	Franklin, NH
Winnipesaukee River	Franklin, NH
Contoocook River	Boscawen/Concord, NH
Soucook River	Concord/Pembroke, NH
Suncook River	Allenstown/Pembroke, NH
Piscataquog River	Manchester, NH
Cohas Brook	Manchester, NH
Souhegan River	Merrimack, NH
Nashua River	Nashua, NH
Salmon Brook	Nashua, NH

Figure 1-1 shows the Pemigewasset and Merrimack River study area and watershed.



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Upper Merrimack and Pemigewasset River Study

Figure 1-1
Study Area Map

0 5 10 20 Miles

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1.2.3 Program Components

This report includes the results of all field program activities. Table 1-2 lists the program components and the date of completion (if applicable), followed by a summary of each.

Table 1-2: Status of Program Components

Program Component	Dates of Field Activities
Impoundment Studies	June to October, 2009
Continuous Monitoring	July to September, 2009
Sediment Oxygen Demand and Nutrient Flux Sampling	September and October, 2009
Low Flow Event #1	July 27, 2010
Low Flow Event #2	September 21, 2010
High Flow Event	May 17, 2012

1.2.3.1 Impoundment Studies

Understanding the water quality and hydrodynamics of the 6 impoundments that lie in the study area is important in order to evaluate the extent of the dissolved oxygen deficits of the Merrimack and Pemigewasset Rivers. In order to do this, surveys of the riverine impoundments were conducted as part of this sampling program. Once a month for five months (June to October, 2009), sampling teams took vertical profiles of dissolved oxygen and temperature and water samples for total phosphorus and chlorophyll-a analyses at three stations within each of the six impoundments.

1.2.3.2 Continuous Dissolved Oxygen Monitoring

Continuous dissolved oxygen data provides insight into the conditions in the river that single sampling events cannot provide. Continuous monitoring indicates variations in temperature and dissolved oxygen levels over time. Information provided by continuous dissolved oxygen monitoring includes daily fluctuations in dissolved oxygen levels, impacts of storm events on dissolved oxygen levels, and changes in dissolved oxygen levels with varying river levels.

Continuous dissolved oxygen monitoring was conducted at 15 locations within the study area from mid-July to mid-September 2009. Data was collected during this period at 15-minute intervals. Field crews performed routine maintenance throughout this monitoring period and downloaded data frequently. The 15 meters were deployed at the following locations:

- Upstream and downstream of each of the six dams
- Downstream of the Winnipesaukee WWTP in Franklin
- Downstream of the Manchester WWTP in Manchester
- Upstream and downstream of the Nashua WWTP in Nashua

1.2.3.3 Low and High Flow Water Quality Surveys

Two low flow surveys were conducted (July 27, 2010 and September 21, 2010) to capture the conditions of the river during a single day event. The purpose of the low flow surveys is to characterize the conditions during periods when the river is stressed with regard to dissolved oxygen, with particular emphasis on nutrient-driven processes that cause oxygen deficits. Low flow targets were established at each of the four mainstem USGS streamflow gages as three times the 7-day 10-year low flow value (7Q10).

A high flow survey was conducted May 17, 2012. The purpose of the high flow survey is to characterize the conditions in the river during a much higher flow regime in order to calibrate the dynamic flow simulation model. High flow targets were set for each of the four USGS gages as the greatest average monthly flow; this is the April average flow for 3 stations and the May average flow for the most upstream station. The target sampling period for both the low and high flow surveys was May through early September.

Sampling locations were chosen to characterize loads from tributary subbasins, WWTPs, major communities, and the conditions within and downstream of the six dam impoundments. The 86 total sampling stations included 52 mainstem, 18 tributary and 14 WWTP sites.

Water quality analyses for the low and high flow surveys included field measurements, nutrients, biomass, bacteria, and oxygen demand measurements. Table 1-3 shows the complete list of analytes and measurements for the low and high flow surveys.

Table 1-3: Sampling Constituents and Field Measurements

Analytical Constituents	Field Measurements
Oxygen and Oxygen Demand	In situ Measurements
Dissolved Oxygen (Winkler method)	Temperature
$CBOD_5$	Dissolved Oxygen
$CBOD_{20}$ (limited sites)	pH
Nutrients and Impacts	Conductivity
Total Suspended Solids	Turbidity
Total Phosphorus	Secchi Disc depth
Orthophosphates	Vertical Temperature and DO Profiles
Nitrate + Nitrite	
Ammonia Nitrogen	Flow (tributaries only)
TKN	
Chlorophyll-a	
Bacteria	
E. coli	

1.2.3.4 Sediment Sampling

The role of sediments as contributors to the dissolved oxygen deficits in the Merrimack and Pemigewasset Rivers was previously unknown. This sampling program included a preliminary assessment of the SOD and sediment nutrient flux at select locations in the study area. The first year of sampling included 17 locations for SOD measurements and 9 locations for phosphorus flux measurements. The sampling sites were primarily located within the impoundments, with a few sites selected in riverine sections to provide comparison data.

1.3 Data Report Overview

This report is intended to provide a summary of the low flow sampling events, high flow sampling event, impoundment studies, continuous dissolved oxygen monitoring, and sediment sampling conducted as part of the Upper Merrimack and Pemigewasset River Study from June 2009 through May 2012.

This report is organized as follows:

- Details on each program component, including a summary of the sampling and quality assurance/quality control (QA/QC) activities performed
- Precipitation and streamflow conditions prior to and during the sampling event
- Summary of any deviations from the approved QAPP and Field Sampling Plan during the field and analytical activities

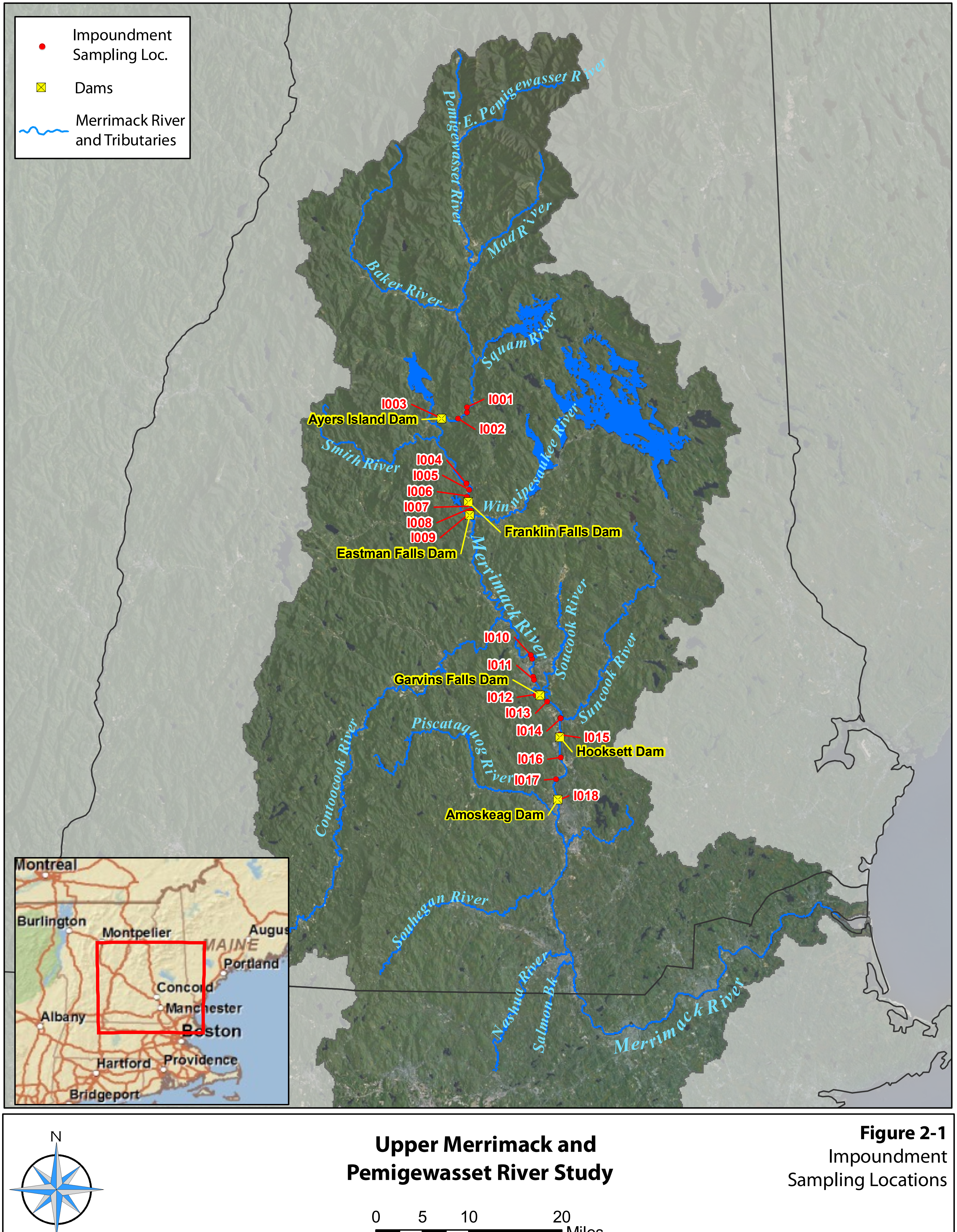
- Analytical results and field measurements for each program component (select results presented in the body of the report; complete results included in appendices)
- Comparison of the data to state water quality standards and results from other sampling events
- Results of data validation and evaluation, including assessment of the data usability

Section 2
Impoundment Studies

Five monthly rounds of impoundment surveys were conducted from June 2009 to October 2009. Each survey consisted of approximately three days of sampling: one field crew visited three sampling locations within each of the six impoundments (18 sites total) to record field measurements and collect water samples for total phosphorus and chlorophyll-a analyses. Samples were generally collected from the top 5 feet of the water column. At one site within each impoundment an additional depth sample was taken from the bottom 25% of the water column and analyzed for total phosphorus. At each location a profile of dissolved oxygen and temperature was recorded to assess impoundment stratification.

The approximate locations of the 18 impoundment sampling stations are shown in Figure 2-1. Whenever possible, the field crew returned to the same locations each month. The order in which the samples were collected during each monthly survey was changed so that not all of the measurements and samples would be taken at the same time of day from each station. The following sections describe the five surveys in detail.

Streamflow conditions during the summer of 2009 are shown in Figure 2-2. Streamflows were generally above average for the summer, which may have prevented stratification in the impoundments that would occur under normal or lower than average summer flow conditions. The impoundment surveys occurred when streamflow was higher than average, but on the receding limb of the hydrograph in all cases except September, when flows had leveled after a period without precipitation. The fifth survey, in October, occurred following a large rain event when the river flows were still very high, but receding at all four tracking gages.



Upper Merrimack and Pemigewasset River Study

Figure 2-1
Impoundment Sampling Locations

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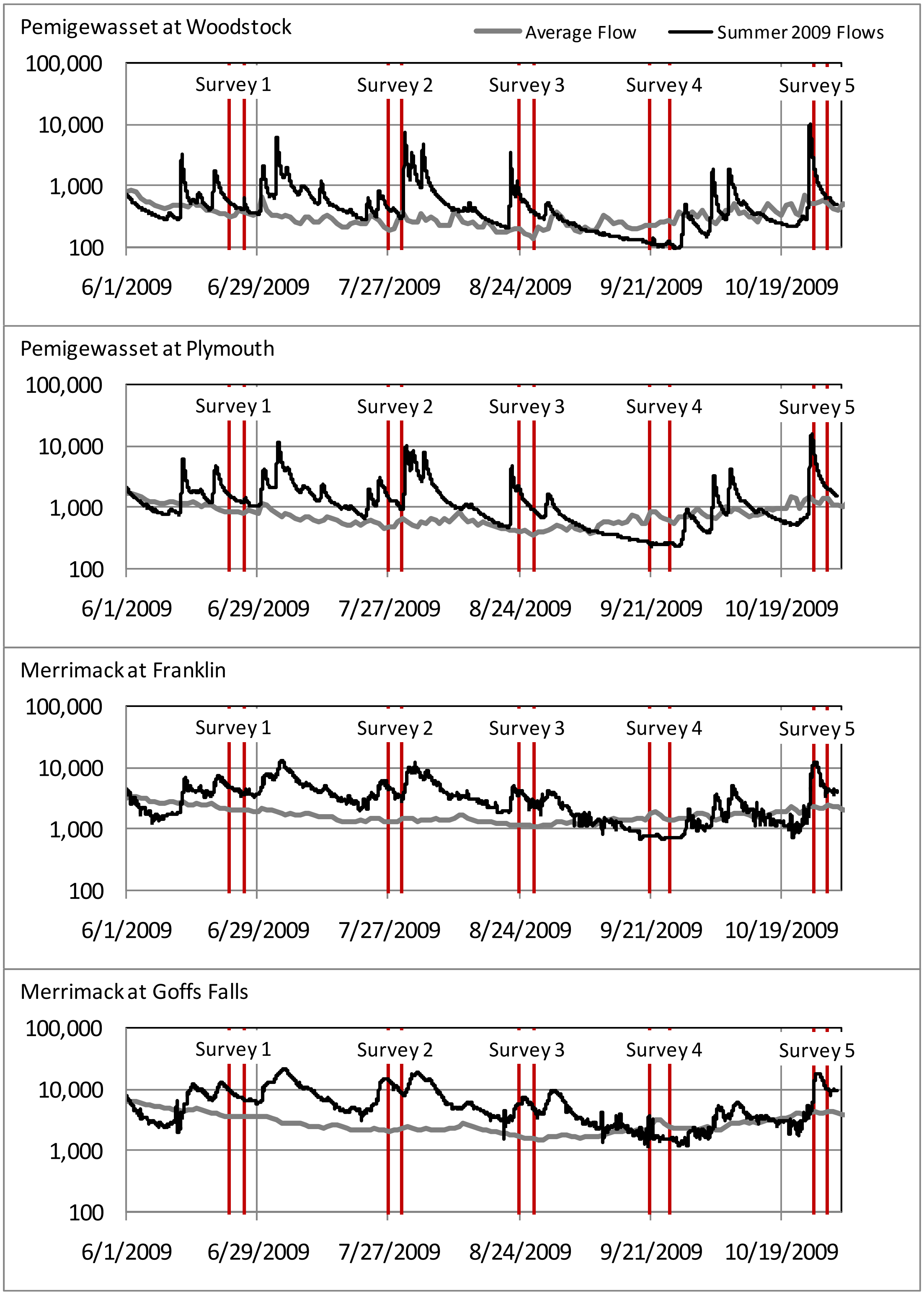
Figure 2-2: Impoundment Studies and Summer 2009 Streamflow Conditions



2.1 Impoundments Survey 1 – June 2009

2.1.1 Event Summary

The first impoundment survey was conducted June 23-25, 2009. Table 2-1 lists the order that samples were taken, the locations that the additional depth samples were taken at, and the locations and times that QA/QC samples were taken. Field blanks, field duplicates, and field equipment blanks were taken at two sampling stations during the first impoundment survey.

Table 2-1: Impoundment Survey #1 Samples

Impoundment	Station	Date	Time	Sample Type
Ayers Island	I001	23-June	12:15 PM	grab
	I002	23-June	1:10 PM	grab
	I002	23-June	1:22 PM	deep grab
	I003	23-June	2:20 PM	grab
	I003	23-June	2:20 PM	field duplicate
Franklin Falls	I004	24-June	10:40 AM	grab
	I005	24-June	9:45 AM	grab
	I005	24-June	10:00 AM	deep grab
	I006	24-June	9:00 AM	field equipment blank
	I006	24-June	9:05 AM	grab
Eastman Falls	I007	24-June	12:10 PM	grab
	I007	24-June	12:25 PM	deep grab
	I008	24-June	12:50 PM	grab
	I008	24-June	12:50 PM	field duplicate
	I009	24-June	1:20 PM	grab
Garvins Falls	I010	24-June	3:30 PM	grab
	I011	24-June	4:00 PM	field blank
	I011	24-June	4:15 PM	grab
	I012	24-June	5:00 PM	grab
	I012	24-June	5:10 PM	deep grab
Hooksett Falls	I013	25-June	8:00 AM	field blank
	I013	25-June	8:20 AM	grab
	I013	25-June	8:20 AM	field equipment blank
	I014	25-June	8:45 AM	grab
	I015	25-June	9:10 AM	grab
	I015	25-June	9:20 AM	deep grab
Amoskeag	I016	25-June	1:00 PM	grab
	I017	25-June	12:15 PM	grab
	I017	25-June	12:20 PM	deep grab
	I018	25-June	11:40 AM	grab

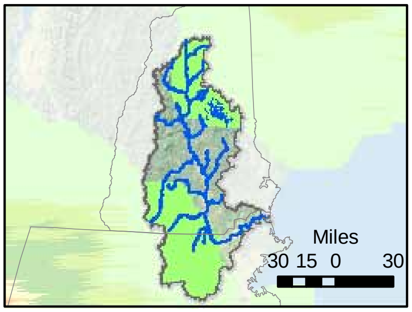
2.1.2 Precipitation and Streamflow Conditions

Precipitation totals on the days of and the days leading up to the first impoundment survey are shown for Woodstock, Franklin, Concord, and Manchester in Table 2-2. The approximate spatial distribution of precipitation for the entire watershed for those dates is shown in Figure 2-3.

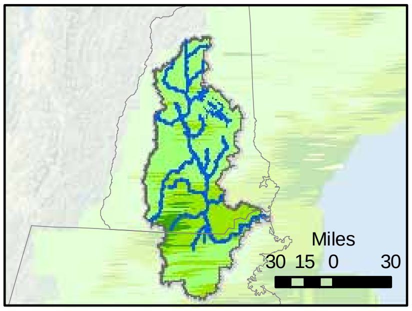
Table 2-2: Precipitation Totals for Impoundment Survey #1

Date	Total Daily Precipitation (inches)			
	Location			
	Franklin, NH	**Woodstock, NH**	**Concord, NH**	**Manchester, NH**
	Gage ID: KNHNORTH4	Gage ID: MNHWOD	Gage ID: KNHCONCO5	Gage ID: 14710
	Source: Franklin Falls Dam	Source: NHDOT	Source: NOAA	Source: NOAA
21-June	0.03	0.08	0.02	0.13
22-June	0.02	0.08	0.08	0.25
23-June	0.02	0.08	0	0.04
24-June	0.01	0.08	0.07	0.26
25-June	0.01	0	0	0.09

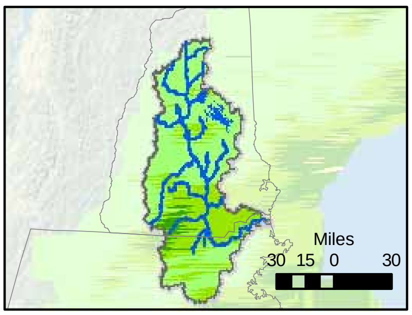
Impoundment Survey #1 occurred when flows were near average at the upstream gages (Woodstock and Plymouth) and well above average at the downstream gages (Franklin and Goffs Falls). All gages were receding from a rain event that occurred four days before the start of the survey. Figure 2-4 shows the streamflow trace at each gage at the time that samples and field readings were collected in each impoundment.



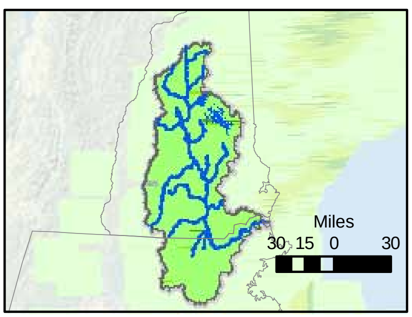
June 21, 2009



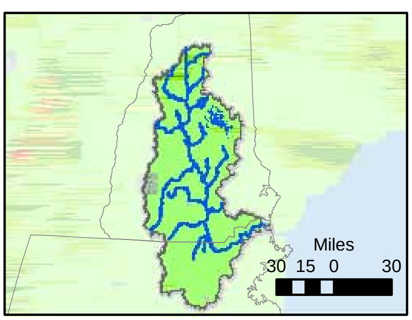
June 22, 2009



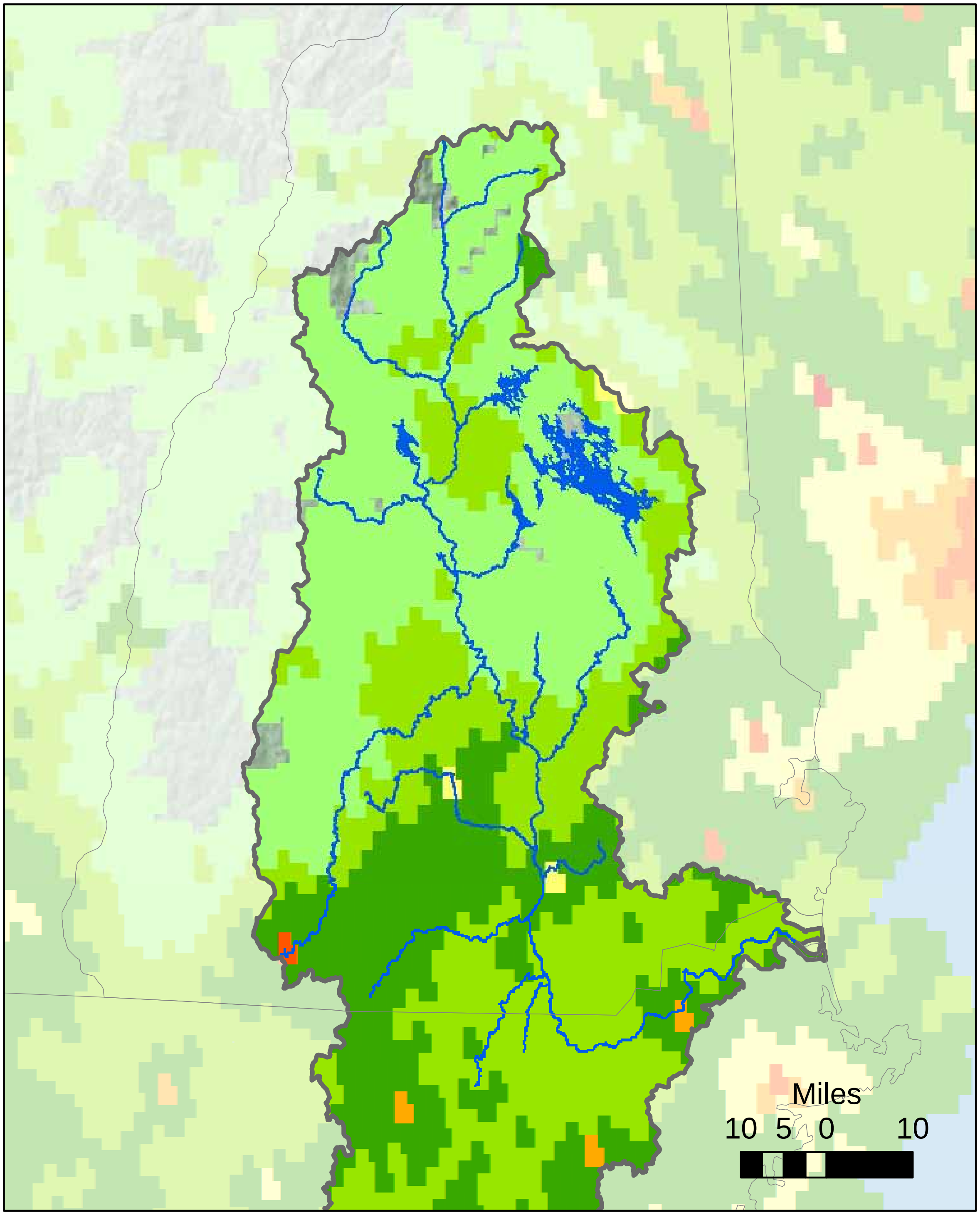
June 23, 2009



June 24, 2009



June 25, 2009



Total Precipitation (in) from June 21, 2009 through June 25, 2009

Legend

State Boundaries
Merrimack River Basin
Water Bodies

Total Precipitation (in)
0.00 - 0.01
0.02 - 0.10
0.11 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 6.10

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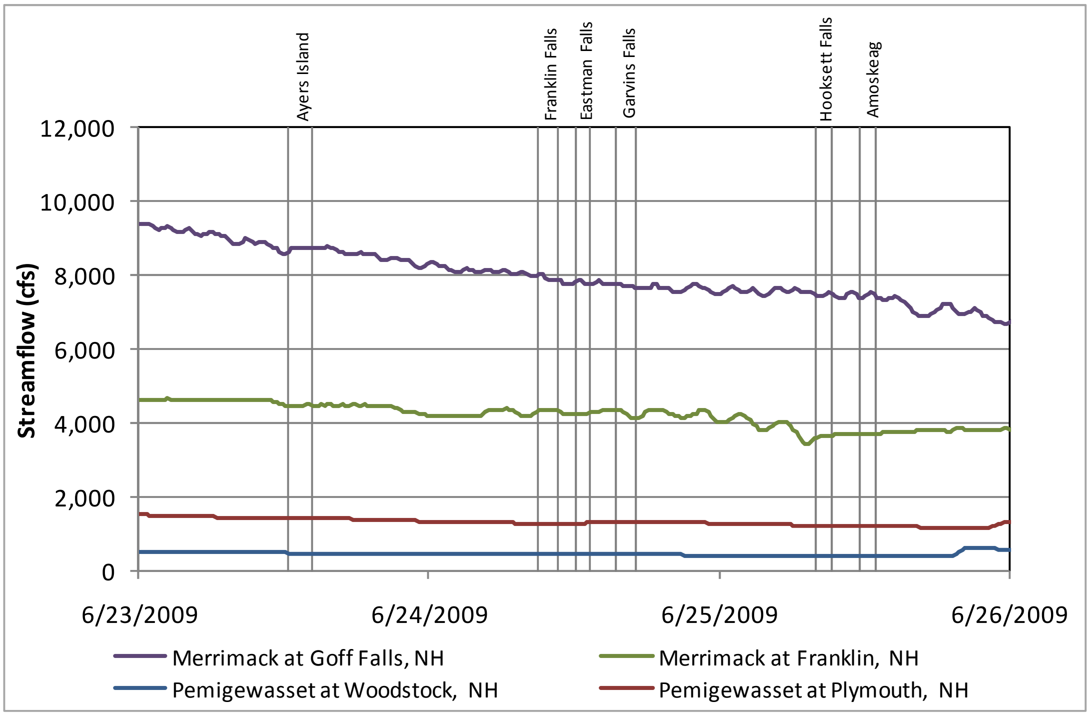
Merrimack River Basin Precipitation (in)
Impoundment Survey 1
June 21 - June 25, 2009

Figure 2-3

Figure 2-4: Streamflow Conditions During Impoundment Survey #1



2.1.3 QAPP and Field Sampling Plan Deviations

Water samples were shipped overnight to the laboratory at the conclusion of each day of sampling. The earliest possible arrival of the samples at the laboratory was at 10:00 am the morning after samples were collected. Chlorophyll-a samples have a hold time of 24 hours, so any samples collected prior to 10:00 am on the day of sampling arrived at the laboratory a few hours after the hold time expired. The earliest sample was collected at 8:00 am, so the largest hold time violation was two hours. Table 2-3 shows the samples that were not within the 24 hour chlorophyll-a hold time.

Table 2-3: Missed Chlorophyll-a Hold Times for Impoundment Survey #1

Impoundment	Station/Sample ID	Date	Time	Sample Type
Franklin Falls	I005	24-June	9:45 AM	grab
	I306	24-June	9:00 AM	field equipment blank
	I006	24-June	9:05 AM	grab
Hooksett Falls	I113	25-June	8:00 AM	field blank
	I013	25-June	8:20 AM	grab
	I313	25-June	8:20 AM	field equipment blank
	I014	25-June	8:45 AM	grab
	I015	25-June	9:10 AM	grab
	I015	25-June	9:20 AM	deep grab

2.2 Impoundments Survey 2 – July 2009

2.2.1 Event Summary

The second impoundment survey was conducted July 27-29, 2009. Table 2-4 lists the order that samples were taken, the locations that the additional depth samples were taken at, and the locations and times that QA/QC samples were taken. Field blanks, field duplicates, and field equipment blanks were taken at two sampling stations during the second impoundment survey.

Table 2-4: Impoundment Survey #2 Samples

Impoundment	Station	Date	Time	Sample Type
Ayers Island	I001	27-July	9:30 AM	grab
	I002	27-July	10:00 AM	grab
	I002	27-July	10:30 AM	field blank
	I003	27-July	10:35 AM	grab
	I003	27-July	10:35 AM	deep grab
Franklin Falls	I004	27-July	1:20 PM	grab
	I004	27-July	1:20 PM	field duplicate
	I005	27-July	1:20 PM	field equipment blank
	I005	27-July	1:00 PM	grab
	I006	27-July	12:25 PM	grab
	I006	27-July	12:25 PM	deep grab
Eastman Falls	I007	28-July	9:00 AM	grab
	I007	28-July	9:00 AM	field duplicate
	I008	28-July	9:30 AM	grab
	I009	28-July	10:00 AM	grab
	I009	28-July	10:05 AM	deep grab
	I009	28-July	10:20 AM	field blank
Garvins Falls	I010	28-July	11:40 AM	grab
	I010	28-July	11:40 AM	field equipment blank
	I011	28-July	1:10 PM	grab
	I012	28-July	12:30 PM	grab
	I012	28-July	12:30 PM	deep grab
Hooksett Falls	I013	29-July	8:20 AM	grab
	I014	29-July	8:55 AM	grab
	I015	29-July	9:20 AM	grab
	I015	29-July	9:25 AM	deep grab
Amoskeag	I016	29-July	11:55 AM	grab
	I017	29-July	11:35 AM	grab
	I018	29-July	10:45 AM	grab
	I018	29-July	10:50 AM	deep grab

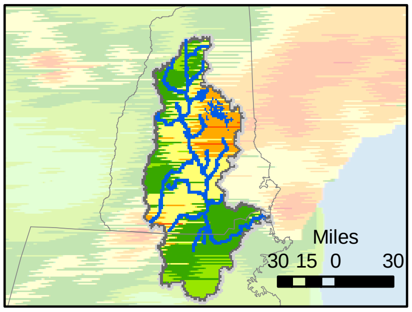
2.2.2 Precipitation and Streamflow Conditions

Precipitation totals on the days of and the days leading up to the second impoundment survey are shown for Woodstock, Franklin, Concord, and Manchester in Table 2-5. The approximate spatial distribution of precipitation for the entire watershed for those dates is shown in Figure 2-5.

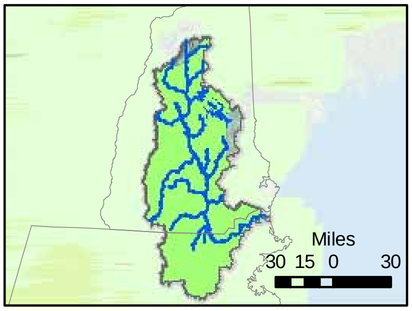
Table 2-5: Precipitation Totals for Impoundment Survey #2

	Total Daily Precipitation (inches)			
	Location			
	Franklin, NH	**Woodstock, NH**	**Concord, NH**	**Manchester, NH**
	Gage ID: KNHNORTH4	Gage ID: MNHWOD	Gage ID: KNHCONCO5	Gage ID: 14710
Date	Source: Franklin Falls Dam	Source: NHDOT	Source: NOAA	Source: NOAA
25-July	0.21	0.16	0.15	0.1
26-July	0.02	0	0.2	0.23
27-July	0.07	0.12	0.09	0.04
28-July	0	0	0	0
29-July	2.14	1.26	0.28	0.08

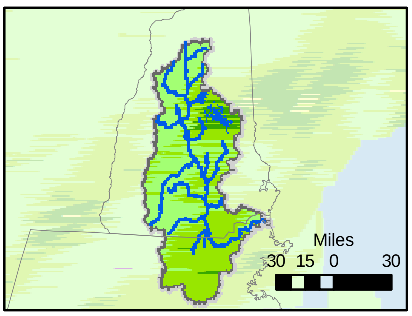
The second impoundment survey occurred when flows were close to the same level as during the first survey, although average flows in July are lower than in June. Again, the survey took place when all four gages were receding from a recent rain event that took place two days before the start of sampling. Figure 2-6 shows the streamflow trace at each gage at the time that samples and field readings were collected in each impoundment.



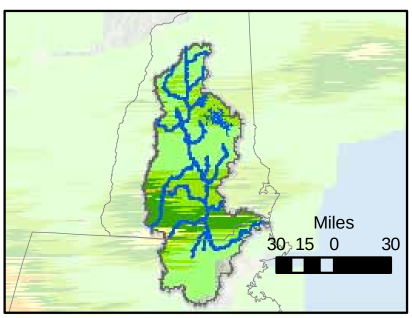
July 25, 2009



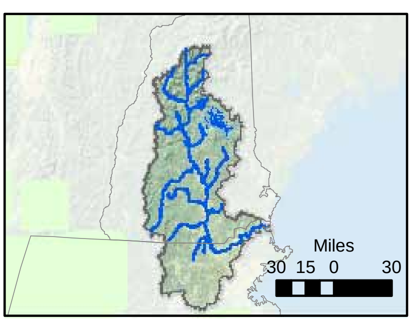
July 26, 2009



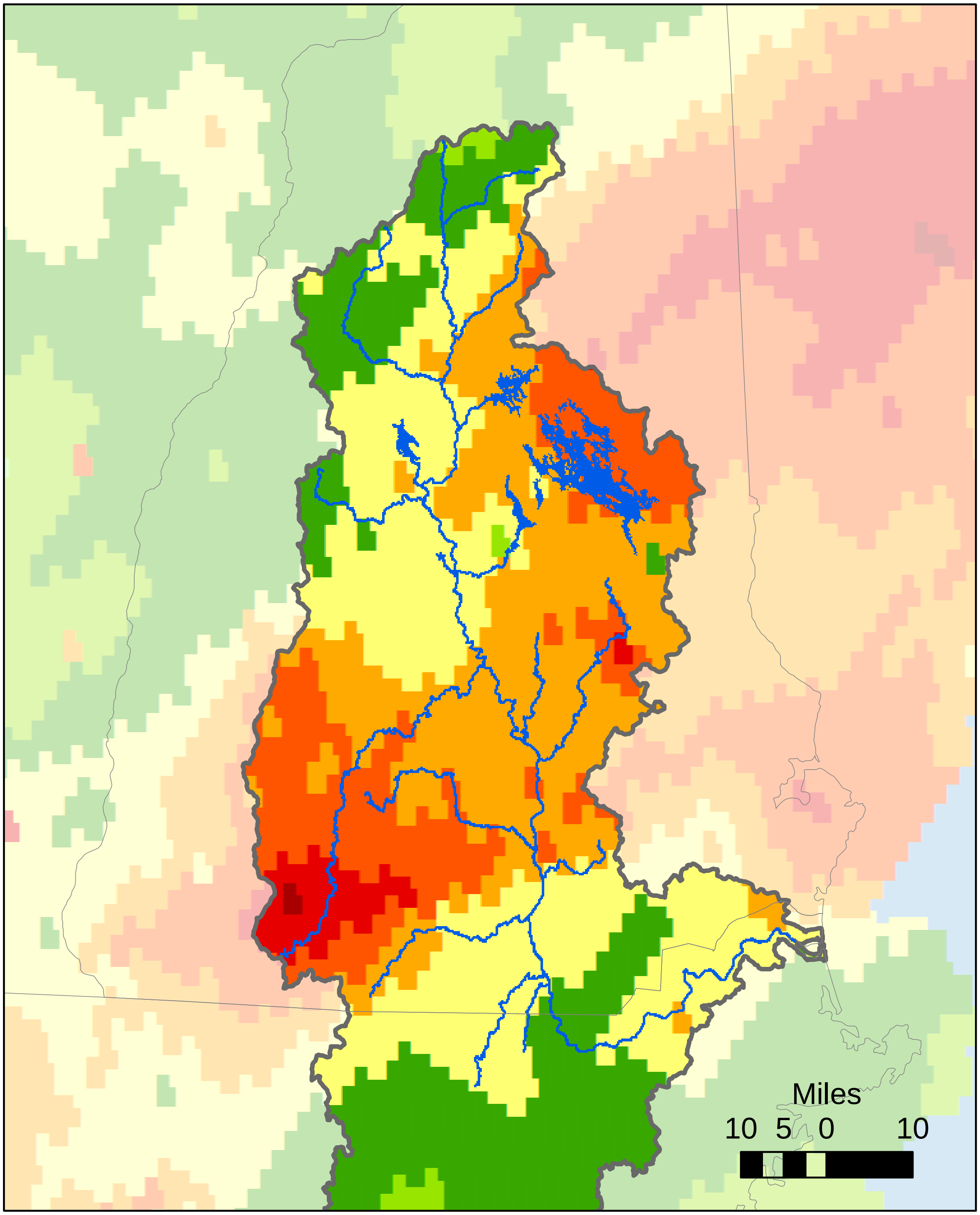
July 27, 2009



July 28, 2009



July 29, 2009



Total Precipitation (in) from July 25, 2009 through July 29, 2009

Legend

State Boundaries
Merrimack River Basin
Water Bodies

Total Precipitation (in)

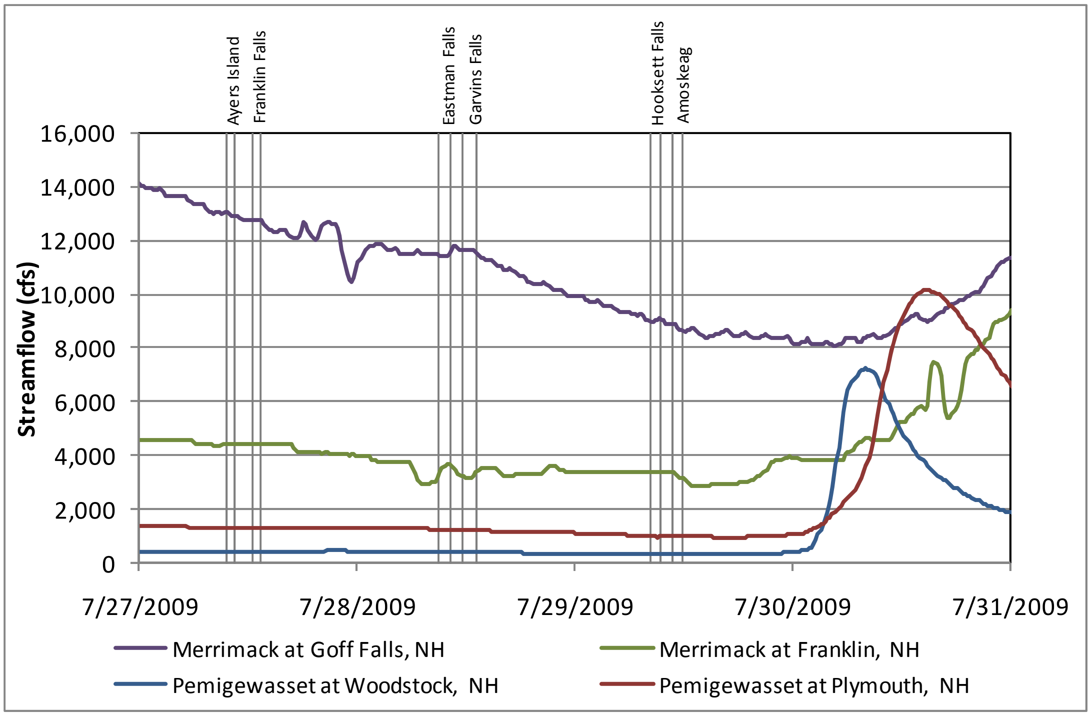
0.00 - 0.01
0.02 - 0.10
0.11 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 6.10

N

Merrimack River Basin Precipitation (in)
Impoundment Survey 2
July 25 - July 29, 2009

Figure 2-5

Figure 2-6: Streamflow Conditions During Impoundment Survey #2



2.2.3 QAPP and Field Sampling Plan Deviations

Water samples were shipped overnight to the laboratory at the conclusion of each day of sampling. The earliest possible arrival of the samples at the laboratory was at 10:00 am the morning after samples were collected. Chlorophyll-a samples have a hold time of 24 hours, so samples collected prior to 10:00 am arrived at the laboratory a few hours after the hold time expired. The earliest sample was collected at 8:20am, so the largest hold time violation was between one and two hours. Table 2-6 shows the samples that were not within the 24 hour chlorophyll-a hold time.

Table 2-6: Missed Chlorophyll-a Hold Times for Impoundment Survey #2

Impoundment	Station/Sample ID	Date	Time	Sample Type
Ayers Island	I001	27-July	9:30 AM	Grab
Eastman Falls	I007	28-July	9:00 AM	Grab
	I207	28-July	9:00 AM	field duplicate
	I008	28-July	9:30 AM	Grab
Hooksett Falls	I013	29-July	8:20 AM	Grab
	I014	29-July	8:55 AM	Grab
	I015	29-July	9:20 AM	Grab
	I015	29-July	9:25 AM	deep grab

2.3 Impoundments Survey 3 – August 2009

2.3.1 Event Summary

The third impoundment survey was conducted August 24-26, 2009. Table 2-7 lists the order that samples were taken, the locations that the additional depth samples were taken at, and the locations and times that QA/QC samples were taken. Field blanks, field duplicates, and field equipment blanks were taken at two sampling stations during the third impoundment survey.

Table 2-7: Impoundment Survey #3 Samples

Impoundment	Station	Date	Time	Sample Type
Ayers Island	I001	25-August	11:36 AM	Grab
	I001	25-August	11:36 AM	field blank
	I002	25-August	1:07 PM	deep grab
	I002	25-August	1:00 PM	grab
	I003	25-August	12:12 PM	grab
	I003	25-August	12:12 PM	field equipment blank
Franklin Falls	I004	25-August	10:03 AM	grab
	I005	25-August	9:36 AM	deep grab
	I005	25-August	9:30 AM	grab
	I006	25-August	8:54 AM	grab
	I006	25-August	8:54 AM	field duplicate
Eastman Falls	I007	26-August	11:30 AM	grab
	I008	26-August	12:08 PM	deep grab
	I008	26-August	12:05 PM	grab
	I009	26-August	11:00 AM	grab
Garvins Falls	I010	26-August	9:46 AM	grab
	I011	26-August	9:13 AM	deep grab
	I011	26-August	9:10 AM	grab
	I012	26-August	8:30 AM	grab
Hooksett Falls	I013	24-August	8:45 AM	grab
	I014	24-August	9:30 AM	deep grab
	I014	24-August	9:20 AM	grab
	I014	24-August	9:20 AM	field blank
	I015	24-August	10:00 AM	grab
	I015	24-August	10:00 AM	field duplicate
Amoskeag	I016	24-August	12:45 PM	grab
	I016	24-August	1:00 PM	field equipment blank
	I017	24-August	11:30 AM	deep grab
	I017	24-August	11:25 AM	grab
	I018	24-August	12:15 PM	grab

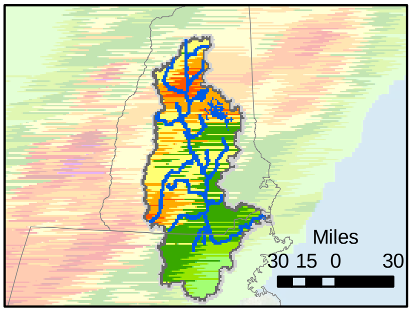
2.3.2 Precipitation and Streamflow Conditions

Precipitation totals on the days of and the days leading up to the third impoundment survey are shown for Woodstock, Franklin, Concord, and Manchester in Table 2-8. The approximate spatial distribution of precipitation for the entire watershed for those dates is shown in Figure 2-7.

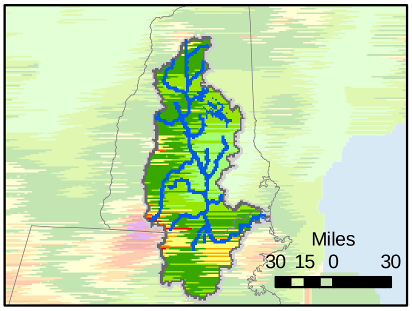
Table 2-8: Precipitation Totals for Impoundment Survey #3

	Total Daily Precipitation (inches)			
	Location			
	Franklin, NH	**Woodstock, NH**	**Concord, NH**	**Manchester, NH**
	Gage ID: KNHNORTH4	Gage ID: MNHWOD	Gage ID: KNHCONCO5	Gage ID: 14710
Date	Source: Franklin Falls Dam	Source: NHDOT	Source: NOAA	Source: NOAA
22-August	0.32	0.28	0.07	0.15
23-August	0.1	0	0.66	0.03
24-August	0.01	0	<0.01	0
25-August	0	0	0	0
26-August	0.06	0	<0.01	<0.01

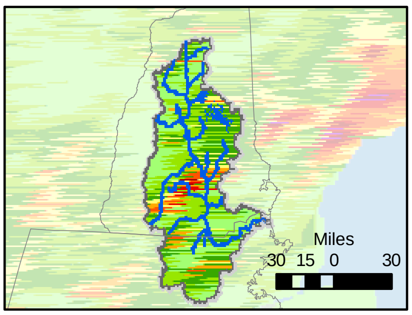
Survey #3 occurred under similar flow conditions to the first two surveys, though average flows in August are lower than June and July. All gages were receding from a recent rain event except Goffs Falls, which peaked after the first day of field work. Figure 2-8 shows the streamflow trace at each gage at the time that samples and field readings were collected in each impoundment.



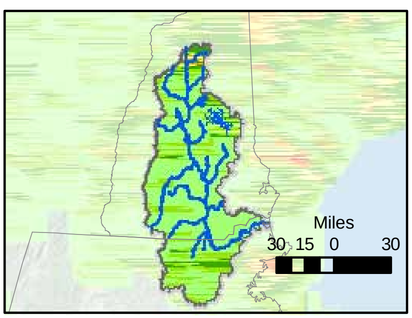
August 22, 2009



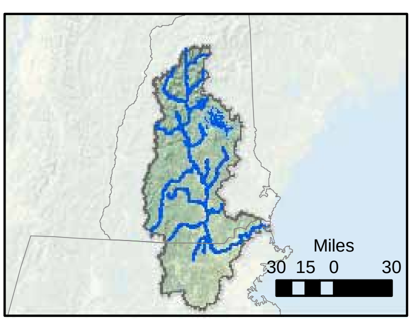
August 23, 2009



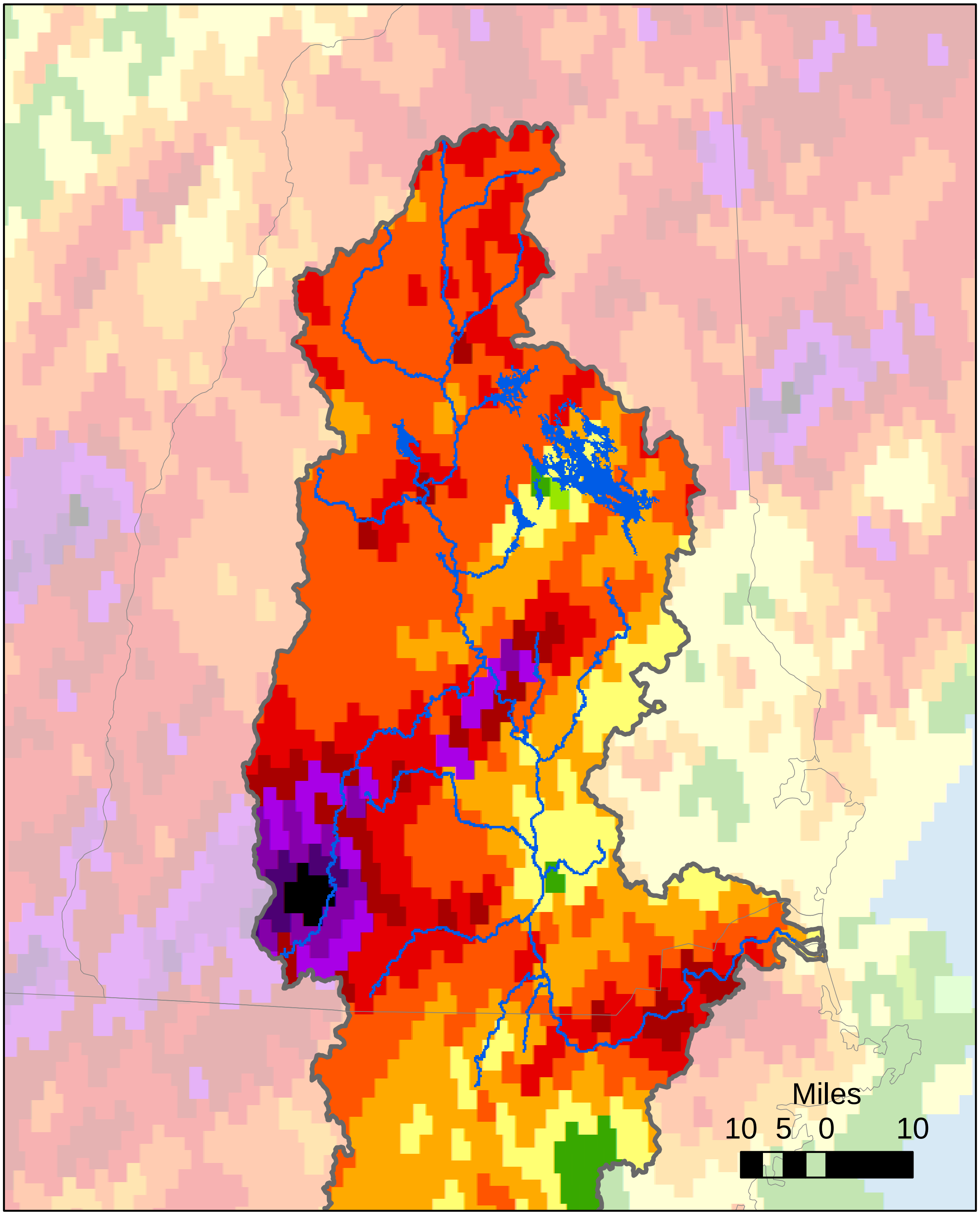
August 24, 2009



August 25, 2009



August 26, 2009



Total Precipitation (in) from August 22, 2009 through August 26, 2009

Legend

- State Boundaries
- Merrimack River Basin
- Water Bodies

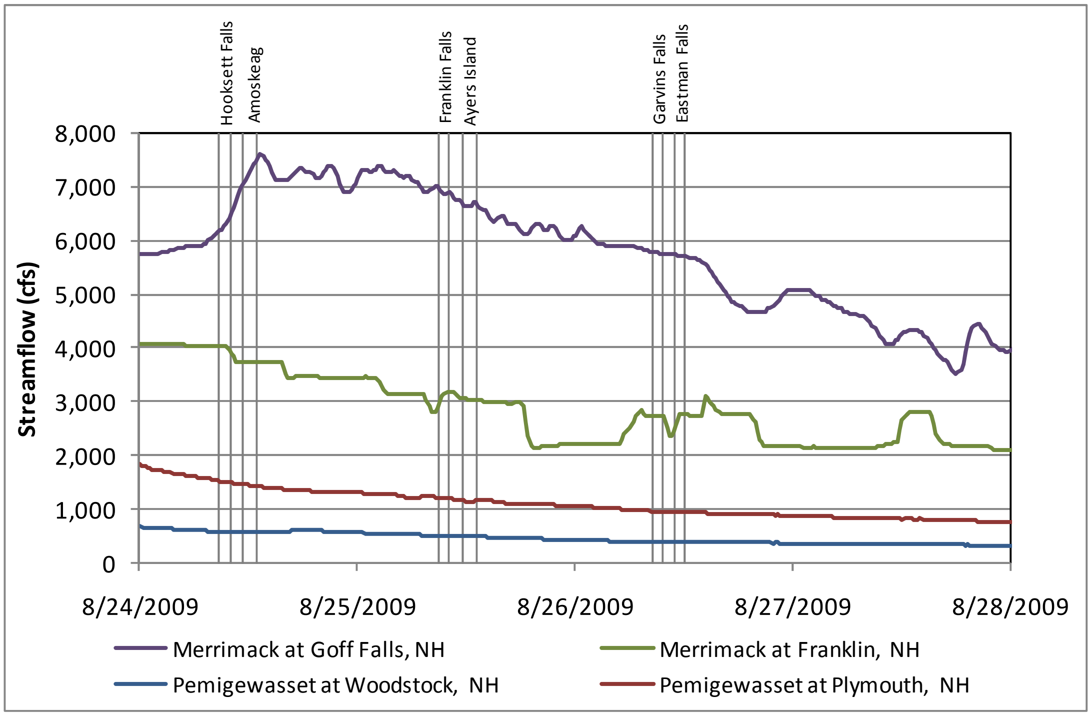
Total Precipitation (in)

- 0.00 - 0.01
- 0.02 - 0.10
- 0.11 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- 3.01 - 3.50
- 3.51 - 4.00
- 4.01 - 6.10

Merrimack River Basin Precipitation (in)
Impoundment Survey 3
August 22 - August 26, 2009

Figure 2-7

Figure 2-8: Streamflow Conditions During Impoundment Survey #3



2.3.3 QAPP and Field Sampling Plan Deviations

Water samples were shipped overnight to the laboratory at the conclusion of each day of sampling. The earliest possible arrival of the samples at the laboratory was 10:00 am the morning after samples were collected. Chlorophyll-a samples have a hold time of 24 hours, so samples collected prior to 10:00 am arrived at the laboratory a few hours after the hold time expired. The earliest sample was collected at 8:30am, so the largest hold time violation between one and two hours. Table 2-9 shows the samples that were not within chlorophyll-a hold times.

Table 2-9: Missed Chlorophyll-a Hold Times for Impoundment Survey #3

Impoundment	Station	Date	Time	Sample Type
Franklin Falls	I005	25-August	9:36 AM	deep grab
	I005	25-August	9:30 AM	grab
	I006	25-August	8:54 AM	grab
	I206	25-August	8:54 AM	field duplicate
Garvins Falls	I010	26-August	9:46 AM	grab
	I011	26-August	9:13 AM	deep grab
	I011	26-August	9:10 AM	grab
	I012	26-August	8:30 AM	grab
Hooksett Falls	I013	24-August	8:45 AM	grab
	I014	24-August	9:30 AM	deep grab
	I014	24-August	9:20 AM	grab
	I114	24-August	9:20 AM	field blank

2.4 Impoundments Survey 4 – September 2009

2.4.1 Event Summary

The fourth impoundment survey was conducted September 21-24, 2009. Table 2-10 lists the order that samples were taken, the locations that the additional depth samples were taken at, and the locations and times that QA/QC samples were taken. Field blanks, field duplicates, and field equipment blanks were taken at two sampling stations during the fourth impoundment survey.

Table 2-10: Impoundment Survey #4 Samples

Impoundment	Station	Date	Time	Sample Type
Ayers Island	I001	21-September	10:09 AM	field blank
	I001	21-September	10:21 AM	field equipment blank
	I001	21-September	10:31 AM	Grab
	I002	21-September	12:07 PM	Grab
	I003	21-September	11:17 AM	grab
	I003	21-September	11:27 AM	deep grab
Franklin Falls	I004	21-September	2:45 PM	grab
	I005	21-September	2:09 PM	grab
	I005	21-September	2:11 PM	field duplicate
	I005	21-September	2:11 PM	field duplicate
	I006	21-September	1:37 PM	grab
	I006	21-September	1:45 PM	deep grab
Eastman Falls	I007	22-September	9:04 AM	grab
	I008	22-September	9:47 AM	grab
	I009	22-September	10:13 AM	grab
	I009	22-September	10:17 AM	deep grab
Garvins Falls	I010	23-September	9:37 AM	grab
	I011	23-September	8:49 AM	grab
	I012	23-September	8:06 AM	grab
	I012	23-September	8:12 AM	deep grab
Hooksett Falls	I013	23-September	11:23 AM	field blank
	I013	23-September	11:33 AM	field equipment blank
	I013	23-September	11:39 AM	grab
	I014	23-September	12:09 PM	grab
	I015	23-September	12:35 PM	grab
	I015	23-September	12:38 PM	deep grab
Amoskeag	I016	24-September	11:05 AM	grab
	I017	24-September	10:19 AM	grab
	I018	24-September	9:06 AM	grab
	I018	24-September	9:09 AM	deep grab

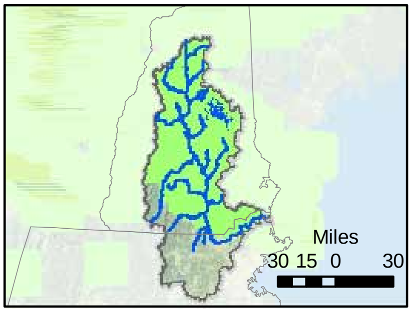
2.4.2 Precipitation and Streamflow Conditions

Precipitation totals on the days of and the days leading up to the fourth impoundment survey are shown for Woodstock, Franklin, Concord, and Manchester in Table 2-11. The approximate spatial distribution of precipitation for the entire watershed for those dates is shown in Figure 2-9.

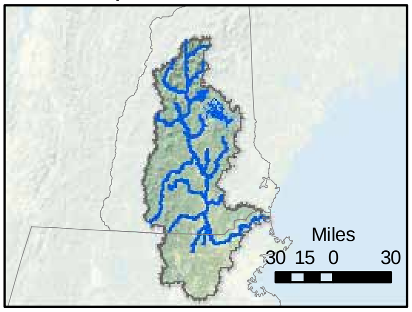
Table 2-11: Precipitation Totals for Impoundment Survey #4

	Total Daily Precipitation (inches)			
	Location			
	Franklin, NH	**Woodstock, NH**	**Concord, NH**	**Manchester, NH**
	Gage ID: KNHNORTH4	Gage ID: MNHWOD	Gage ID: KNHCONCO5	Gage ID: 14710
Date	Source: Franklin Falls Dam	Source: NHDOT	Source: NOAA	Source: NOAA
19-September	0	0	0	0
20-September	0	0	0	0
21-September	0.01	0	0	0
22-September	0	0	0	0
23-September	0.01	0.12	<0.01	<0.01
24-September	0.03	0	0	0

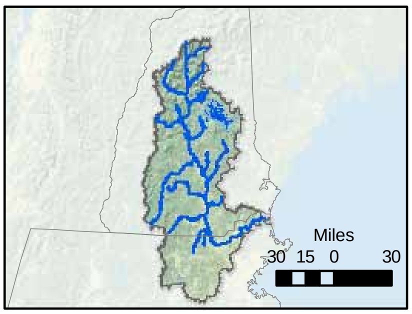
Streamflows during the fourth survey were below average at all four tracking gages. The flows were between two and three times 7Q10 at Woodstock, Plymouth and Goffs Falls, and between 7Q10 and two times 7Q10 at Franklin. Figure 2-10 shows the streamflow trace at each gage at the time that samples and field readings were collected in each impoundment.



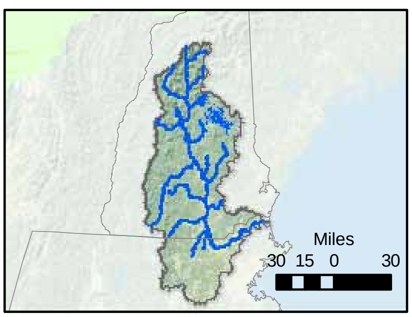
September 19, 2009



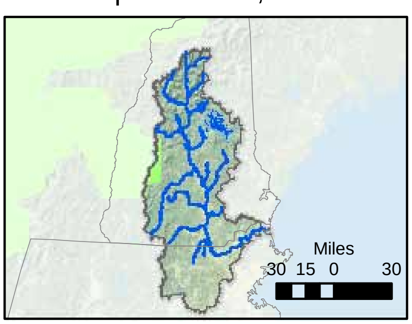
September 20, 2009



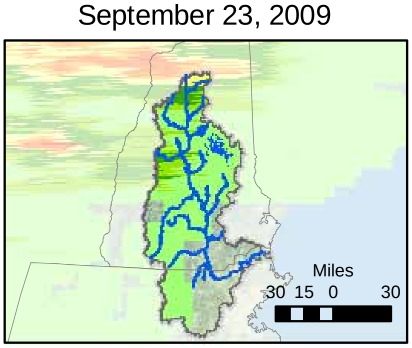
September 21, 2009



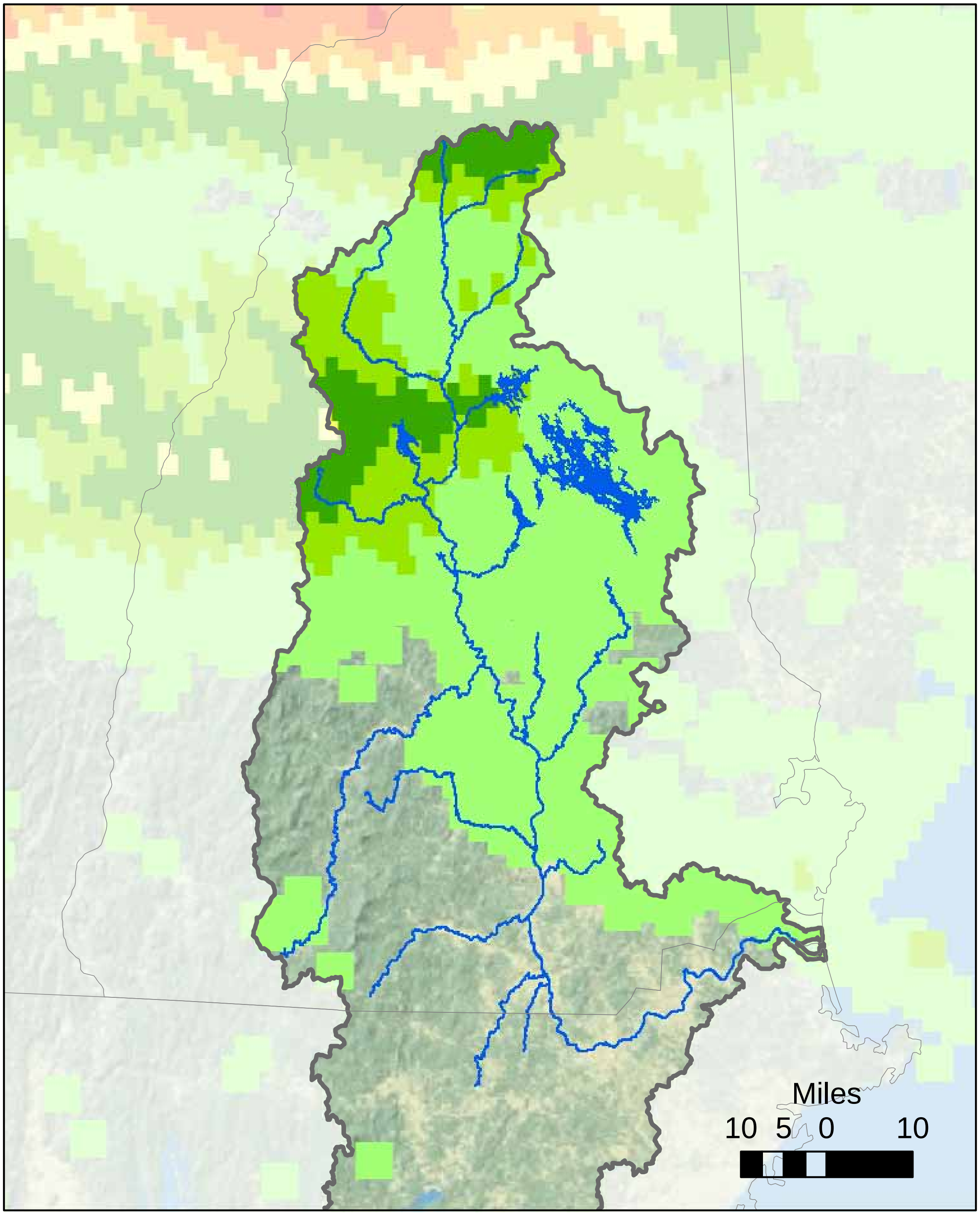
September 22, 2009



September 23, 2009



September 24, 2009



Total Precipitation (in) from September 19, 2009 through September 24, 2009

Legend

- State Boundaries
- Merrimack River Basin
- Water Bodies

Total Precipitation (in)

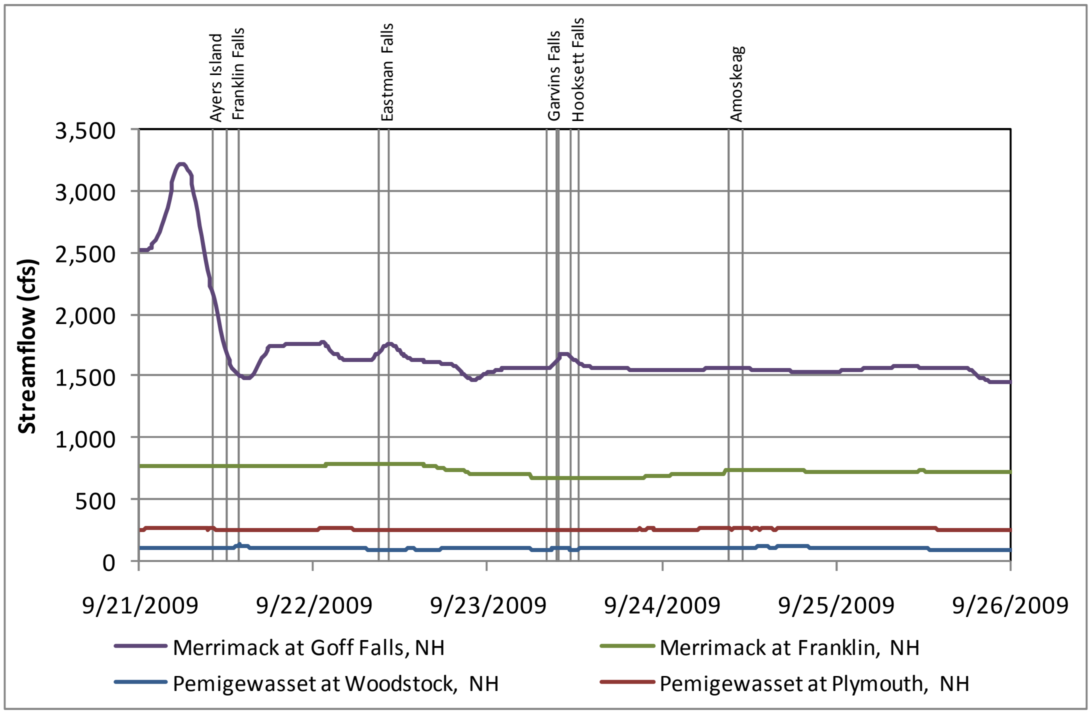
- 0.00 - 0.01
- 0.02 - 0.10
- 0.11 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- 3.01 - 3.50
- 3.51 - 4.00
- 4.01 - 6.10

N

Merrimack River Basin Precipitation (in)
Impoundment Survey 4
September 19 - September 24, 2009

Figure 2-9

Figure 2-10: Streamflow Conditions During Impoundment Survey #4



2.4.3 QAPP and Field Sampling Plan Deviations

Water samples were shipped overnight to the laboratory at the conclusion of each day of sampling. The earliest possible arrival of the samples at the laboratory was at 10:00 am the morning after samples were collected. Chlorophyll-a samples have a hold time of 24 hours, so samples collected prior to 10:00 am arrived at the laboratory a few hours after the hold time expired. The earliest sample was collected at 8:06am, so the largest hold time violation was two hours. Table 2-12 shows the samples that were not within the 24 hour chlorophyll-a hold time.

Table 2-12: Missed Chlorophyll-a Hold Times for Impoundment Survey #4

Impoundment	Station	Date	Time	Sample Type
Eastman Falls	I007	22-September	9:04 AM	grab
	I008	22-September	9:47 AM	grab
Garvins Falls	I010	23-September	9:37 AM	grab
	I011	23-September	8:49 AM	grab
	I012	23-September	8:06 AM	grab
	I012	23-September	8:12 AM	deep grab
Amoskeag	I018	24-September	9:06 AM	grab
	I018	24-September	9:09 AM	deep grab

2.5 Impoundments Survey 5 – October 2009

2.5.1 Event Summary

The fifth impoundment survey was conducted October 26-28, 2009. Table 2-13 lists the order that samples were taken, the locations that the additional depth samples were taken at, and the locations and times that QA/QC samples were taken. Field blanks and field duplicates were taken at two sampling stations during the fifth impoundment survey, and a field equipment blank was taken at one sampling station.

High water levels resulted in flooding at the access point for the Franklin Falls impoundment during the fifth impoundment survey. Therefore, it was not possible to access stations I004, I005, and I006 during this impoundment survey.

Table 2-13: Impoundment Survey #5 Samples

Impoundment	Station	Date	Time	Sample Type
Ayers Island	I001	26-October	9:25 AM	grab
	I002	26-October	9:50 AM	grab
	I003	26-October	10:20 AM	grab
	I003	26-October	10:20 AM	field duplicate
	I003	26-October	10:25 AM	deep grab
Eastman Falls	I007	26-October	12:15 PM	grab
	I008	26-October	12:50 PM	grab
	I009	26-October	1:10 PM	grab
	I009	26-October	1:15 PM	deep grab
	I009	26-October	1:20 PM	field blank
Garvins Falls	I010	27-October	8:40 AM	grab
	I011	27-October	9:10 AM	grab
	I012	27-October	9:45 AM	grab
	I012	27-October	9:45 AM	field duplicate
	I012	27-October	9:50 AM	deep grab
Hooksett Falls	I013	27-October	11:40 AM	grab
	I014	27-October	12:00 PM	grab
	I015	27-October	12:20 PM	grab
	I015	27-October	12:30 PM	deep grab
	I015	27-October	12:40 PM	field equipment blank
Amoskeag	I016	28-October	10:05 AM	grab
	I017	28-October	8:50 AM	grab
	I018	28-October	9:35 AM	grab
	I018	28-October	9:40 AM	deep grab
	I018	28-October	9:45 AM	field blank

2.5.2 Precipitation and Streamflow Conditions

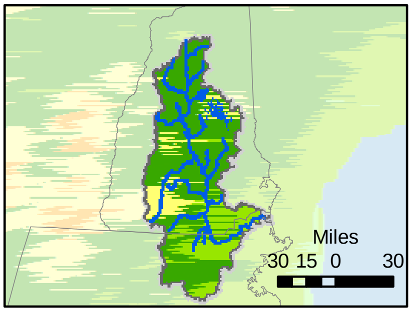
Precipitation totals on the days of and the days leading up to the fifth impoundment survey are shown for Woodstock, Franklin, Concord, and Manchester in Table 2-14.

The approximate spatial distribution of precipitation for the entire watershed for those dates is shown in Figure 2-11.

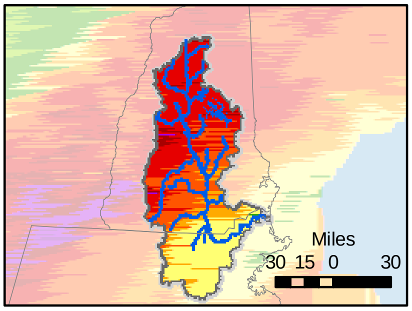
Table 2-14: Precipitation Totals for Impoundment Survey #5

Date	Total Daily Precipitation (inches)			
	Location			
	Franklin, NH	**Woodstock, NH**	**Concord, NH**	**Manchester, NH**
	Gage ID: KNHNORTH4	Gage ID: MNHWOD	Gage ID: KNHCONCO5	Gage ID: 14710
	Source: Franklin Falls Dam	Source: NHDOT	Source: NOAA	Source: NOAA
24-October	3.14	2.32	1.87	1.07
25-October	0	0.04	0	0
26-October	0	0.04	0	0
27-October	0	0.04	<0.01	0.01
28-October	0.67	0.24	0.94	1.21

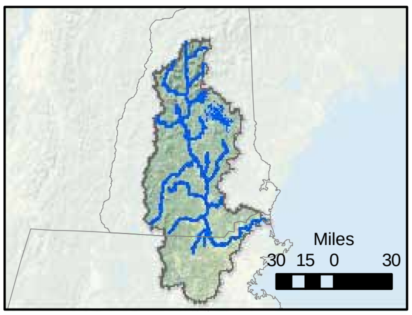
Streamflows during the final impoundment survey were above average at all four tracking gages due to a large rain event that occurred two days before the first day of field work. Flows at the start of the survey were receding at the two upstream gages, peaking at the Franklin gage, and still rising at the Goffs Falls gage. Field crews observed significant flooding upstream of the Franklin Falls Dam at the boat access point. Figure 2-12 shows the streamflow trace at each gage at the time that samples and field readings were collected in each impoundment.



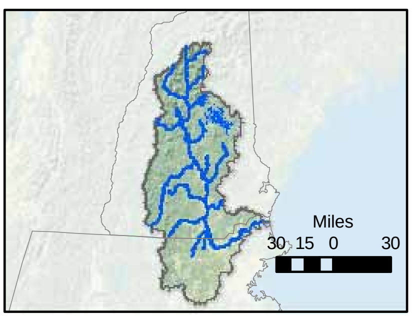
October 24, 2009



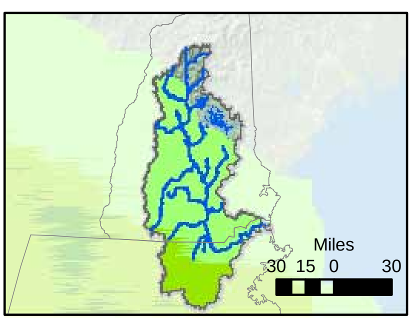
October 25, 2009



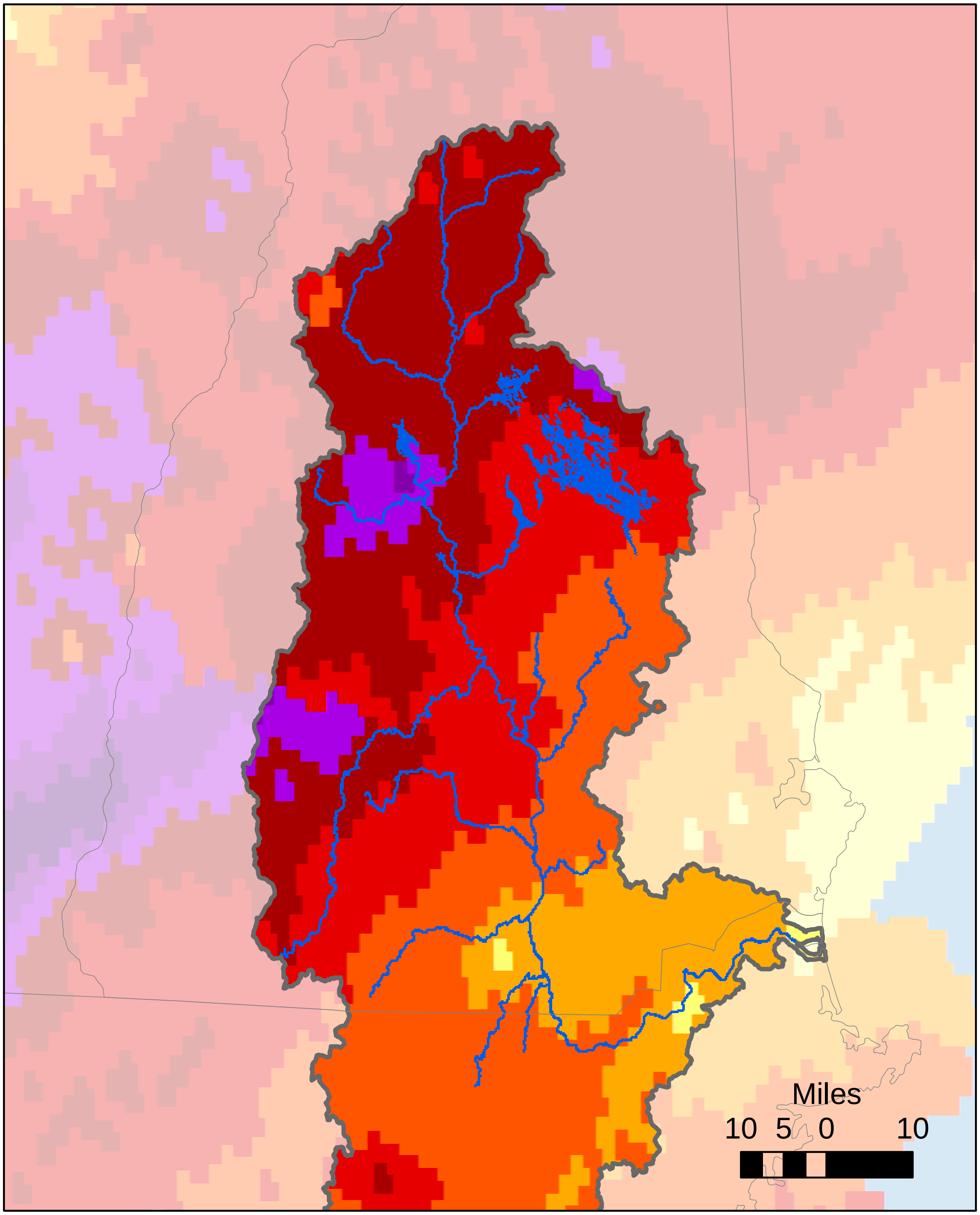
October 26, 2009



October 27, 2009



October 28, 2009



Total Precipitation (in) from October 24, 2009 through October 28, 2009

Legend

State Boundaries
Merrimack River Basin
Water Bodies

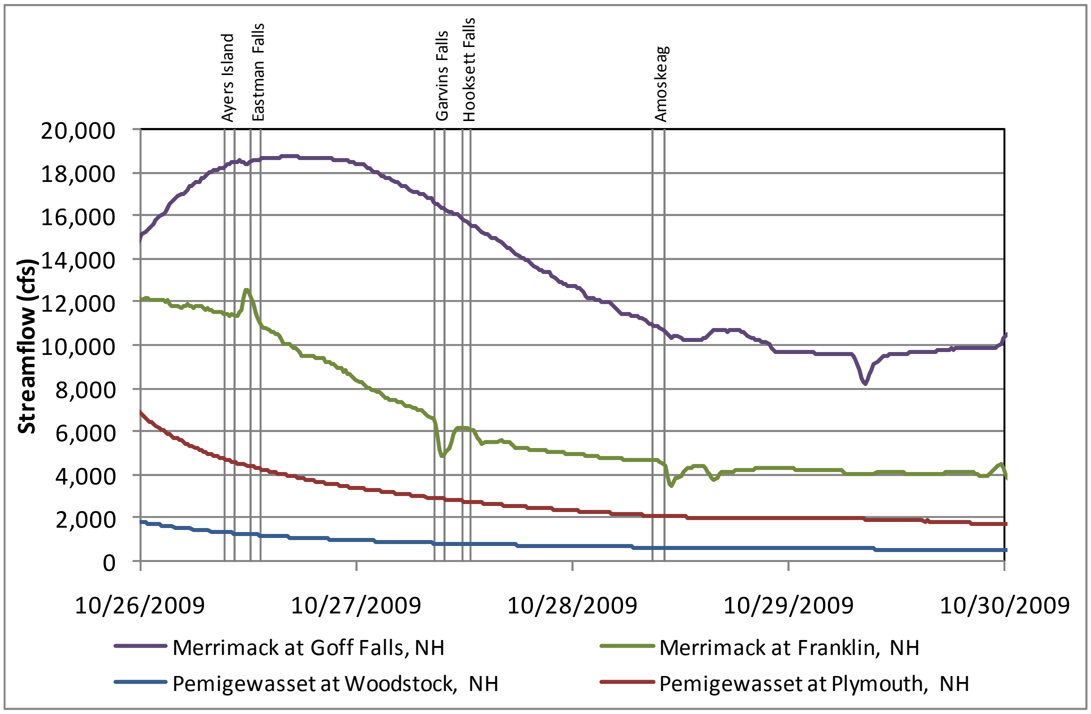
Total Precipitation (in)

0.00 - 0.01
0.02 - 0.10
0.11 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 6.10

Merrimack River Basin Precipitation (in)
Impoundment Survey 5
October 24 - October 28, 2009

Figure 2-11

Figure 2-12: Streamflow Conditions During Impoundment Survey #5



2.5.3 QAPP and Field Sampling Plan Deviations

Water samples were shipped overnight to the laboratory at the conclusion of each day of sampling. The earliest possible arrival of the samples at the laboratory was at 10:00 am the morning after samples were collected. Chlorophyll-a samples have a hold time of 24 hours, so samples collected prior to 10:00 am arrived at the laboratory a few hours after the hold time expired. The earliest sample was collected at 8:40am, so the largest hold time violation was between one and two hours. Table 2-15 shows the samples that were not within the 24 hour chlorophyll-a hold time.

Table 2-15: Missed Chlorophyll-a Hold Times for Impoundment Survey #5

Impoundment	Station	Date	Time	Sample Type
Ayers Island	I001	26-October	9:25 AM	Grab
	I002	26-October	9:50 AM	Grab
Garvins Falls	I010	27-October	8:40 AM	Grab
	I011	27-October	9:10 AM	Grab
	I012	27-October	9:45 AM	Grab
	I212	27-October	9:45 AM	field duplicate
	I012	27-October	9:50 AM	deep grab
Amoskeag	I017	28-October	8:50 AM	grab
	I018	28-October	9:35 AM	grab
	I018	28-October	9:40 AM	deep grab
	I118	28-October	9:45 AM	field blank

Water levels prevented sampling at the Franklin Falls impoundment during the fifth impoundment survey. This also resulted in one less field equipment blank sample that the usual two collected for the previous four surveys. The total number of samples collected for this event was 15, so the overall percentage of field equipment blanks collected was 6.7%, as compared with the usual 11% QA/QC samples (or two for 18 samples). However, the overall percentage of field equipment blank samples collected for the five impoundment surveys was 10% (or nine for 87 samples).

2.6 Impoundment Studies Data Summary

2.6.1 Dissolved Oxygen and Temperature Profiles

The dissolved oxygen and temperature profiles for the 18 impoundment sampling locations are presented in Appendix B. No stratification of the impoundments was observed during the five impoundment surveys. All readings for dissolved oxygen were above the state standard of 5 mg/L or 75% saturation. As shown in Figure 2-13 below, the flows in the Upper Merrimack and Pemigewasset Rivers were above average for the summer except for part of the month of September. This likely increased flushing of the impoundments and prevented stratification at locations that may stratify under normal or below average summer streamflow conditions.

2.6.2 Water Quality Sample Results

Total phosphorus concentrations from samples taken in the impoundments were generally greater in the lower impoundments (Garvins Falls, Hooksett Falls, and Amoskeag) and generally greater in all impoundments later in the summer. The highest total phosphorus concentrations, 30-40 ug/L, were found in the lower impoundments in September and October. The lowest total phosphorus concentrations, 5-10 ug/L, were found in the upper impoundments (Ayers Island, Franklin Falls, and Eastman Falls) in the June, July and September samples.

The results of all the individual total phosphorus samples are shown in Figure 2-14. The samples taken from near the bottom of the water column are shown as points, while samples taken from near the surface are shown as points with connecting lines.

The average total phosphorus concentrations for all three samples taken within each impoundment (bars) and the values of the samples taken from near the bottom of the water column (lines) are shown in Figure 2-15. The phosphorus concentrations at the bottom of the water column were neither consistently greater than nor less than the concentrations at the top of the water column. The following observations were made when comparing the average surface concentrations with the deep concentrations:

- Bottom concentrations were less than surface concentrations in June-August and greater in September and October in Ayers Island impoundment
- The bottom concentration was much greater than the surface concentration in June in the Franklin Falls and Eastman Falls impoundments
- The bottom concentration was much greater than the surface concentration in August and September in Garvins Falls impoundment
- The bottom concentrations were always greater than the surface in Amoskeag impoundments, and by the most in October

Chlorophyll-a concentrations in the impoundment samples generally ranged from non-detect (detection limit: 0.05 ug/L) to 3 ug/L. Concentrations were significantly greater on the upper impoundments (Ayers Island, Franklin Falls, and Eastman Falls) in September, ranging from 2 to 7 ug/L. Figure 2-16 shows the concentrations of the individual samples from each impoundment for all five surveys. Figure 2-17 shows the average concentrations for the three samples taken in each impoundment for each survey.

The total phosphorus concentrations in the lower impoundments were at levels that would generally be of concern for overproduction during normal late summer conditions (greater than 25 ug/L), however there was not evidence of significant algal growth in the chlorophyll-a concentrations in September or October. This suggests that the higher than average flows in the impoundments in the summer of 2009 prevented excessive growth that could result in stressed dissolved oxygen conditions.

Figure 2-13: Summer 2009 Streamflow Compared With Average Streamflow Conditions, cfs

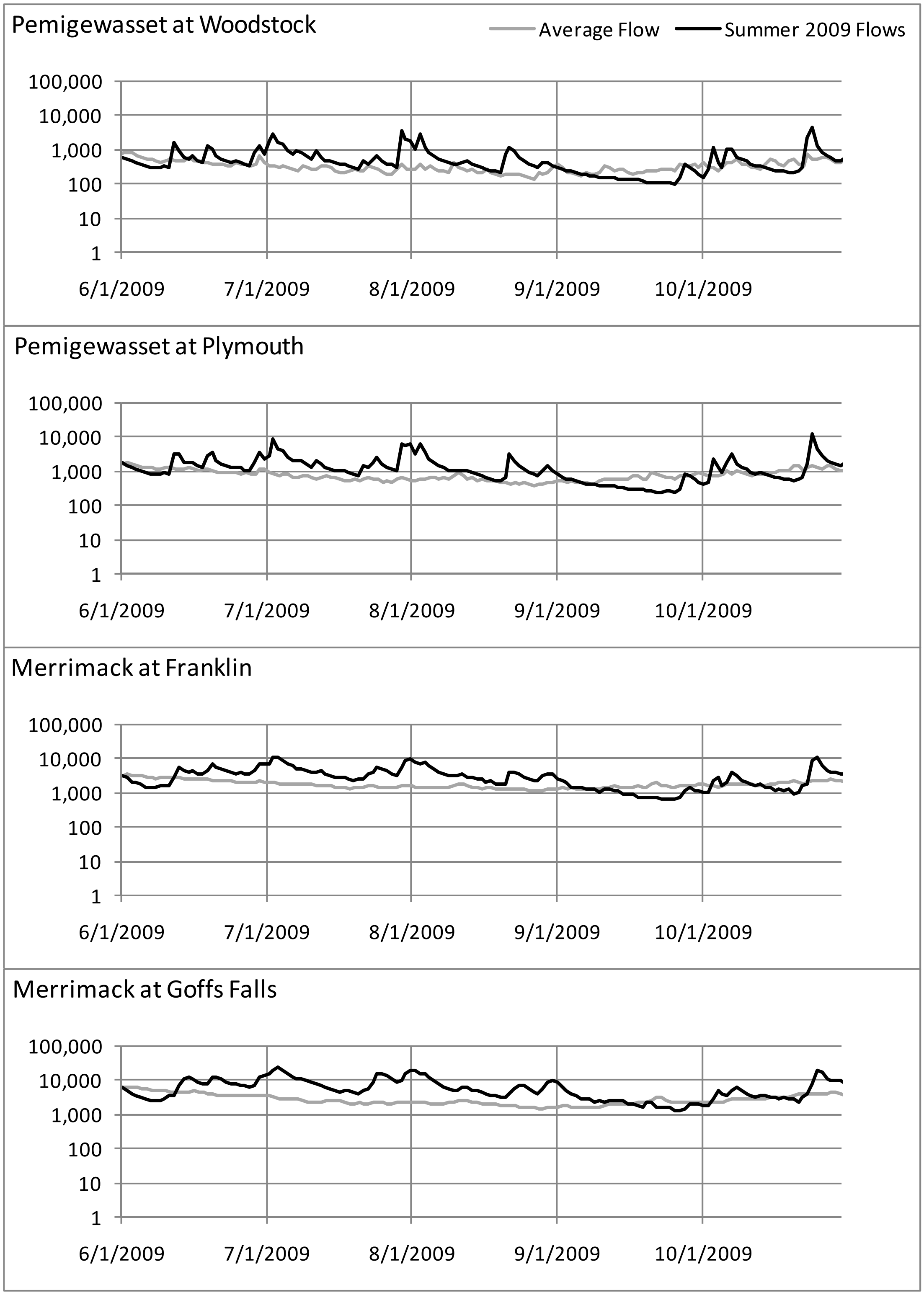
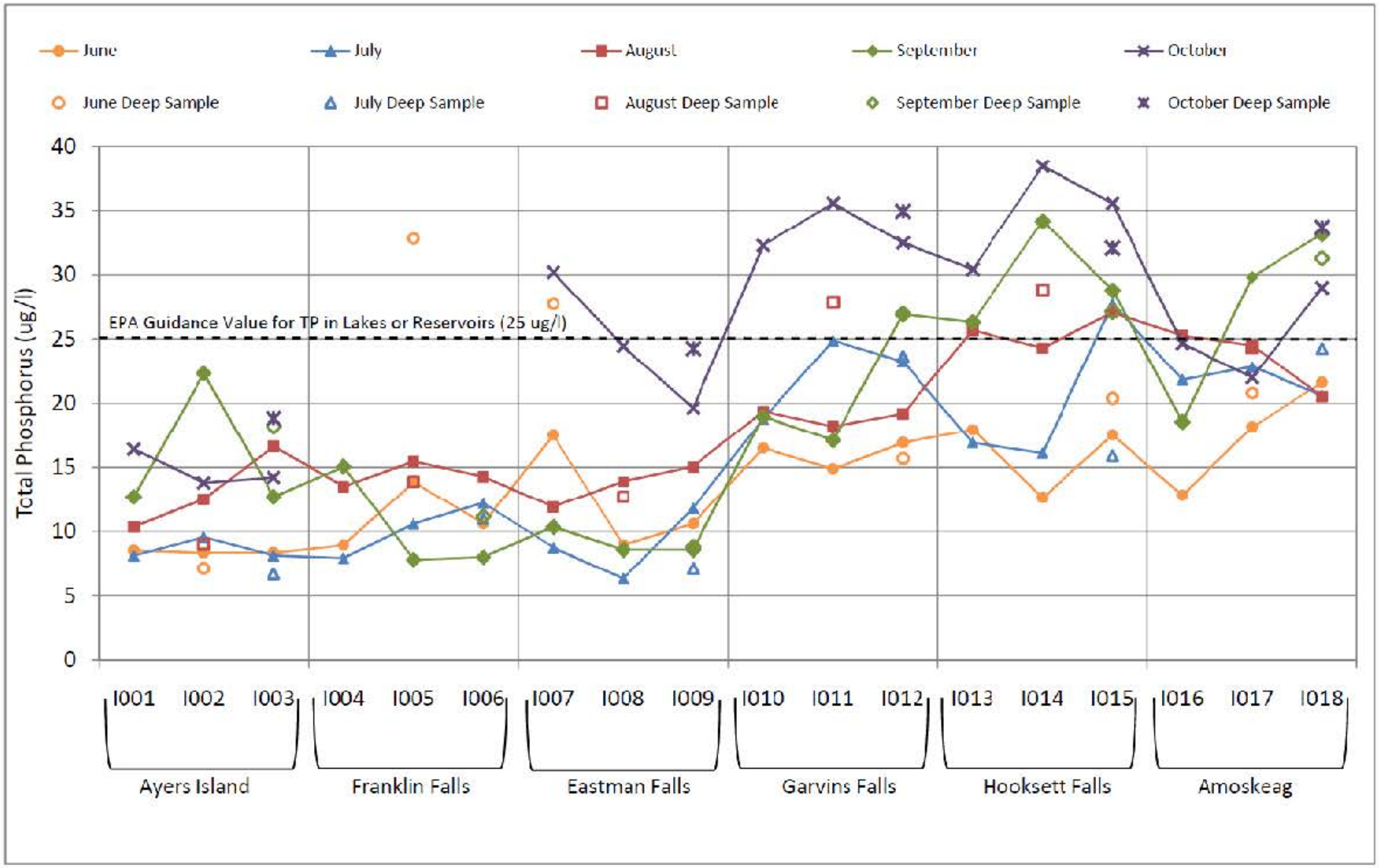


Figure 2-14: Total Phosphorus Concentrations in Impoundment Samples



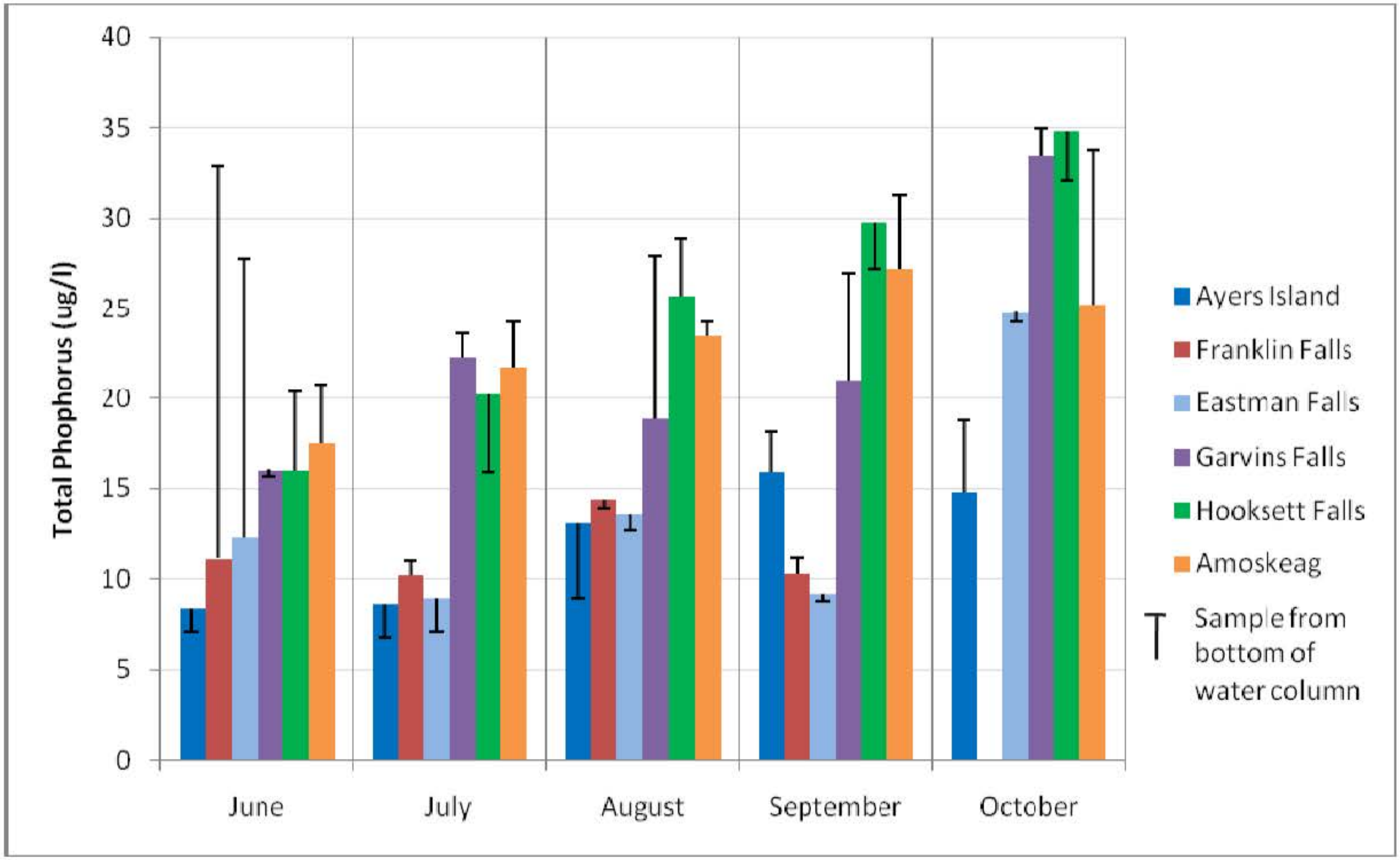


Figure 2-15: Average Total Phosphorus in Impoundments

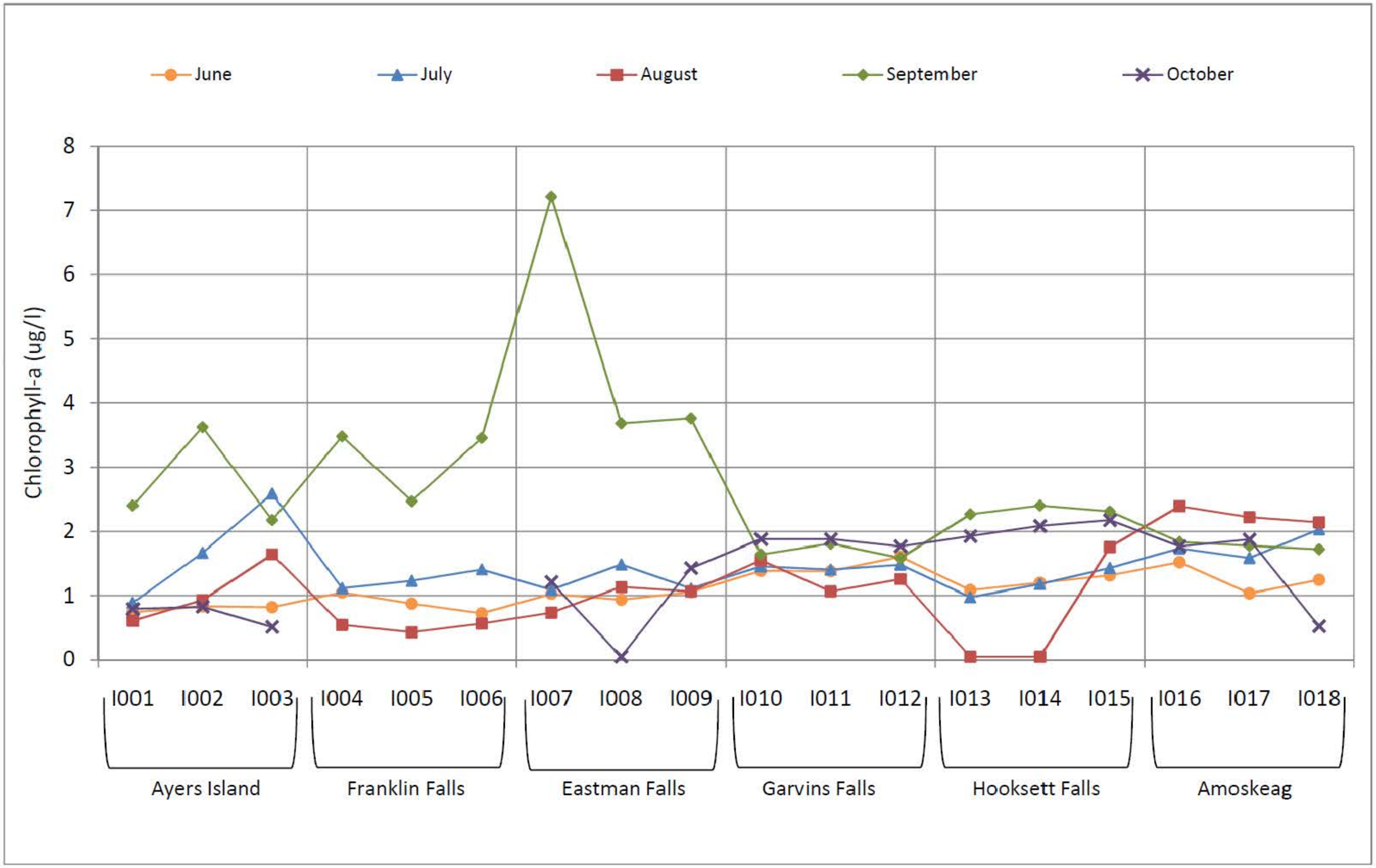
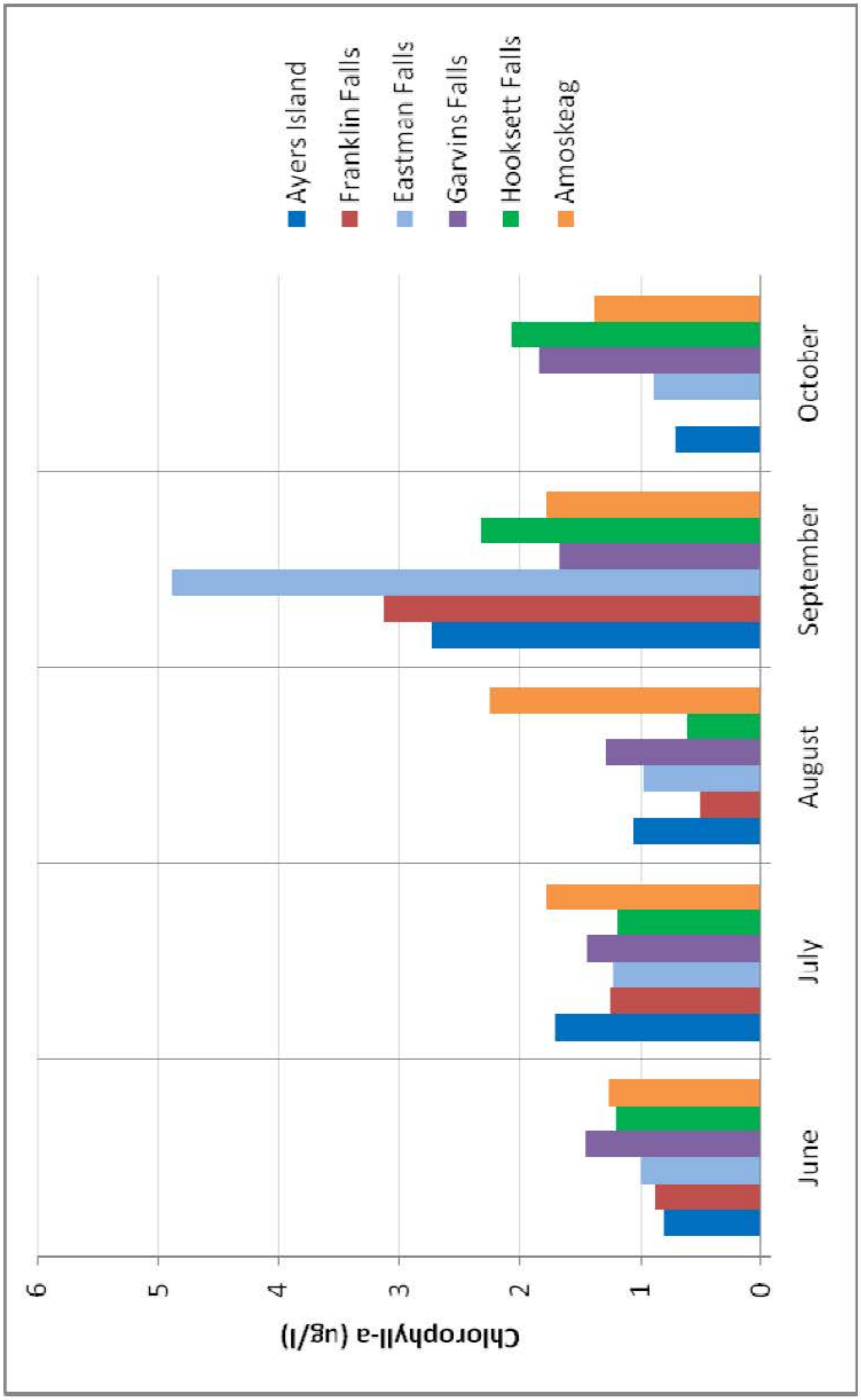


Figure 2-16: Chlorophyll-a Concentrations in Impoundment Samples

Figure 2-17: Average Chlorophyll-a Concentrations in Impoundments



Section 3
Continuous Dissolved Oxygen and Temperature Monitoring

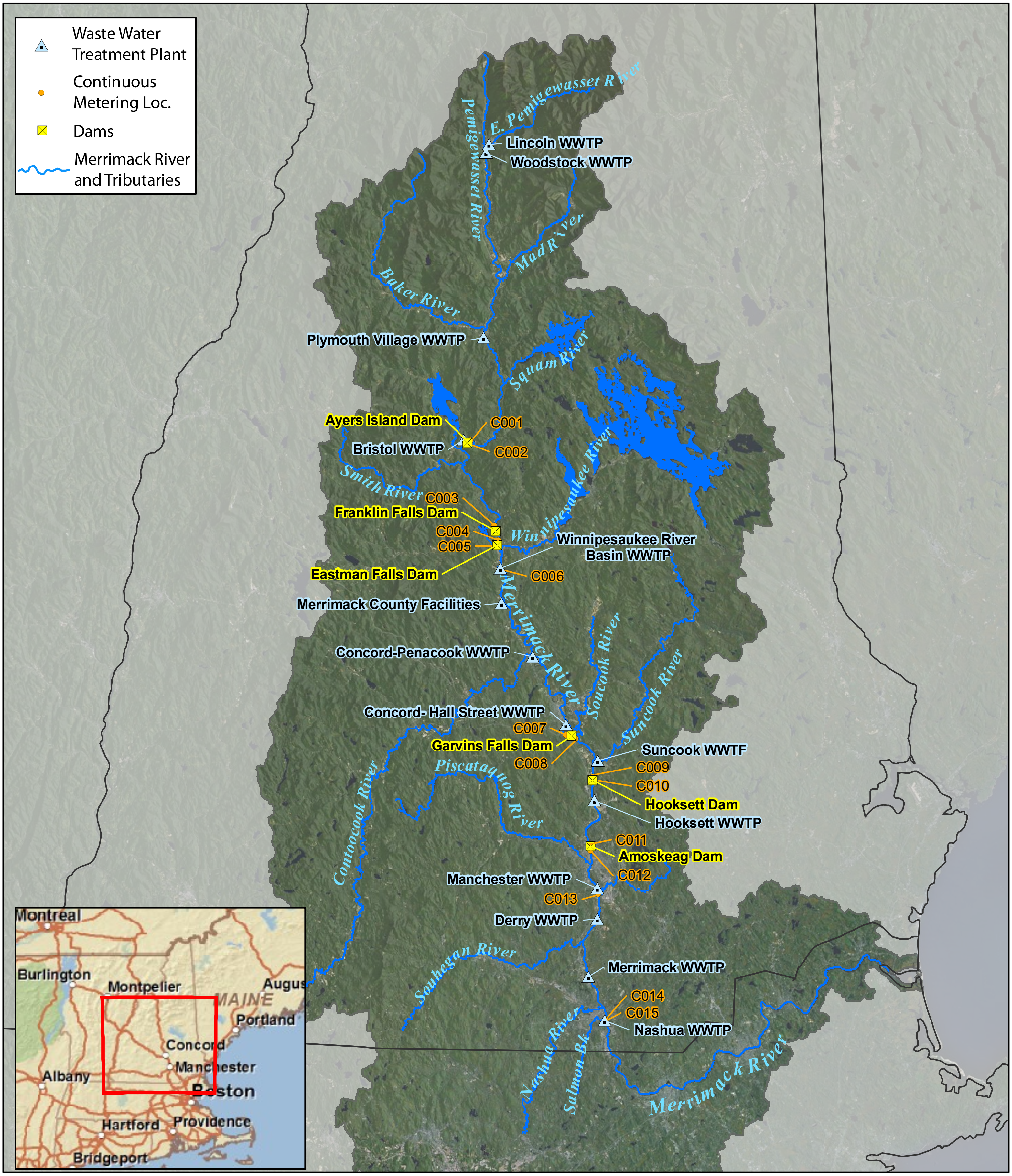
Continuous dissolved oxygen and temperature measurements were made at 15 locations in the Study Area between mid-July and mid-September, 2009. Measurements were logged at 15-minute intervals and downloaded weekly by field crews. These continuous dissolved oxygen meters placed in key locations throughout the study area provide valuable time-sensitive information which cannot be extracted from single sampling events.

Depths of the meters at each of the 15 selected locations were determined based on vertical profile findings. For stratified areas, the probe would have been installed within the epilimnion in accordance with the NHDES guidelines. For areas without stratification, the meter was installed within the top 25% of depth. During the impoundment studies of 2009 (see Section 2), stratification was not observed in any of the six impoundments, therefore all meters were placed at approximately 25% depth from the surface. Each meter was re-calibrated on a weekly bases when field crews maintained equipment and downloaded meter data.

The meters were deployed at locations upstream and downstream of each of the six dams, downstream of the Winnipesaukee WWTP in Franklin, downstream of the Manchester WWTP in Manchester, and upstream and downstream of the Nashua WWTP in Nashua. The two-month time period was selected for continuous dissolved oxygen and temperature sampling due to the typical DO concentrations during summer streamflow conditions. Streamflow conditions for this period in 2009 are shown in Figure 3-2 and are discussed further in Section 3.2. The installation and removal time as well as location for each of the 15 continuous dissolved oxygen and temperature meters are shown in Table 3-1. Additionally, locations of each of the 15 meters are shown within the Study Area in Figure 3-1.

Table 3-1: Continuous Meter Installation and Removal Schedule

Monitor Station ID	Installation Date	Removal Date	Location
C001	7/22/09	9/16/09	U/S of Ayers Island Dam
C002	8/20/09	9/18/09	D/S of Ayers Island Dam
C003	7/22/09	9/16/09	U/S of Franklin Falls Dam
C004	7/22/09	9/16/09	D/S of Franklin Falls Dam and U/S of Eastman Falls Dam
C005	7/23/09	9/18/09	D/S of Eastman Falls Dam
C006	7/27/09	9/17/09	D/S of the Winnipesaukee WWTP
C007	7/21/09	9/17/09	U/S of Garvins Falls Dam
C008	7/28/09	9/15/09	D/S of Garvins Falls Dam
C009	7/20/09	9/15/09	U/S of Hooksett Falls Dam
C010	7/21/09	9/15/09	D/S of Hooksett Falls Dam
C011	7/21/09	9/15/09	U/S of Amoskeag Dam
C012	7/27/09	9/17/09	D/S of Amoskeag Dam
C013	7/24/09	9/17/09	D/S of Manchester WWTP
C014	7/20/09	9/15/09	U/S of Nashua WWTP
C015	7/20/09	9/15/09	D/S of Nashua WWTP



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Upper Merrimack and Pemigewasset River Study

Figure 3-1
Continuous Metering Locations

0 5 10 20 Miles

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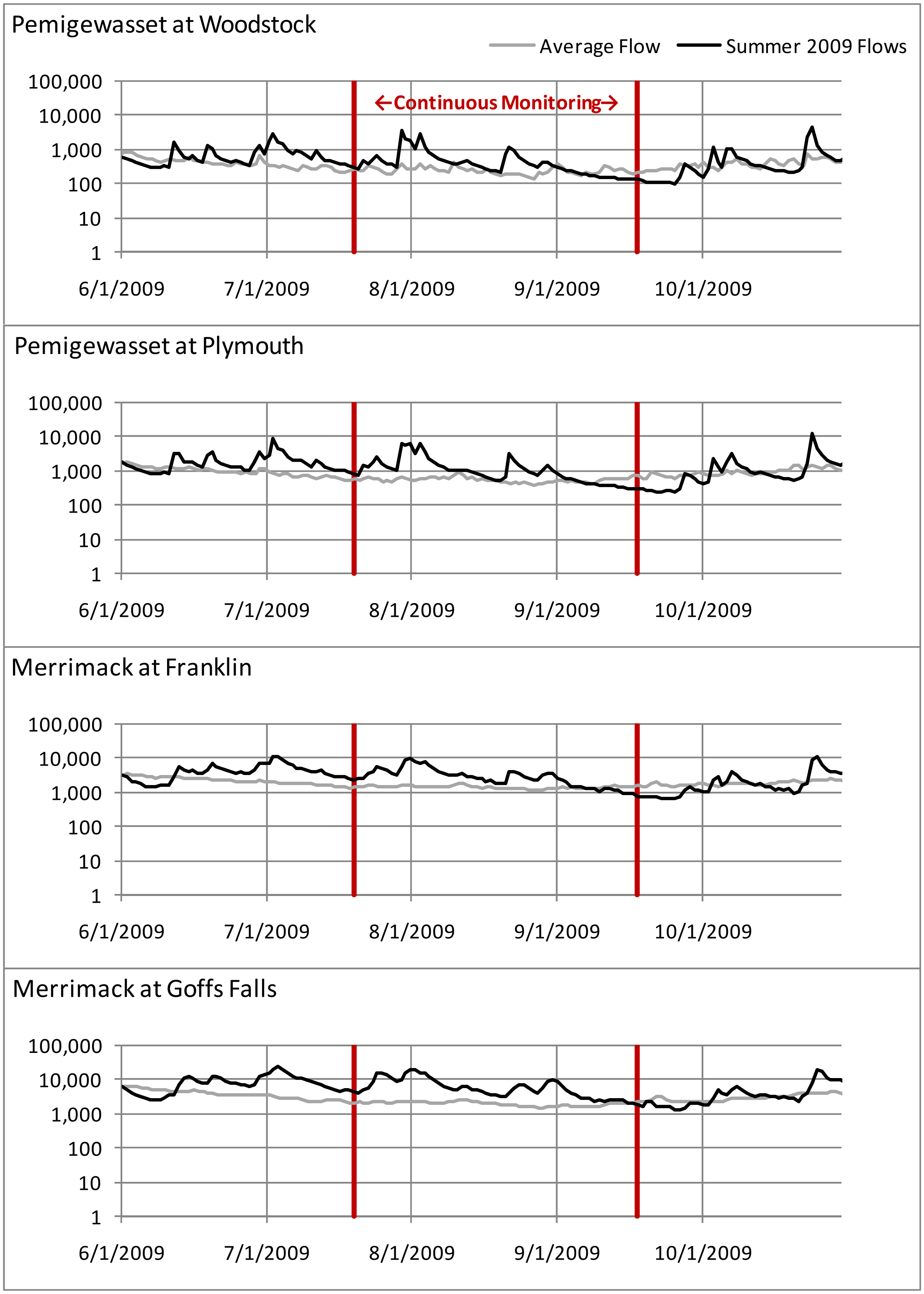
3.1 Dissolved Oxygen and Temperature Water Quality Standards

The Pemigewasset River and Merrimack River have been identified as Class B for water quality. Class B waters are of the second highest quality, which are considered acceptable for fishing, swimming and other recreational purposes, and, after adequate treatment, for use as water supplies. With regard to dissolved oxygen levels, Class B waters are defined as being impaired by oxygen depletions with concentrations of dissolved oxygen below 5 mg/L or percent saturation of dissolved oxygen less than 75% of the daily average. To meet temperature standards in a Class B water body, thermal waste must be regulated based on the most effective level of control of the New Hampshire Fish and Game Department, the New England Interstate Water Pollution Control Commission, or the United States Environmental Protection Agency.

3.2 Summary of Streamflow Conditions

The continuous dissolved oxygen and temperature meters were deployed during a period of mostly greater than average streamflows. Figure 3-2 shows the streamflow at the four mainstem tracking gages along with the average streamflow at each gage and the period during which the meters were deployed. Two significant flow changes occurred during the metering period: July 30 and August 21-22.

Figure 3-2: Streamflow Conditions During 2009 Continuous Dissolved Oxygen and Temperature Monitoring



3.3 QA/QC Procedures

Routine data recording, equipment calibration, and maintenance was performed on the DO and temperature probes to ensure that measurements were accurate. Table 3-2 shows a schedule of dates when each continuous dissolved oxygen and temperature meter was calibrated during the two-month period.

Table 3-2: Continuous Monitoring Schedule of Meter Calibration

Meter ID	Calibration Dates, 2009								
C001	22-Jul	29-Jul	4-Aug	11-Aug	18-Aug	24-Aug	1-Sep	9-Sep	
C002	20-Aug	27-Aug	3-Sep	11-Sep					
C003	22-Jul	29-Jul	6-Aug	11-Aug	18-Aug	25-Aug	1-Sep	9-Sep	
C004	22-Jul	29-Jul	4-Aug	11-Aug	18-Aug	25-Aug	1-Sep	9-Sep	
C005	23-Jul	30-Jul	6-Aug	13-Aug	20-Aug	27-Aug	3-Sep	11-Sep	18-Sep
C006	27-Jul	30-Jul	5-Aug	13-Aug	19-Aug	27-Aug	3-Sep	10-Sep	
C007	21-Jul	30-Jul	5-Aug	12-Aug	19-Aug	26-Aug	2-Sep	10-Sep	
C008	28-Jul	3-Aug	10-Aug	17-Aug	24-Aug	31-Aug	8-Sep		
C009	20-Jul	28-Jul	4-Aug	10-Aug	17-Aug	24-Aug	31-Aug	8-Sep	
C010	21-Jul	29-Jul	3-Aug	10-Aug	17-Aug	24-Aug	31-Aug	8-Sep	
C011	21-Jul	29-Jul	3-Aug	10-Aug	17-Aug	27-Aug	31-Aug	8-Sep	
C012	27-Jul	20-Aug	26-Aug	2-Sep	10-Sep				
C013	24-Jul	31-Jul	5-Aug	12-Aug	19-Aug	26-Aug	2-Sep	10-Sep	
C014	20-Jul	28-Jul	3-Aug	10-Aug	17-Aug	24-Aug	31-Aug	8-Sep	
C015	20-Jul	28-Jul	3-Aug	10-Aug	17-Aug	24-Aug	31-Aug	8-Sep	

During the time between calibration visits, some meters ran out of batteries or were inadvertently damaged due to high flows or other unforeseen circumstances. In most cases, no more than 10 days of data were lost when a meter malfunctioned. Downstream of the Ayers Island Dam (C002), the river level increased dramatically during a rain event causing the unit to break loose, resulting in loss of the unit and its data. Another unit was redeployed in mid-August at this location.

Dissolved oxygen (DO) data was corrected to adjust for instrument calibration drift that may occur between instrument servicing visits (i.e. over a sampling period). During instrument servicing for each YSI meter, the YSI meter was used to measure DO concentration (mg/L) of a known standard, the meter was then recalibrated and DO concentration of the known standard was re-measured. The difference in the two measurements is the data-correction. DO data was corrected when the data-correction exceeded ±0.3 mg/L. Calibration drift is assumed to occur at a constant rate over the correction period, therefore the data-correction is prorated over time. Hence, a zero correction is applied for the first sample of the sampling period and the full correction is applied to the last sample of the sampling period with the value of the data-correction for each sample increasing linearly with time.[1]

The data plots in the following section show the original data for dissolved oxygen concentration and percent saturation along with the corrected data. There were cases when the data could not be corrected according to the method above and the plots show only the original data for those time periods.

3.4 Continuous Monitoring Results

3.4.1 Impoundments

Temperature

River temperatures in impoundments fluctuated during the two-month continuous monitoring period. The highest water temperature observed in an impoundment during the two-month period was approximately 27 ˚C on August 19 upstream of the Hooksett Dam. The lowest water temperature observed in an impoundment during the study period was upstream of the Franklin Falls Dam, which recorded the coldest temperature of approximately 17 ˚C on September 2.

Impoundment water temperatures varied throughout the day with daily temperature changes of around 4˚C in some instances, such as on July 31 upstream of the Ayers Island Dam. As a general trend, the lowest water temperature of the day occurred in the late morning, before noon. Water temperatures in impoundments tended to increase after noon and continue to increase through the evening before dropping around midnight. Daily temperature fluctuations are seen in every impoundment, but are more pronounced in the Hooksett and Franklin Falls impoundments than other impoundments, such as Ayers Island and Amoskeag impoundments where the daily temperature fluctuations are weaker. Daily temperature fluctuation patterns were least obvious in the Ayers Island impoundment.

Increases and decreases in overall water temperature in impoundments occurred throughout the two month period. A drastic drop of around 4 - 7˚C in water temperatures occurred around July 30, which corresponds with an increase in streamflow caused by a rain event during which the watershed experienced up to 1.5 inches of rain per day. A gradual increase in impoundment water temperatures was found from August 1 through August 21. Following this increase, temperatures decreased again. These general increases and decreases in water temperatures were consistent variations displayed across all impoundments along the river. Figure 3-3 shows an example of the temperature variability seen in impoundments during this continuous monitoring period. Continuous temperature data for all six impoundments can be found in Appendix B of this report.

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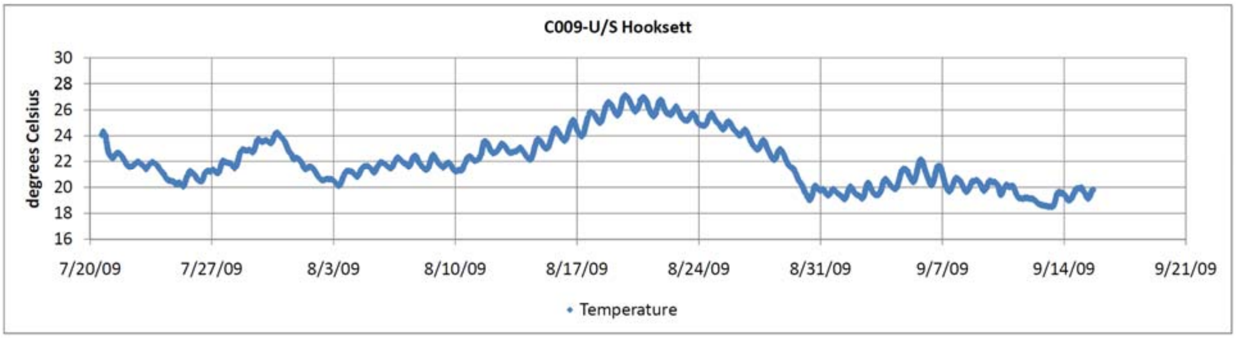
[1] Wagner, R.J., Boulger, R.W., Oblinger, C.J., and Smith, B.A., 2006. *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting. U.S. Geological Survey Techniques and Methods 1-D3.*

Figure 3-3: Representative Impoundment Continuous Temperature Monitoring



Dissolved Oxygen Concentrations

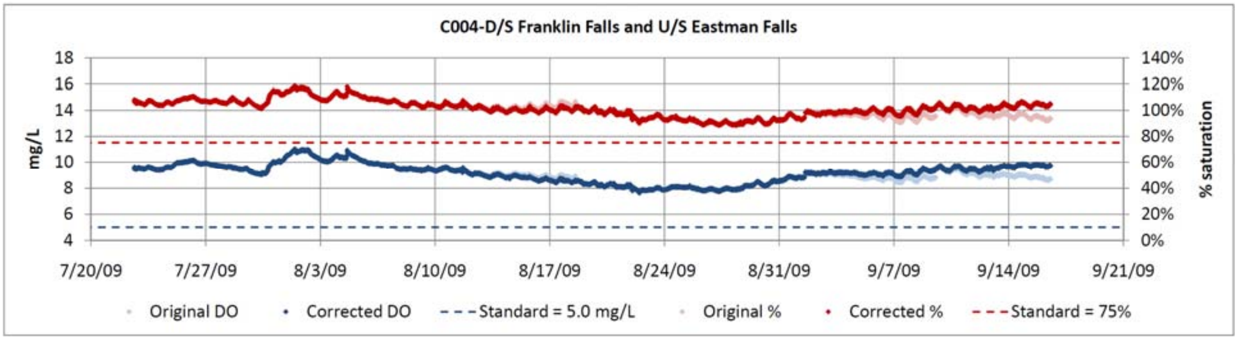
Every impoundment continuously recorded levels above the dissolved oxygen percent saturation standard of 75% and the concentration standard of 5 mg/L with the exception of a short period during August 23, when dissolved oxygen in the Ayers Island impoundment dropped briefly to 72% saturation. This was the lowest recorded level of dissolved oxygen over the two-month monitoring period and corresponded to a dissolved oxygen concentration of 6.1 mg/L.

The highest recorded concentration of dissolved oxygen in an impoundment during the continuous monitoring period was 11.6 mg/L at the Hooksett impoundment. The highest percent saturation of dissolved oxygen, 127%, also occurred at the Hooksett impoundment.

A diurnal pattern of dissolved oxygen concentration and percent saturation is visible at each impoundment. Impoundment locations with strong diurnal patterns in temperature also display strong diurnal patterns in concentration and percent saturation of dissolved oxygen. Ayers Island and Amoskeag impoundments exhibit a weak diurnal pattern while the Franklin Falls and Hooksett impoundments have strong diurnal dissolved oxygen fluctuations.

Concentrations and percent saturation of dissolved oxygen remain fairly constant in impoundments for the monitoring period. Variations in dissolved oxygen levels are seen in the Hooksett impoundment in September towards the end of the monitoring period. Additionally, Ayers Island impoundment exhibits slight variations in dissolved oxygen levels throughout the monitoring period. Figure 3-4 below shows dissolved oxygen levels at the monitoring station between Franklin Falls Dam and Eastman Falls Dam, which is a representative plot of the dissolved oxygen data collected during this continuous monitoring study. Continuous dissolved oxygen data for all six impoundments is included in Appendix B of this report.

Figure 3-4: Representative Dissolved Oxygen Trends Upstream of Dams

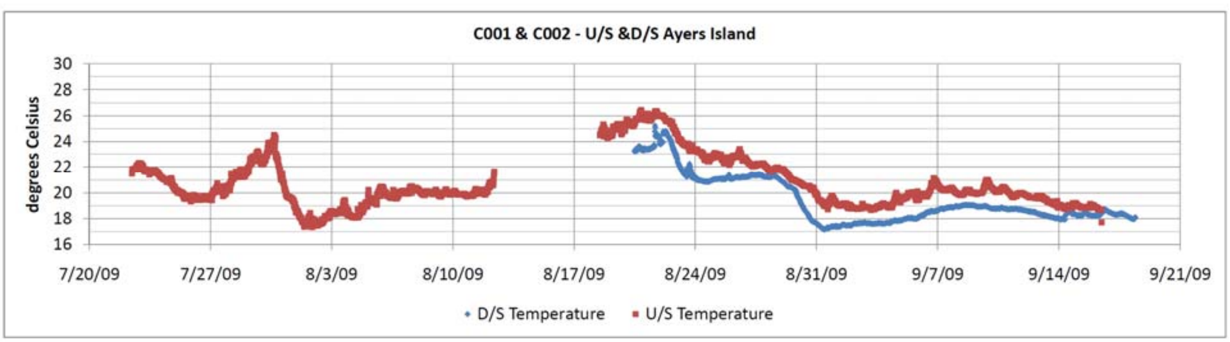


3.4.2 Downstream of Dams

Temperature

The temperature data recorded downstream of dams followed similar general trends and diurnal patterns found in impoundment temperature data. Ayers Island showed a significant temperature differential between the impoundment and downstream of the dam with temperatures varying close to two degrees Celsius in some instances. Figure 3-5 shows the change in temperature from upstream and downstream of the Ayers Island Dam (note that the downstream meter was lost due to high water and a new meter was installed in mid-August). The Hooksett Dam showed a slight temperature differential across the dam, while the Eastman Falls Dam, Garvins Falls Dam, and Amoskeag Dam showed almost no temperature change across the dam.

Figure 3-5: Temperature Change from Upstream to Downstream of Ayers Island Dam



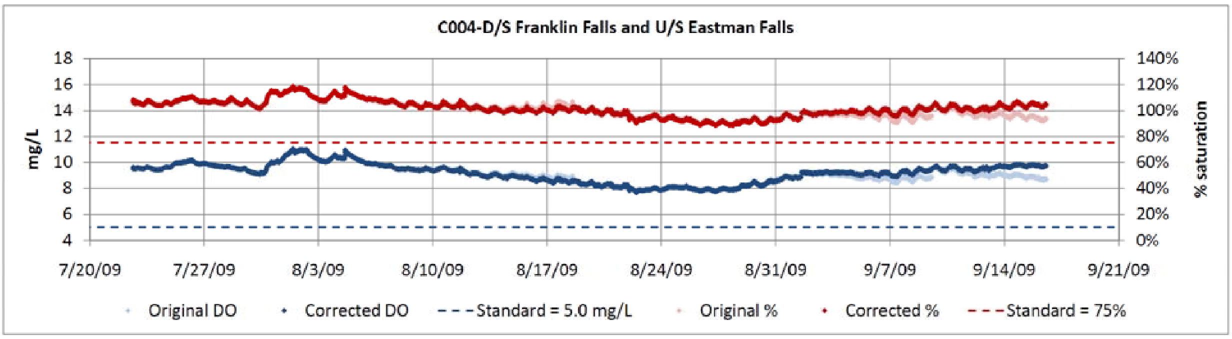
Dissolved Oxygen Concentrations

All stations downstream of dams recorded levels above the dissolved oxygen percent saturation standard of 75% and the concentration standard of 5 mg/L. The area downstream of Ayers Island had the lowest percent saturation of dissolved oxygen recorded at a station downstream of a dam, with a percent saturation of 75.5% and a corresponding low concentration of 6.4 mg/L.

The highest recorded concentration of dissolved oxygen downstream of a dam during the continuous monitoring period was 11.6 mg/L below the Hooksett Dam. The highest percent saturation of dissolved oxygen, 133%, also occurred below the Hooksett Dam.

Dissolved oxygen levels recorded below dams during the continuous monitoring period followed the same general patterns and fluctuations which were found in impoundments. Figure 3-6 shows a representative plot of continuous dissolved oxygen readings below impoundments. Figures of dissolved oxygen readings during the study period downstream of all six dams can be found in Appendix B.

Figure 3-6: Representative Dissolved Oxygen Downstream of Dams



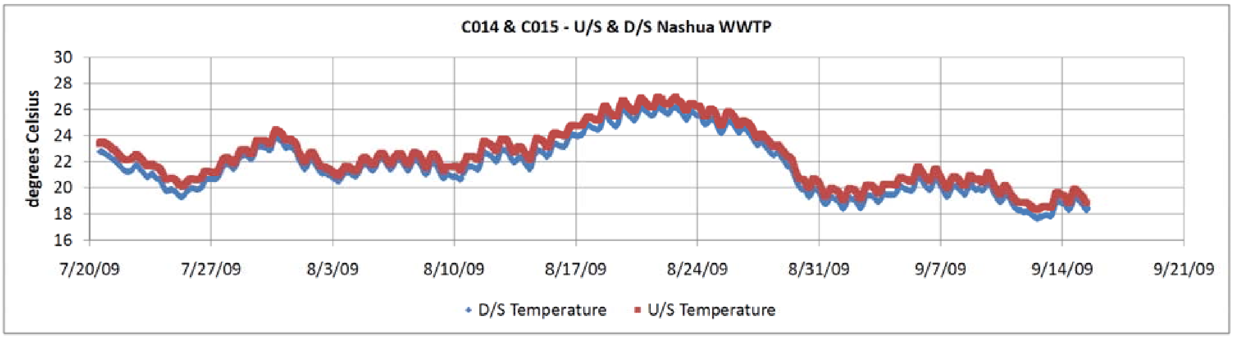
3.4.3 Upstream and Downstream of WWTPs

Temperature

Temperatures recorded upstream and downstream of WWTPs show very similar patterns to those shown in impoundments and downstream of impoundments. Temperature data upstream and downstream of WWTPs exhibits a very strong diurnal pattern shown throughout the study period in all four locations monitored. Temperatures tended to be lowest during the late morning and highest in the afternoon. The highest recorded temperature upstream or downstream of a WWTP was 27.2˚C, which was recorded downstream of the Manchester WWTP. The lowest recorded temperature upstream or downstream of a WWTP was 17.7˚C, which was recorded downstream of the Nashua WWTP.

The Nashua WWTP was the only location where continuous monitoring was performed upstream and downstream of the facility. Comparing the temperature changes across the WWTP shows a decrease in temperature downstream of the WWTP by one degree or less. Figure 3-7 shows the change in temperature from upstream to downstream of the Nashua WWTP. Additional figures of temperatures upstream and downstream of WWTPs are included in Appendix B.

Figure 3-7: Temperatures Upstream and Downstream of Nashua WWTP

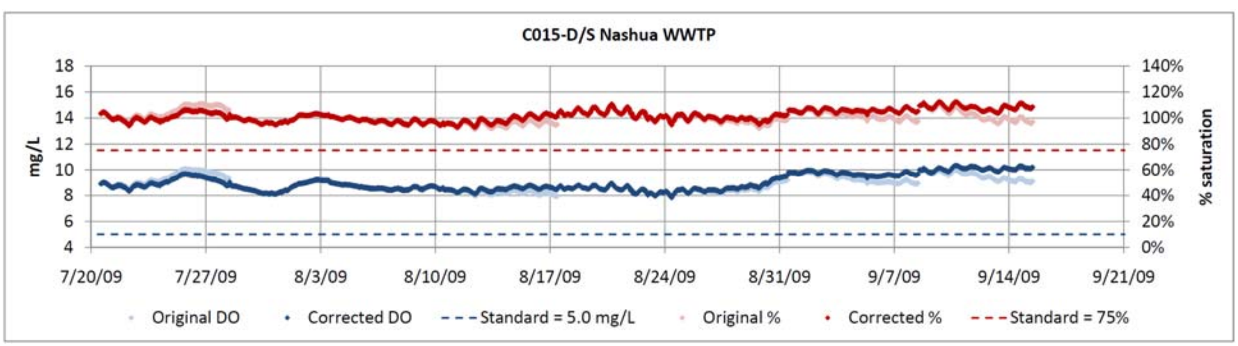


Dissolved Oxygen Concentrations

Percent saturation and concentration of dissolved oxygen recorded upstream and downstream of wastewater treatment plants exhibit similar trends and fluctuations as monitoring results found at other stations throughout the study area. The dissolved oxygen readings show a diurnal pattern, as was seen in dissolved oxygen readings from other stations. This diurnal pattern is strongest downstream of the Winnipesaukee WWTP during the continuous monitoring period. Figure 3-8 shows representative continuous dissolved oxygen readings downstream of WWTPs. Additional continuous dissolved oxygen readings upstream and downstream of a WWTP are located in Appendix B.

The highest percent saturation dissolved oxygen recorded upstream or downstream of wastewater treatment plants was 114% downstream of the Winnipesaukee WWTP with a high dissolved oxygen concentration of 10.4 mg/L. The lowest percent saturation dissolved oxygen recorded upstream or downstream of wastewater treatment plants was 88% with a low dissolved oxygen concentration of 7.4 mg/L. Very little change is shown in dissolved oxygen readings from upstream and downstream of the Nashua WWTP.

Figure 3-8: Continuous Dissolved Oxygen Measurements Downstream of Nashua WWTP



Section 4
Low Flow and High Flow Water Quality Surveys

Two low flow surveys and one high flow survey were conducted in order to evaluate water quality conditions in the river under typical spring and summer conditions. The objective was to capture a snapshot of the water quality conditions that may cause low dissolved oxygen and nutrient enrichment and to collect a comprehensive set of data to be used to calibrate a water quality model of the system. Both low flow surveys were conducted in the summer of 2010: July 27 and September 21. The high flow survey was conducted on May 17, 2012. A map showing the locations of the river sampling stations, major tributaries, and WWTPs is shown in Figure 4-1; Tables 4-1 and 4-2 list the stations and descriptions.

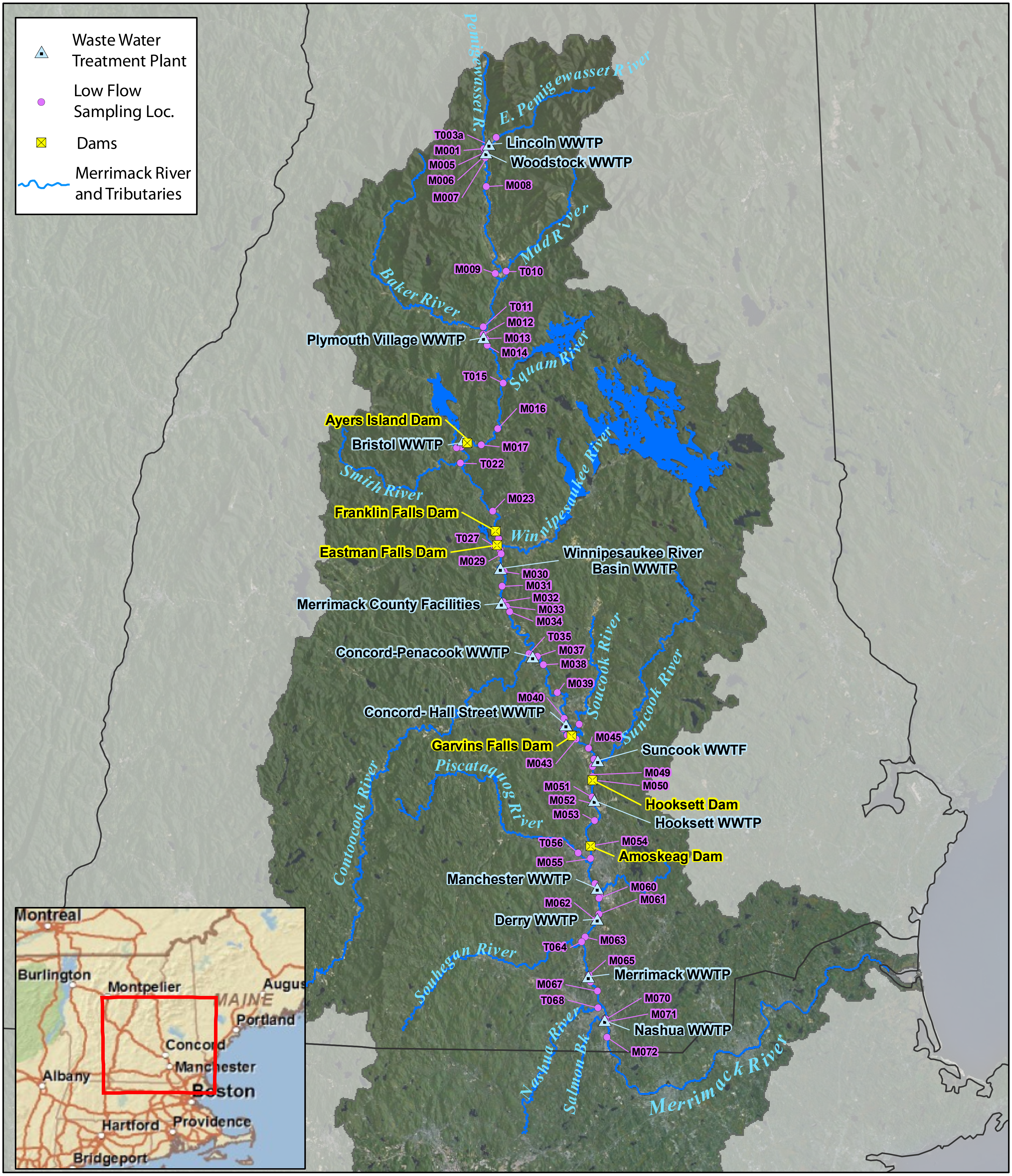
The low flow surveys consisted of the following activities:

- Collected samples for water quality analysis from 56 mainstem river and 16 major tributary sampling stations (analysis constituents listed in Table 1-3)
- Collected 24 hour composite effluent samples from 14 WWTPs that discharge directly to the Upper Merrimack and Pemigewasset Rivers
- Recorded early morning and late afternoon dissolved oxygen levels for 31 select stations to evaluate diurnal fluctuations
- Collected flow measurements at 8 ungaged tributaries
- Recorded field readings *in situ* for dissolved oxygen, temperature, conductivity, turbidity, pH and Secchi disc depth (where applicable); and
- Developed vertical profiles of temperature and dissolved oxygen at deep, slow moving sections of the river to evaluate stratification.

The high flow survey had a slightly lesser scope, which consisted of the following activities:

- Collected samples for water quality analysis from 32 mainstem river and 18 major tributary sampling stations (analysis constituents listed in Table 1-3)
- Collected 24 hour composite effluent samples from 14 WWTPs that discharge directly to the Upper Merrimack and Pemigewasset Rivers; and
- Recorded field readings *in situ* for dissolved oxygen, temperature, conductivity, turbidity, pH and Secchi disc depth (where applicable).

Descriptions of precipitation and streamflow conditions, an event summary, deviations from the QAPP and Field Sampling Plan, and a discussion of observations based on the data for each of the events are contained in Sections 4.1 through 4.3. A summary of the complete set of low flow and high flow data is presented in Sections 4.4 and 4.5, respectively.



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Upper Merrimack and Pemigewasset River Study

Figure 4-1

Sampling Locations

0 5 10 20 Miles

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Table 4-1: Low Flow Sampling Stations

Station ID	NHDES ID	River Mile (from Newburyport, MA)	Location	Station Type	Sample Type	Diurnal Measurements	Flow Measurements
M001	24C-PMI	169.9	Headwaters	mainstem riverine	grab		
T002	03-EBP	169.8	U/S Lincoln WWTF	tributary	grab	X	
T003	01-EBP	169.7	D/S Lincoln WWTF 1	tributary	grab	X	
T004	00F-EBP	169.5	D/S Lincoln WWTF 2	tributary	grab		
M005	23D-PMI	169.3	U/S Woodstock WWTF	mainstem riverine	grab		
M006	23-PMI	169.2	D/S Woodstock WWTF1	mainstem riverine	lateral composite	X	
M007	22M-PMI	168.9	D/S Woodstock WWTF 2	mainstem riverine	grab		
M008	21P-PMI	165.3	Woodstock Gage	mainstem riverine	grab		
M009	19-PMI	154.1	Campton	mainstem riverine	grab		
T010	01-MAD	153.2	Mad River	tributary	grab		X
T011	01-BKR	147.2	Baker River	tributary	grab	X	
M012	14X-PMI	146.9	U/S Plymouth Village WWTF	mainstem riverine	grab		
M013	14J-PMI	146.4	D/S Plymouth Village WWTF 1	mainstem riverine	lateral composite	X	
M014	14-PMI	146.2	D/S Plymouth Village WWTF 2	mainstem riverine	grab		
T015	00E-SQM	141.0	Squam River	tributary	grab		X
M016	09J-PMI	137.4	U/S Ayers Island 1	mainstem impoundment	grab	X	
M017	08J-PMI	134.5	U/S Ayers Island 2	mainstem impoundment	grab	X	
M018	07R-PMI	131.3	D/S Ayers Island, U/S Bristol WWTF	mainstem riverine	grab		
M019	07K-PMI	130.9	D/S Bristol WWTF 1	mainstem riverine	lateral composite	X	
M020	07-PMI	130.6	D/S Bristol WWTF 2	mainstem riverine	grab		
T021	01-NFD	130.4	Newfound River	tributary	grab		X
T022	00P-SMT	127.9	Smith River	tributary	grab		
M023	04-PMI	122.0	U/S Franklin Falls 1	mainstem impoundment	lateral composite	X	
M024	02-PMI	118.7	D/S Franklin Falls, U/S Eastman Falls 1	mainstem impoundment	lateral composite		
M025	01K-PMI	117.5	U/S Eastman Falls 2	mainstem impoundment	lateral composite	X	
M026	01D-PMI	117.1	D/S Eastman Falls	mainstem riverine	grab		
T027	01-CPB	117.0	Chance Pond Brook	tributary	grab		X
T028	01-WIN	116.2	Winnipesaukee River	tributary	grab	X	
M029	34-MER	114.3	U/S Winnipesaukee WWTF	mainstem riverine	grab		
M030	32-MER	113.6	D/S Winnipesaukee WWTF 1	mainstem riverine	lateral composite	X	
M031	31K-MER	113.4	D/S Winnipesaukee WWTF 2	mainstem riverine	lateral composite		
M032	31A-MER	110.6	U/S Merrimack County WWTF	mainstem riverine	grab		
M033	30X-MER	109.8	D/S Merrimack County WWTF 1	mainstem riverine	lateral composite	X	
M034	30J-MER	109.4	D/S Merrimack County WWTF 2	mainstem riverine	lateral composite		
T035	01G-CTC	101.0	Contoocook River	tributary	grab	X	X
M036	28A-MER	100.9	U/S Penacook WWTF	mainstem riverine	lateral composite		
M037	27X-MER	98.9	D/S Penacook WWTF 1	mainstem riverine	lateral composite	X	
M038	27-MER	97.6	D/S Penacook WWTF 2	mainstem riverine	grab		
M039	26-MER	94.5	U/S Concord	mainstem impoundment	grab		
M040	22X-MER	90.3	U/S Hall Street WWTF	mainstem impoundment	lateral composite		
M041	22-MER	88.7	D/S Hall Street WWTF 1, U/S Garvins Falls 1	mainstem impoundment	lateral composite	X	
M042	20-MER	88.0	D/S Hall Street WWTF 2, U/S Garvins Falls	mainstem impoundment	grab	X	
M043	19-MER	86.4	D/S Garvins Falls	mainstem riverine	grab		
T044	01-SCK	86.0	Soucook River	tributary	grab		

Table 4-1: Low Flow Sampling Stations (continued)

Station ID	NHDES ID	River Mile (from Newburyport, MA)	Location	Station Type	Sample Type	Diurnal Measurements	Flow Measurements
M045	18-MER	84.7	U/S Hooksett 1	mainstem impoundment	lateral composite	X	
T046	00G-SNK	83.1	Suncook River	tributary	grab	X	X
M047	17-MER	82.7	U/S Suncook WWTF	mainstem riverine	lateral composite	X	
M048	16J-MER	82.2	D/S Suncook WWTF 1	mainstem riverine	lateral composite	X	
M049	16E-MER	81.8	U/S Hooksett 2, D/S Suncook WWTF 2	mainstem impoundment	lateral composite	X	
M050	16-MER	80.7	D/S Hooksett Dam	mainstem impoundment	grab		
M051	15J-MER	79.2	U/S Hooksett WWTF	mainstem impoundment	grab		
M052	15E-MER	78.7	D/S Hooksett WWTF 1	mainstem impoundment	lateral composite		
M053	14X-MER	77.6	D/S Hooksett WWTF 2, U/S Amoskeag 1	mainstem impoundment	grab	X	
M054	14B-MER	73.4	U/S Amoskeag 2	mainstem impoundment	lateral composite	X	
M055	12-MER	71.9	D/S Amoskeag	mainstem riverine	grab	X	
T056	03-PQG	71.3	Picataquog River	tributary	grab	X	
M057	09-MER	69.1	U/S Manchester WWTF	mainstem riverine	grab		
M058	08-MER	68.0	D/S Manchester WWTF 1	mainstem riverine	lateral composite	X	
T059	01E-COH	67.7	Cohas Brook	tributary	grab		X
M060	07AX-MER	67.5	D/S Manchester WWTF 2	mainstem riverine	grab		
M061	07A-MER	65.6	U/S Derry WWTF	mainstem riverine	grab		
M062	06K-MER	63.8	D/S Derry WWTF 1	mainstem riverine	lateral composite	X	
M063	06D-MER	63.1	D/S Derry WWTF 2	mainstem riverine	grab		
T064	01-SHG	62.3	Souhegan River	tributary	grab	X	
M065	04AM-MER	59.0	U/S Merrimack WWTF	mainstem riverine	grab		
M066	04AJ-MER	57.5	D/S Merrimack WWTF 1	mainstem riverine	lateral composite	X	
M067	04AF-MER	56.5	D/S Merrimack WWTF 2	mainstem riverine	grab		
T068	01P-NSH	54.6	Nashua River	tributary	grab		X
T069	00-SMN	53.3	Salmon Brook	tributary	grab		X
M070	02M-MER	53.0	U/S Nashua WWTF	mainstem riverine	grab		
M071	02K-MER	51.6	D/S Nashua WWTF 1	mainstem riverine	lateral composite	X	
M072	01X-MER	51.5	D/S Nashua WWTF 2	mainstem riverine	grab		
Lincoln WWTP	NH0100706	169.8	WWTP	WWTP effluent	grab		
Woodstock WWTP	NH0100293	169.3	WWTP	WWTP effluent	24-hr composite		
Plymouth WWTP	NH0100242	146.5	WWTP	WWTP effluent	24-hr composite		
Bristol WWTP	NHG580021	132.0	WWTP	WWTP effluent	24-hr composite		
Franklin/Winnipesaukee WWTP	NH0100960	114.0	WWTP	WWTP effluent	24-hr composite		
Merrimack Co. WWTP	NHG580935	110.0	WWTP	WWTP effluent	24-hr composite		
Penacook WWTP	NH0100331	99.5	WWTP	WWTP effluent	24-hr composite		
Hall St WWTP	NH0100901	89.0	WWTP	WWTP effluent	24-hr composite		
Suncook/Allenstown WWTP	NHG580714	82.5	WWTP	WWTP effluent	24-hr composite		
Hooksett WWTP	NH0100129	79.0	WWTP	WWTP effluent	24-hr composite		
Manchester WWTP	NH0100447	68.5	WWTP	WWTP effluent	24-hr composite		
Derry WWTP	NH0100056	64.5	WWTP	WWTP effluent	grab		
Merrimack WWTP	NH0100161	58.5	WWTP	WWTP effluent	24-hr composite		
Nashua WWTP	NH0100170	52.5	WWTP	WWTP effluent	24-hr composite		

Table 4-2: High Flow Sampling Stations

Station ID	NHDES ID	River Mile (from Newburyport, MA)	Location	Station Type	Sample Type	Flow Measurements
M001	24C-PMI	169.9	Headwaters	mainstem riverine	grab	
T002	03-EBP	169.8	U/S Lincoln WWTF	tributary	grab	
T003	01-EBP	169.7	D/S Lincoln WWTF 1	tributary	grab	
T004	00F-EBP	169.5	D/S Lincoln WWTF 2	tributary	grab	
M006	23-PMI	169.2	D/S Woodstock WWTF1	mainstem riverine	grab	
M008	21P-PMI	165.3	Woodstock Gage	mainstem riverine	grab	
M009	19-PMI	154.1	Campton	mainstem riverine	grab	
T010	01-MAD	153.2	Mad River	tributary	grab	
T011	01-BKR	147.2	Baker River	tributary	grab	
M012	14X-PMI	146.9	U/S Plymouth Village WWTF	mainstem riverine	grab	
M013	14J-PMI	146.4	D/S Plymouth Village WWTF 1	mainstem riverine	grab	
T015	00E-SQM	141.0	Squam River	tributary	grab	X
M017	08J-PMI	134.5	U/S Ayers Island 2	mainstem impoundment	grab	
M018	07R-PMI	131.3	D/S Ayers Island, U/S Bristol WWTF	mainstem riverine	grab	
M020	07-PMI	130.6	D/S Bristol WWTF 2	mainstem riverine	grab	
T021	01-NFD	130.4	Newfound River	tributary	grab	
T022	00P-SMT	127.9	Smith River	tributary	grab	
M023	04-PMI	122.0	U/S Franklin Falls 1	mainstem impoundment	grab	
M024	02-PMI	118.7	D/S Franklin Falls, U/S Eastman Falls 1	mainstem impoundment	grab	
M026	01D-PMI	117.1	D/S Eastman Falls	mainstem riverine	grab	
T027	01-CPB	117.0	Chance Pond Brook	tributary	grab	X
T028	01-WIN	116.2	Winnipesaukee River	tributary	grab	
M030	32-MER	113.6	D/S Winnipesaukee WWTF 1	mainstem riverine	grab	
M032	31A-MER	110.6	U/S Merrimack County WWTF	mainstem riverine	grab	
M033	30X-MER	109.8	D/S Merrimack County WWTF 1	mainstem riverine	grab	
T035	01G-CTC	101.0	Contoocook River	tributary	grab	
M036	28A-MER	100.9	U/S Penacook WWTF	mainstem riverine	grab	
M037	27X-MER	98.9	D/S Penacook WWTF 1	mainstem riverine	grab	
M039	26-MER	94.5	U/S Concord	mainstem impoundment	grab	
M041	22-MER	88.7	D/S Hall Street WWTF 1, U/S Garvins Falls 1	mainstem impoundment	grab	
T044	01-SCK	86.0	Soucook River	tributary	grab	
M045	18-MER	84.7	U/S Hooksett 1	mainstem impoundment	grab	
T046	00G-SNK	83.1	Suncook River	tributary	grab	
M048	16J-MER	82.2	D/S Suncook WWTF 1	mainstem riverine	grab	
M051	15J-MER	79.2	U/S Hooksett WWTF	mainstem impoundment	grab	
M052	15E-MER	78.7	D/S Hooksett WWTF 1	mainstem impoundment	grab	
M054	14B-MER	73.4	U/S Amoskeag 2	mainstem impoundment	grab	
M055	12-MER	71.9	D/S Amoskeag	mainstem riverine	grab	
T056	03-PQG	71.3	Picataquog River	tributary	grab	
M058	08-MER	68.0	D/S Manchester WWTF 1	mainstem riverine	grab	
T059	01E-COH	67.7	Cohas Brook	tributary	grab	
M061	07A-MER	65.6	U/S Derry WWTF	mainstem riverine	grab	

Table 4-2: High Flow Sampling Stations (continued)

Station ID	NHDES ID	River Mile (from Newburyport, MA)	Location	Station Type	Sample Type	Flow Measurements
M062	06K-MER	63.8	D/S Derry WWTF 1	mainstem riverine	grab	
T064	01-SHG	62.3	Souhegan River	tributary	grab	
M065	04AM-MER	59.0	U/S Merrimack WWTF	mainstem riverine	grab	
M066	04AJ-MER	57.5	D/S Merrimack WWTF 1	mainstem riverine	grab	
T068	01P-NSH	54.6	Nashua River	tributary	grab	
T069	00-SMN	53.3	Salmon Brook	tributary	grab	X
M070	02M-MER	53.0	U/S Nashua WWTF	mainstem riverine	grab	
M071	02K-MER	51.6	D/S Nashua WWTF 1	mainstem riverine	grab	
Lincoln WWTP	NH0100706	169.8	WWTP	WWTP effluent	24-hr composite	
Woodstock WWTP	NH0100293	169.3	WWTP	WWTP effluent	24-hr composite	
Plymouth WWTP	NH0100242	146.5	WWTP	WWTP effluent	24-hr composite	
Bristol WWTP	NHG580021	132.0	WWTP	WWTP effluent	24-hr composite	
Franklin/Winnipesaukee WWTP	NH0100960	114.0	WWTP	WWTP effluent	24-hr composite	
Merrimack Co. WWTP	NHG580935	110.0	WWTP	WWTP effluent	24-hr composite	
Penacook WWTP	NH0100331	99.5	WWTP	WWTP effluent	24-hr composite	
Hall St WWTP	NH0100901	89.0	WWTP	WWTP effluent	24-hr composite	
Suncook/Allenstown WWTP	NHG580714	82.5	WWTP	WWTP effluent	24-hr composite	
Hooksett WWTP	NH0100129	79.0	WWTP	WWTP effluent	24-hr composite	
Manchester WWTP	NH0100447	68.5	WWTP	WWTP effluent	24-hr composite	
Derry WWTP	NH0100056	64.5	WWTP	WWTP effluent	24-hr composite	
Merrimack WWTP	NH0100161	58.5	WWTP	WWTP effluent	24-hr composite	
Nashua WWTP	NH0100170	52.5	WWTP	WWTP effluent	24-hr composite	

4.1 Low Flow Event #1

The first low flow water quality survey was conducted on July 27, 2010. Field crews collected samples and field readings from 5:00am to approximately 8:00pm. Sample runners transported bacteria samples from the sampling teams to the EPA New England Regional Laboratory (NERL) for *E. coli* analysis throughout the day in order to meet the six hour hold time for those samples. All other samples were transported to the School for Marine Science and Technology (SMAST) at UMASS Dartmouth at the conclusion of the day of sampling.

QA/QC samples were collected at five locations to achieve >5% frequency (or 5 out of 86 samples), consisting of field blanks, field duplicates, and field equipment blanks. Table 4-3 lists the sample times and analyses for each of the sample stations and WWTP effluent composites.

Table 4-3: Low Flow Event #1 Sampling Details

Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	$CBOD_5$	$CBOD_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
M001	24C-PMI	Headwaters	mainstem riverine	grab	9:30 AM	X	X	X		X	X	X			
T002	03-EBP	U/S Lincoln WWTF	tributary	grab	6:20 PM	X	X	X		X	X	X			
T003	01-EBP	D/S Lincoln WWTF 1	tributary	grab	5:30 PM	X	X	X	X	X	X	X			
T004	00F-EBP	D/S Lincoln WWTF 2	tributary	grab	10:50 AM	X	X	X		X	X	X	X	X	X
M005	23D-PMI	U/S Woodstock WWTF	mainstem riverine	grab	1:05 PM	X	X	X		X	X				
M006	23-PMI	D/S Woodstock WWTF1	mainstem riverine	lateral composite	4:55 PM	X	X	X		X	X	X			
M007	22M-PMI	D/S Woodstock WWTF 2	mainstem riverine	grab	2:04 PM	X	X	X		X	X				
M008	21P-PMI	Woodstock Gage	mainstem riverine	grab	3:05 PM	X	X	X		X	X				
M009	19-PMI	Campton	mainstem riverine	grab	1:05 PM	X	X	X		X	X				
T010	01-MAD	Mad River	tributary	grab	12:15 PM	X	X	X		X	X	X			
T011	01-BKR	Baker River	tributary	grab	6:00 PM	X	X	X		X	X	X			
M012	14X-PMI	U/S Plymouth Village WWTF	mainstem riverine	grab	2:50 PM	X	X	X		X	X				
M013	14J-PMI	D/S Plymouth Village WWTF 1	mainstem riverine	lateral composite	3:55 PM	X	X	X		X	X	X			
M014	14-PMI	D/S Plymouth Village WWTF 2	mainstem riverine	grab	4:30 PM	X	X	X		X	X				
T015	00E-SQM	Squam River	tributary	grab	10:53 AM	X	X	X		X	X	X			
M016	09J-PMI	U/S Ayers Island 1	mainstem impoundment	grab	7:34 PM	X	X	X		X	X	X	X		
M017	08J-PMI	U/S Ayers Island 2	mainstem impoundment	grab	6:43 PM	X	X	X		X	X	X			X
M018	07R-PMI	D/S Ayers Island, U/S Bristol WWTF	mainstem riverine	grab	8:15 AM	X	X	X		X	X	X			
M019	07K-PMI	D/S Bristol WWTF 1	mainstem riverine	lateral composite	7:30 PM	X	X	X		X	X	X			
M020	07-PMI	D/S Bristol WWTF 2	mainstem riverine	grab	11:20 AM	X	X	X		X	X	X			
T021	01-NFD	Newfound River	tributary	grab	8:40 PM	X	X	X		X	X				
T022	00P-SMT	Smith River	tributary	grab	8:20 PM	X	X	X		X	X				
M023	04-PMI	U/S Franklin Falls 1	mainstem impoundment	lateral composite	5:20 PM	X	X	X		X	X	X			
M024	02-PMI	D/S Franklin Falls, U/S Eastman Falls 1	mainstem impoundment	lateral composite	8:30 AM	X	X	X		X	X	X			
M025	01K-PMI	U/S Eastman Falls 2	mainstem impoundment	lateral composite	3:36 PM	X	X	X		X	X	X			
M026	01D-PMI	D/S Eastman Falls	mainstem riverine	grab	1:15 PM	X	X	X		X	X	X		X	
T027	01-CPB	Chance Pond Brook	tributary	grab	2:35 PM	X	X	X		X	X				
T028	01-WIN	Winnipesaukee River	tributary	grab	4:40 PM	X	X	X		X	X				
M029	34-MER	U/S Winnipesaukee WWTF	mainstem riverine	grab	12:12 PM	X	X	X		X	X	X			
M030	32-MER	D/S Winnipesaukee WWTF 1	mainstem riverine	lateral composite	3:00 PM	X	X	X	X	X	X				X
M031	31K-MER	D/S Winnipesaukee WWTF 2	mainstem riverine	lateral composite	1:56 PM	X	X	X		X	X		X	X	
M032	31A-MER	U/S Merrimack County WWTF	mainstem riverine	grab	9:25 AM	X	X	X		X	X	X			
M033	30X-MER	D/S Merrimack County WWTF 1	mainstem riverine	lateral composite	5:35 PM	X	X	X	X	X	X				
M034	30J-MER	D/S Merrimack County WWTF 2	mainstem riverine	lateral composite	8:20 AM	X	X	X		X	X				
T035	01G-CTC	Contoocook River	tributary	grab	3:42 PM	X	X	X		X	X				
M036	28A-MER	U/S Penacook WWTF	mainstem riverine	lateral composite	2:10 PM	X		X		X	X			X	

Table 4-3: Low Flow Event #1 Sampling Details (continued)

Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	$CBOD_5$	$CBOD_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
M037	27X-MER	D/S Penacook WWTF 1	mainstem riverine	lateral composite	3:17 PM	X		X		X	X				
M038	27-MER	D/S Penacook WWTF 2	mainstem riverine	grab	10:46 AM	X	X	X		X	X	X			
M039	26-MER	U/S Concord	mainstem impoundment	grab	11:00 AM	X		X		X	X	X			
M040	22X-MER	U/S Hall Street WWTF	mainstem impoundment	lateral composite	12:00 PM	X		X		X	X	X			
M041	22-MER	D/S Hall Street WWTF 1, U/S Garvins Falls 1	mainstem impoundment	lateral composite	6:55 PM	X	X	X	X	X	X	X	X		
M042	20-MER	D/S Hall Street WWTF 2, U/S Garvins Falls	mainstem impoundment	grab	6:25 PM	X		X		X	X	X			X
M043	19-MER	D/S Garvins Falls	mainstem riverine	grab	11:55 AM	X	X	X		X	X				
T044	01-SCK	Soucook River	tributary	grab	12:35 PM	X	X	X		X	X				
M045	18-MER	U/S Hooksett 1	mainstem impoundment	lateral composite	2:16 PM	X	X	X		X	X	X			
T046	00G-SNK	Suncook River	tributary	grab	2:44 PM	X	X	X		X	X	X			
M047	17-MER	U/S Suncook WWTF	mainstem riverine	lateral composite	3:10 PM	X	X	X		X	X	X			
M048	16J-MER	D/S Suncook WWTF 1	mainstem riverine	lateral composite	3:40 PM	X	X	X	X	X	X	X			
M049	16E-MER	U/S Hooksett 2, D/S Suncook WWTF 2	mainstem impoundment	lateral composite	4:10 PM	X	X	X		X	X	X			
M050	16-MER	D/S Hooksett Dam	mainstem impoundment	grab	10:30 AM	X	X	X		X	X				
M051	15J-MER	U/S Hooksett WWTF	mainstem impoundment	grab	9:48 AM	X	X	X		X	X	X			
M052	15E-MER	D/S Hooksett WWTF 1	mainstem impoundment	lateral composite	8:13 AM	X	X	X		X	X	X			
M053	14X-MER	D/S Hooksett WWTF 2, U/S Amoskeag 1	mainstem impoundment	grab	5:45 PM	X	X	X		X	X	X			
M054	14B-MER	U/S Amoskeag 2	mainstem impoundment	lateral composite	5:22 PM	X	X	X		X	X	X			
M055	12-MER	D/S Amoskeag	mainstem riverine	grab	5:30 PM	X	X	X		X	X				
T056	03-PQG	Picataquog River	tributary	grab	6:35 PM	X	X	X		X	X				
M057	09-MER	U/S Manchester WWTF	mainstem riverine	grab	8:15 PM	X	X	X		X	X				
M058	08-MER	D/S Manchester WWTF 1	mainstem riverine	lateral composite	5:45 PM	X	X	X	X	X	X				
T059	01E-COH	Cohas Brook	tributary	grab	5:10 PM	X	X	X		X	X				
M060	07AX-MER	D/S Manchester WWTF 2	mainstem riverine	grab	4:15 PM	X	X	X		X	X				
M061	07A-MER	U/S Derry WWTF	mainstem riverine	grab	2:00 PM	X	X	X		X	X	X			
M062	06K-MER	D/S Derry WWTF 1	mainstem riverine	lateral composite	7:34 PM	X	X	X		X	X	X			
M063	06D-MER	D/S Derry WWTF 2	mainstem riverine	grab	12:30 PM	X	X	X		X	X	X			
T064	01-SHG	Souhegan River	tributary	grab	8:20 PM	X	X	X		X	X				
M065	04AM-MER	U/S Merrimack WWTF	mainstem riverine	grab	9:00 AM	X	X	X		X	X	X			
M066	04AJ-MER	D/S Merrimack WWTF 1	mainstem riverine	lateral composite	4:35 PM	X	X	X	X	X	X	X			
M067	04AF-MER	D/S Merrimack WWTF 2	mainstem riverine	grab	10:42 AM	X	X	X		X	X				
T068	01P-NSH	Nashua River	tributary	grab	12:00 PM	X	X	X		X	X				
T069	00-SMN	Salmon Brook	tributary	grab	12:35 PM	X	X	X		X	X				
M070	02M-MER	U/S Nashua WWTF	mainstem riverine	grab	1:10 PM	X	X	X		X	X				
M071	02K-MER	D/S Nashua WWTF 1	mainstem riverine	lateral composite	2:30 PM	X	X	X	X	X	X	X			
M072	01X-MER	D/S Nashua WWTF 2	mainstem riverine	grab	1:50 PM	X	X	X		X	X		X	X	X

Table 4-3: Low Flow Event #1 Sampling Details (continued)

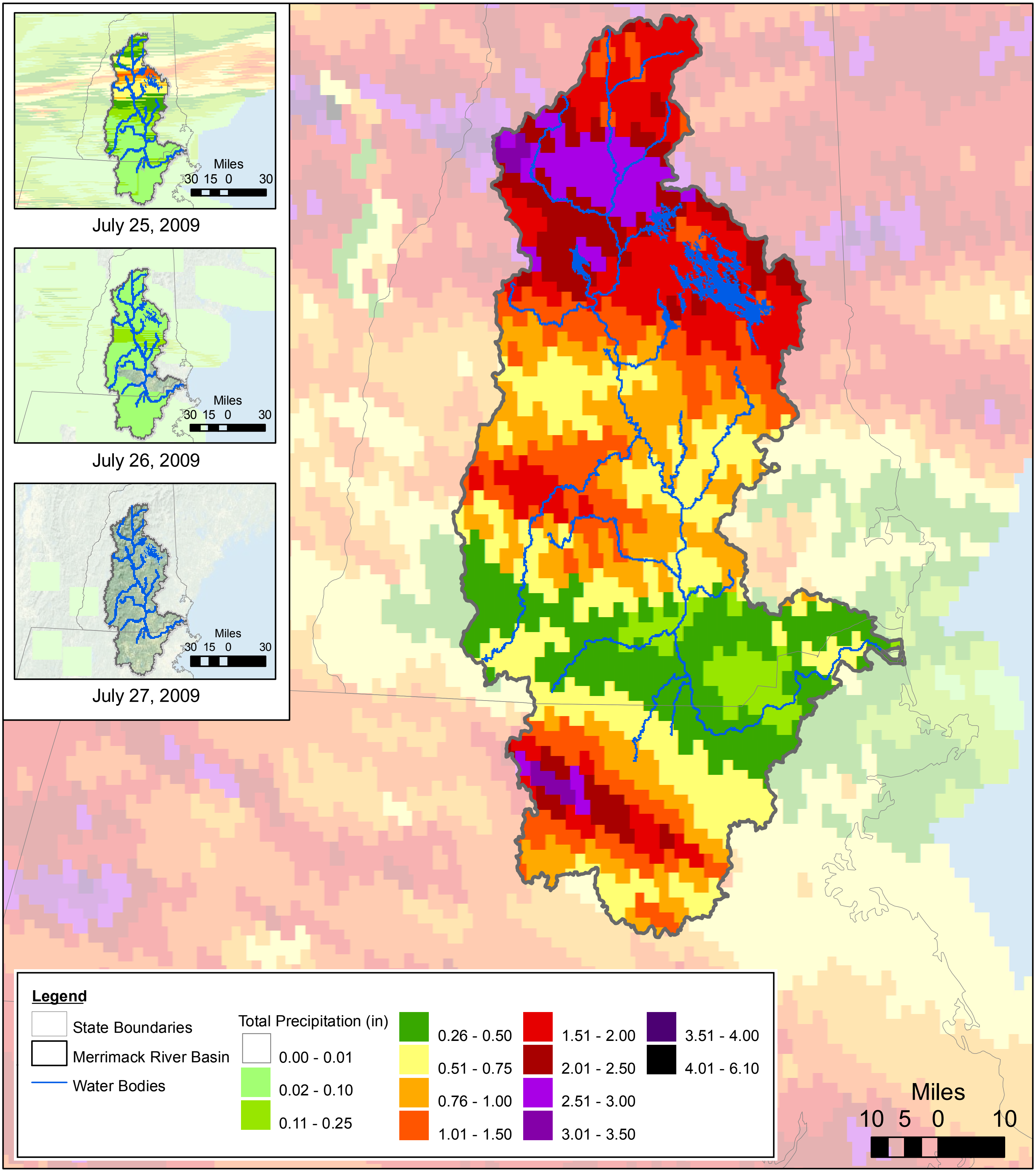
Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	$CBOD_5$	$CBOD_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
Lincoln WWTP	NH0100706	WWTP	WWTP effluent	grab	9:00 AM	X		X	X	X					
Woodstock WWTP	NH0100293	WWTP	WWTP effluent	24-hr composite	9:00 AM	X		X	X	X					
Plymouth WWTP	NH0100242	WWTP	WWTP effluent	24-hr composite	7:30 AM	X		X	X	X					
Bristol WWTP	NHG580021	WWTP	WWTP effluent	24-hr composite	7:00 AM	X		X	X	X					
Franklin/Winnipesaukee WWTP	NH0100960	WWTP	WWTP effluent	24-hr composite	7:15 AM	X		X	X	X					
Merrimack Co. WWTP	NHG580935	WWTP	WWTP effluent	24-hr composite	8:40 AM	X		X	X	X					
Penacook WWTP	NH0100331	WWTP	WWTP effluent	24-hr composite	8:00 AM	X		X	X	X					
Hall St WWTP	NH0100901	WWTP	WWTP effluent	24-hr composite	8:15 AM	X		X	X	X					
Suncook/Allenstown WWTP	NHG580714	WWTP	WWTP effluent	24-hr composite	9:00 AM	X		X	X	X					
Hooksett WWTP	NH0100129	WWTP	WWTP effluent	24-hr composite	8:15 AM	X		X	X	X					
Manchester WWTP	NH0100447	WWTP	WWTP effluent	24-hr composite	12:00 AM	X		X	X	X					
Derry WWTP	NH0100056	WWTP	WWTP effluent	grab	8:00 AM	X		X	X	X					
Merrimack WWTP	NH0100161	WWTP	WWTP effluent	24-hr composite	8:00 AM	X		X	X	X					
Nashua WWTP	NH0100170	WWTP	WWTP effluent	24-hr composite	7:00 AM	X		X	X	X					

4.1.1 Precipitation and Streamflow Conditions

The precipitation totals for four locations within the watershed are shown in Table 4-4, and the spatial distribution of the rainfall for the three days preceding the event are shown along with the 7-day total in Figure 4-2. The upper watershed received more rain in the 7 days preceding the first low flow sampling event than the lower watershed. Two rain events occurred in the upper watershed in the seven days before the low flow event.. The very dry antecedent conditions throughout the watershed minimized the impact of these rain events on streamflow. The hydrograph receded quickly back to average summer flow levels in the upper watershed and did not cause the lower watershed gages to increase above average summer flow levels. See Figure 4-3.

Table 4-4: Precipitation Totals for Low Flow Event #1

	Total Daily Precipitation (inches)			
	Location			
	Woodstock, NH	**Franklin, NH**	**Concord, NH**	**Manchester, NH**
	Gage ID: MNHWOD	Gage ID: KNHNORTH4	Gage ID: KNHCONCO5	Gage ID: 14710
Date	Source: NHDOT	Source: Franklin Falls Dam	Source: NOAA	Source: NOAA
7/20/2010	0.00	0.00	0.01	0.00
7/21/2010	3.85	0.33	0.01	0.00
7/22/2010	0.00	0.01	0.00	0.00
7/23/2010	0.00	0.02	0.00	0.22
7/24/2010	0.00	0.00	0.00	0.00
7/25/2010	0.65	0.32	0.00	0.00
7/26/2010	0.00	0.00	0.00	0.00
7/27/2010	0.00	0.00	0.00	0.00
7 Day Total	4.5	0.68	0.02	0.22
3 Day Total	0.65	0.32	0.00	0.00



Total Precipitation (in) from July 20, 2009 through July 27, 2009

Merrimack River Basin Precipitation (in)
Low Flow Sampling Event 1
7-Day Total Precipitation July 21 - July 27, 2009

Figure 4-2

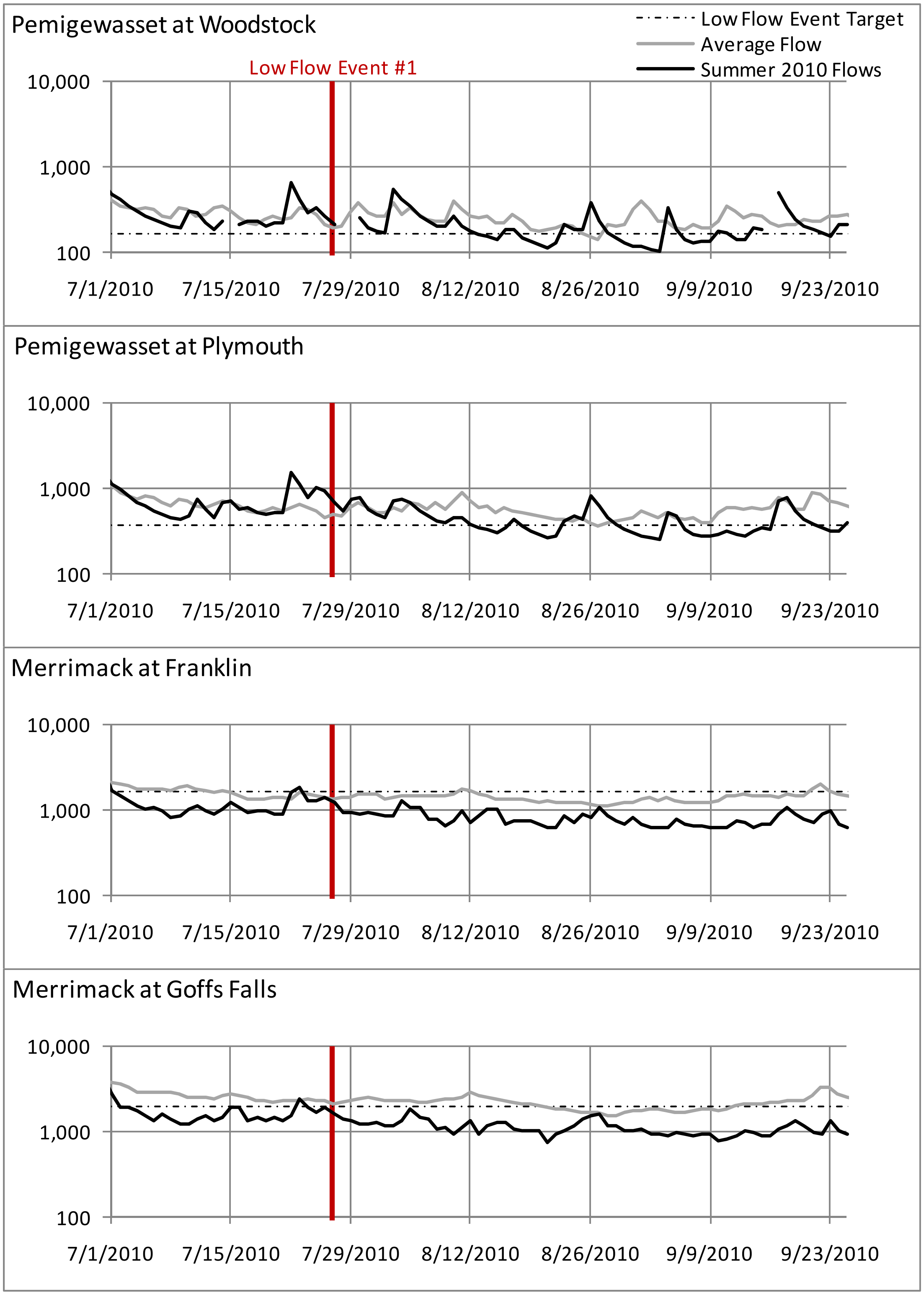
The decision to conduct the first low flow sampling event was made by NHDES and USACE based on data review and interpretation from CDM. Streamflows in the summers of 2008 and 2009 were too high to conduct a low flow event. When flows approached the targets (3x7Q10) at the four mainstem tracking gages after a very warm and dry June and July, the project team decided that conditions were sufficient to conduct the low flow sampling. Table 4-5 shows the average flows on the day of the first low flow event with comparisons to the target flow and the 7Q10 value for each gage. Target flows were met at the two Merrimack gages (Franklin and Goffs Falls) and were above but approaching targets at the two Pemigewasset gages (Woodstock and Plymouth).

Table 4-5: Daily Average Flow at Mainstem USGS Gages for Low Flow Event #1

Gage	Daily Average Flow 7/27/2010, cfs	7Q10 Flow, cfs	Low Flow Target (3x7Q10), cfs	Daily Average Flow Compared to 7Q10
Pemigewasset at Woodstock	214	56	168	3.8 x 7Q10
Pemigewasset at Plymouth	660	121	364	5.5 x 7Q10
Merrimack at Franklin	1,200	551	1,653	2.2 x 7Q10
Merrimack at Goffs Falls	1,600	644	1,932	2.5 x 7Q10

Figure 4-3 shows the summer 2010 streamflow time series at each gage and the date when the first low flow event took place. Streamflows were generally below average at all four gages for the month of July, except for a storm event that caused flows to rise in the northern watershed on July 22. Another rain event that resulted in approximately 1.0 inches of rain in the upper watershed occurred a few days before the sampling event on the night of July 24, but flows did not respond dramatically, and therefore did not cause postponement of the sampling event. The sampling event occurred on the receding limbs of the hydrographs as flows were near or below average for late July.

Figure 4-3: Streamflow Conditions for Summer 2010, cfs



Flows at each of the major tributaries were calculated in one of two ways: 1) using basin area to transpose upstream USGS gage flows to the point of confluence with the mainstem, or 2) field measurements of stream velocity and cross sectional area collected on the day of sampling. Table 4-6 shows the calculated flows at each tributary for July 27, 2010. The Contoocook River gaging station is a significant distance from the confluence, and there are hydraulic control structures between the flow measurements point and the confluence. While the ratio of flow to drainage area (cfs per square mile, cfsm) is lower for this tributary than others in the watershed, the ratio is comparable to the Warner River, a tributary to the Contoocook which is gaged near its confluence, and other Merrimack River tributaries in that region (Piscataquog, Soucook, and Suncook Rivers). The Contoocook drainage area is the largest subbasin within the study area watershed; the Winnipesaukee River contributed the largest volume of flow on the day of the first low flow sampling event.

Table 4-6: Measured and Gaged Tributary Flows During Low Flow Event #1

Location	Station ID	Drainage Area	Flow		Method
		square miles	cfs	mgd	
Winnipesaukee River	T028	485.8	297.0	192.0	Gage Transposition
Nashua River	T068	416.06	220.0	142.2	Flow Meter
East Branch Pemigewasset River	T004	116.74	162.0	104.7	Gage Transposition
Baker River	T011	213.41	153.7	99.36	Gage Transposition
Contoocook River	T035	764.03	102.0	65.92	Gage Transposition
Mad River	T010	62.17	86.50	55.91	Flow Meter
Newfound River	T021	98.67	66.41	42.93	Flow Meter
Squam River	T015	65.18	63.38	40.97	Flow Meter
Souhegan River	T064	219.64	38.53	24.90	Gage Transposition
Smith River	T022	87.84	32.75	21.17	Gage Transposition
Piscataquog River	T056	217.52	29.07	18.79	Gage Transposition
Suncook River	T046	255.88	25.57	16.53	Flow Meter
Salmon Brook	T069	30.74	11.76	7.60	Flow Meter
Soucook River	T044	91.38	11.16	7.21	Gage Transposition
Chance Pond Brook	T027	18.5	1.79	1.16	Flow Meter
Cohas Brook	T059	69.92	1.41	0.91	Flow Meter

Average flows exiting the WWTPs were taken from Jul 2010 Monthly Operating Reports for each of the 14 plants. Table 4-7 below lists the average flow for the day of Low Flow Event #1 in cubic feet per second and million gallons per day.

Table 4-7: Average WWTP Discharges During Low Flow Event #1

WWTP	Average Flow - July 27, 2010	
	cfs	Mgd
Manchester WWTP	16.40	10.60
Nashua WWTP	12.53	8.10
Franklin/Winnipesaukee WWTP	6.38	4.12
Hall St WWTP	6.00	3.88
Merrimack WWTP	2.79	1.80
Derry WWTP	1.44	0.93
Lincoln WWTP	0.88	0.57
Hooksett WWTP	0.75	0.49
Suncook/Allenstown WWTP	0.74	0.48
Penacook WWTP	0.40	0.26
Plymouth WWTP	0.37	0.24
Bristol WWTP	0.28	0.18
Woodstock WWTP	0.19	0.13
Merrimack Co. WWTP	0.07	0.05

Source: MOR Reports for July 2010

4.1.2 QAPP and Field Sampling Plan Deviations

The EPA NERL provided laboratory services to analyze the bacteria samples. Volume of samples and timing required that the bacteria sampling plan be reduced so that only *E. coli* analysis was performed and that samples not be brought to the laboratory after 2:30 pm. Table 4-8 lists the sampling stations that were intended to have bacteria analyses, but were not transported to NERL before the cut-off. Water samples from 50 of the 72 sampling stations were received by the lab and analyzed for *E. coli.* Table 4-9 lists the bacteria samples that, according to the NERL lab report, missed the 6 hour hold time. The laboratory analysis times indicate that no bacteria sample missed the hold time by more than 1.5 hours (7.5 hours between sampling and analysis).

Table 4-8: Missed Bacteria Samples for Low Flow Event #1

Station	NHDES ID	Location
M005	23D-PMI	U/S Woodstock WWTF
M007	22M-PMI	D/S Woodstock WWTF 2
M008	21P-PMI	Woodstock Gage
M009	19-PMI	Campton
M012	14X-PMI	U/S Plymouth Village WWTF
M014	14-PMI	D/S Plymouth Village WWTF 2
T021	01-NFD	Newfound River
T022	00P-SMT	Smith River
M026	01D-PMI	D/S Eastman Falls
T027	01-CPB	Chance Pond Brook
M031	31K-MER	D/S Winnipesaukee WWTF 2
M036	28A-MER	U/S Penacook WWTF
M043	19-MER	D/S Garvins Falls
T044	01-SCK	Soucook River
M057	09-MER	U/S Manchester WWTF
T059	01E-COH	Cohas Brook
M060	07AX-MER	D/S Manchester WWTF 2
M067	04AF-MER	D/S Merrimack WWTF 2
T068	01P-NSH	Nashua River
T069	00-SMN	Salmon Brook
M070	02M-MER	U/S Nashua WWTF
M072	01X-MER	D/S Nashua WWTF 2

Table 4-9: Missed Bacteria Hold Times for Low Flow Event #1

Station	NHDES ID	Location
M001	24C-PMI	Headwaters
T002	03-EBP	U/S Lincoln WWTF
M016	09J-PMI	U/S Ayers Island 1
M017	08J-PMI	U/S Ayers Island 2
M024	02-PMI	D/S Franklin Falls, U/S Eastman Falls 1
T028	01-WIN	Winnipesaukee River
M032	31A-MER	U/S Merrimack County WWTF
M045	18-MER	U/S Hooksett 1
T046	00G-SNK	Suncook River
M047	17-MER	U/S Suncook WWTF
M049	16E-MER	U/S Hooksett 2, D/S Suncook WWTF 2
T064	01-SHG	Souhegan River
M066	04AJ-MER	D/S Merrimack WWTF 1

Winker dissolved oxygen samples are collected in glass bottles with stoppers. In the field, possibly due to warm temperatures, a field team had difficulty opening the glass bottles to fill for the Winkler analysis. Table 4-10 lists the Winkler dissolved oxygen samples that were missed due to this issue.

Table 4-10: Missed Winkler Dissolved Oxygen Samples for Low Flow Event #1

Station ID	NHDES ID	Location
M036	28A-MER	U/S Penacook WWTF
M037	27X-MER	D/S Penacook WWTF 1
M039	26-MER	U/S Concord
M040	22X-MER	U/S Hall Street WWTF
M042	20-MER	D/S Hall Street WWTF 2, U/S Garvins Falls

While every effort was made to stay on schedule in order to collect field readings at the diurnal stations between 5:00 and 8:00 am and again between 2:00 and 7:00 pm, unforeseen circumstances resulted in some readings happening outside of these windows. Table 4-11 lists the timing of field dissolved oxygen readings taken outside the preferred timeframes at diurnal stations.

Table 4-11: Diurnal Field Readings Collected Outside Preferred Timeframe

Morning diurnal field readings collected later than 8:00 am		
Station ID	**NHDES ID**	**Time of Field Reading**
M041	22-MER	9:50 AM
M042	20-MER	9:50 AM
M055	12-MER	9:15 AM
M062	06K-MER	9:15 AM
Afternoon diurnal field readings collected later than 7:00 pm		
Station ID	**NHDES ID**	**Time of Field Reading**
M016	09J-PMI	7:34 PM
M019	07K-PMI	7:30 PM
M062	06K-MER	7:34 PM
T064	01-SHG	8:20 PM

4.2 Low Flow Event #2

The second low flow sampling event was conducted on September 21, 2010. Field crews collected samples and field readings from 6:45am to 6:30pm. Sample runners transported bacteria samples from the sampling teams to EPA-NERL for *E. coli* analysis throughout the day in order to meet the six hour hold time for those samples. Samples for chlorophyll-a, TSS, and CBOD were transported to Eastern Analytical Laboratory (EAI, and the remaining samples were transported to SMAST at the conclusion of the day of sampling.

Due to the second low flow event occurring late in the summer season, there was not as many daylight hours to work in and the sampling plan needed to be adjusted to ensure that the most valuable data were collected. Two locations were not sampled: M014 and M063, the second locations downstream of the Plymouth Village and Derry WWTPs. These locations are difficult to access and it was decided that the time needed to collect the samples would likely have prevented sampling teams from completing other, more critical, locations. Also, visiting sites twice to collect diurnal measurements was not possible within the daylight hours on the sampling day, and it was deemed too dangerous for crews to navigate the river in the darkness. The diurnal measurement results of the first low flow sampling event were mixed, and it was decided that the time would be better spent completing the regular sampling and field measurements within the limited daylight hours.

QA/QC samples were collected at five locations to achieve >5% frequency (or 5 out of 84 samples), consisting of field blanks, field duplicates, and field equipment blanks. Table 4-12 lists the sample times and analyses for each of the sample stations and WWTP effluent composites.

Table 4-12: Low Flow Event #2 Sampling Details

Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	$CBOD_5$	$CBOD_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
M001	24C-PMI	Headwaters	mainstem riverine	grab	10:45 AM	X	X	X		X	X		X	X	X
T002	03-EBP	U/S Lincoln WWTF	tributary	grab	9:30 AM	X	X	X		X	X				
T003	01-EBP	D/S Lincoln WWTF 1	tributary	grab	8:15 AM	X	X	X	X	X	X				
T004	00F-EBP	D/S Lincoln WWTF 2	tributary	grab	1:00 PM	X	X	X		X	X				
M005	23D-PMI	U/S Woodstock WWTF	mainstem riverine	grab	2:15 PM	X	X	X		X	X				
M006	23-PMI	D/S Woodstock WWTF1	mainstem riverine	lateral composite	7:10 AM	X	X	X		X	X				
M007	22M-PMI	D/S Woodstock WWTF 2	mainstem riverine	grab	3:00 PM	X	X	X		X	X				
M008	21P-PMI	Woodstock Gage	mainstem riverine	grab	3:50 PM	X	X	X		X	X				
M009	19-PMI	Campton	mainstem riverine	grab	9:35 AM	X	X	X		X	X		X	X	X
T010	01-MAD	Mad River	tributary	grab	10:45 AM	X	X	X		X	X				
T011	01-BKR	Baker River	tributary	grab	12:00 PM	X	X	X		X	X				
M012	14X-PMI	U/S Plymouth Village WWTF	mainstem riverine	grab	1:30 PM	X	X	X		X	X				
M013	14J-PMI	D/S Plymouth Village WWTF 1	mainstem riverine	lateral composite	7:55 AM	X	X	X		X	X				
M014	14-PMI	D/S Plymouth Village WWTF 2	mainstem riverine	no sample											
T015	00E-SQM	Squam River	tributary	grab	3:40 PM	X	X	X		X	X				
M016	09J-PMI	U/S Ayers Island 1	mainstem impoundment	grab	10:15 AM	X	X	X		X	X				
M017	08J-PMI	U/S Ayers Island 2	mainstem impoundment	grab	11:00 AM	X	X	X		X	X				
M018	07R-PMI	D/S Ayers Island, U/S Bristol WWTF	mainstem riverine	grab	8:10 AM	X	X	X		X	X				
M019	07K-PMI	D/S Bristol WWTF 1	mainstem riverine	lateral composite	7:20 AM	X	X	X		X	X				
M020	07-PMI	D/S Bristol WWTF 2	mainstem riverine	grab	9:00 AM	X	X	X		X	X				
T021	01-NFD	Newfound River	tributary	grab	6:31 PM	X	X	X		X	X				
T022	00P-SMT	Smith River	tributary	grab	6:35 PM	X	X	X		X	X				
M023	04-PMI	U/S Franklin Falls 1	mainstem impoundment	lateral composite	12:20 PM	X	X	X		X	X				
M024	02-PMI	D/S Franklin Falls, U/S Eastman Falls 1	mainstem impoundment	lateral composite	2:00 PM	X	X	X		X	X				
M025	01K-PMI	U/S Eastman Falls 2	mainstem impoundment	lateral composite	1:30 PM	X	X	X		X	X				
M026	01D-PMI	D/S Eastman Falls	mainstem riverine	grab	3:00 PM	X	X	X		X	X				
T027	01-CPB	Chance Pond Brook	tributary	grab	5:10 PM	X	X	X		X	X				
T028	01-WIN	Winnipesaukee River	tributary	grab	10:20 AM	X	X	X		X	X		X	X	X
M029	34-MER	U/S Winnipesaukee WWTF	mainstem riverine	grab	11:15 AM	X	X	X		X	X				
M030	32-MER	D/S Winnipesaukee WWTF 1	mainstem riverine	lateral composite	8:00 AM	X	X	X	X	X	X				
M031	31K-MER	D/S Winnipesaukee WWTF 2	mainstem riverine	lateral composite	9:10 AM	X	X	X		X	X				
M032	31A-MER	U/S Merrimack County WWTF	mainstem riverine	grab	1:10 PM	X	X	X		X	X				
M033	30X-MER	D/S Merrimack County WWTF 1	mainstem riverine	lateral composite	7:15 AM	X	X	X	X	X	X				
M034	30J-MER	D/S Merrimack County WWTF 2	mainstem riverine	lateral composite	6:45 AM	X	X	X		X	X				
T035	01G-CTC	Contoocook River	tributary	grab	1:09 PM	X		X		X	X				
M036	28A-MER	U/S Penacook WWTF	mainstem riverine	lateral composite	1:24 PM	X		X		X	X				

Table 4-12: Low Flow Event #1 Sampling Details (continued)

Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	$CBOD_5$	$CBOD_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
M037	27X-MER	D/S Penacook WWTF 1	mainstem riverine	lateral composite	7:04 AM	X		X		X	X				
M038	27-MER	D/S Penacook WWTF 2	mainstem riverine	grab	12:10 PM	X	X	X		X	X				
M039	26-MER	U/S Concord	mainstem impoundment	grab	12:10 PM	X		X		X	X				
M040	22X-MER	U/S Hall Street WWTF	mainstem impoundment	lateral composite	11:45 AM	X		X		X	X				
M041	22-MER	D/S Hall Street WWTF 1, U/S Garvins Falls 1	mainstem impoundment	lateral composite	9:20 AM	X	X	X	X	X	X		X	X	X
M042	20-MER	D/S Hall Street WWTF 2, U/S Garvins Falls	mainstem impoundment	grab	10:30 AM	X		X		X	X				
M043	19-MER	D/S Garvins Falls	mainstem riverine	grab	1:20 PM	X	X	X		X	X				
T044	01-SCK	Soucook River	tributary	grab	12:50 PM	X	X	X		X	X				
M045	18-MER	U/S Hooksett 1	mainstem impoundment	lateral composite	1:50 PM	X	X	X		X	X				
T046	00G-SNK	Suncook River	tributary	grab	3:00 PM	X	X	X		X	X				
M047	17-MER	U/S Suncook WWTF	mainstem riverine	lateral composite	2:35 PM	X	X	X		X	X				
M048	16J-MER	D/S Suncook WWTF 1	mainstem riverine	lateral composite	6:48 AM	X	X	X		X	X				
M049	16E-MER	U/S Hooksett 2, D/S Suncook WWTF 2	mainstem impoundment	lateral composite	3:30 PM	X	X	X		X	X				
M050	16-MER	D/S Hooksett Dam	mainstem impoundment	grab	11:20 AM	X	X	X		X	X				
M051	15J-MER	U/S Hooksett WWTF	mainstem impoundment	grab	10:50 AM	X	X	X		X	X				
M052	15E-MER	D/S Hooksett WWTF 1	mainstem impoundment	lateral composite	8:15 AM	X	X	X		X	X				
M053	14X-MER	D/S Hooksett WWTF 2, U/S Amoskeag 1	mainstem impoundment	grab	10:11 AM	X	X	X		X	X				
M054	14B-MER	U/S Amoskeag 2	mainstem impoundment	lateral composite	9:35 AM	X	X	X		X	X				
M055	12-MER	D/S Amoskeag	mainstem riverine	grab	5:15 PM	X	X	X		X	X				
T056	03-PQG	Picataquog River	tributary	grab	11:20 AM	X	X	X		X	X				
M057	09-MER	U/S Manchester WWTF	mainstem riverine	grab	5:30 PM	X	X	X		X	X				
M058	08-MER	D/S Manchester WWTF 1	mainstem riverine	lateral composite	8:00 AM	X		X		X	X				
T059	01E-COH	Cohas Brook	tributary	grab	8:15 AM	X	X	X		X	X				
M060	07AX-MER	D/S Manchester WWTF 2	mainstem riverine	grab	10:00 AM	X	X	X		X	X				
M061	07A-MER	U/S Derry WWTF	mainstem riverine	grab	12:45 PM	X	X	X		X	X				
M062	06K-MER	D/S Derry WWTF 1	mainstem riverine	lateral composite	6:45 AM	X	X	X		X	X				
M063	06D-MER	D/S Derry WWTF 2	mainstem riverine	no sample											
T064	01-SHG	Souhegan River	tributary	grab	2:15 PM	X	X	X		X	X				
M065	04AM-MER	U/S Merrimack WWTF	mainstem riverine	grab	11:00 AM	X	X	X		X	X		X	X	X
M066	04AJ-MER	D/S Merrimack WWTF 1	mainstem riverine	lateral composite	6:57 AM	X		X	X	X	X				
M067	04AF-MER	D/S Merrimack WWTF 2	mainstem riverine	grab	3:15 PM	X	X	X		X	X				
T068	01P-NSH	Nashua River	tributary	grab	12:45 PM	X	X	X		X	X				
T069	00-SMN	Salmon Brook	tributary	grab	1:45 PM	X	X	X		X	X				
M070	02M-MER	U/S Nashua WWTF	mainstem riverine	grab	2:07 PM	X	X	X		X	X				
M071	02K-MER	D/S Nashua WWTF 1	mainstem riverine	lateral composite	8:00 AM	X	X	X	X	X	X				
M072	01X-MER	D/S Nashua WWTF 2	mainstem riverine	grab	8:50 AM	X	X	X		X	X				

Table 4-12: Low Flow Event #1 Sampling Details (continued)

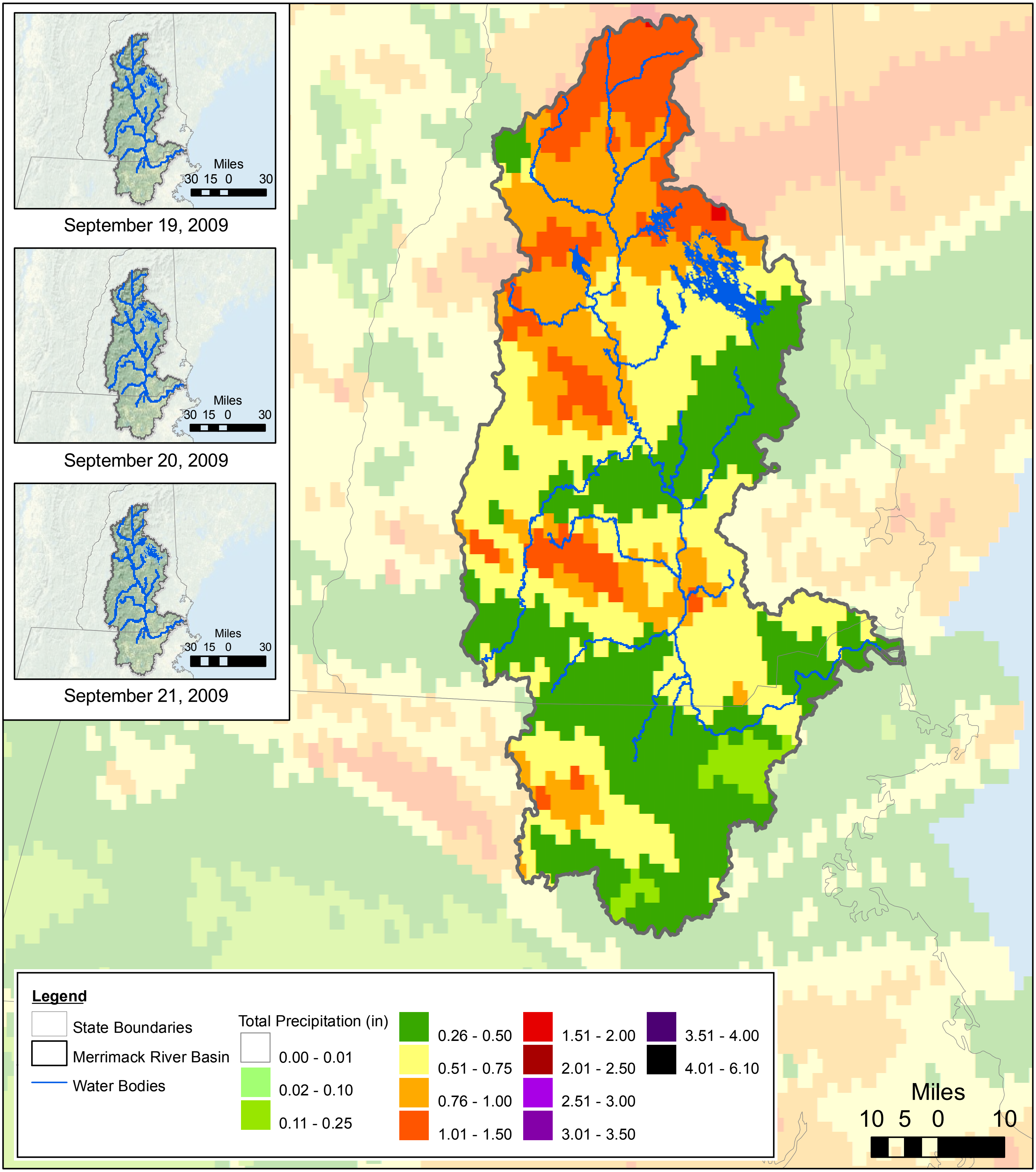
Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	$CBOD_5$	$CBOD_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
Lincoln WWTP	NH0100706	WWTP	WWTP effluent	grab	9:30 AM	X		X	X	X					
Woodstock WWTP	NH0100293	WWTP	WWTP effluent	24-hr composite	10:00 AM	X		X	X	X					
Plymouth WWTP	NH0100242	WWTP	WWTP effluent	24-hr composite	9:00 AM	X		X	X	X					
Bristol WWTP	NHG580021	WWTP	WWTP effluent	24-hr composite	10:45 AM	X		X	X	X					
Franklin/Winnipesaukee WWTP	NH0100960	WWTP	WWTP effluent	24-hr composite	11:15 AM	X		X	X	X					
Merrimack Co. WWTP	NHG580935	WWTP	WWTP effluent	24-hr composite	11:30 AM	X		X	X	X					
Penacook WWTP	NH0100331	WWTP	WWTP effluent	24-hr composite	12:15 PM	X		X	X	X					
Hall St WWTP	NH0100901	WWTP	WWTP effluent	24-hr composite	12:00 PM	X		X	X	X					
Suncook/Allenstown WWTP	NHG580714	WWTP	WWTP effluent	24-hr composite	12:30 PM	X		X	X	X					
Hooksett WWTP	NH0100129	WWTP	WWTP effluent	24-hr composite	1:00 PM	X		X	X	X					
Manchester WWTP	NH0100447	WWTP	WWTP effluent	24-hr composite	2:30 PM	X		X	X	X					
Derry WWTP	NH0100056	WWTP	WWTP effluent	grab	1:00 PM	X		X	X	X					
Merrimack WWTP	NH0100161	WWTP	WWTP effluent	24-hr composite	1:30 PM	X		X	X	X					
Nashua WWTP	NH0100170	WWTP	WWTP effluent	24-hr composite	1:45 PM	X		X	X	X					

4.2.1 Precipitation and Streamflow Conditions

The precipitation totals for four locations within the watershed are shown in Table 4-13, and the spatial distribution of the rainfall for the three days preceding the event are shown along with the 7-day total in Figure 4-4. A rain event occurred in the watershed five days before the sampling event, resulting in almost two inches of precipitation locally in the upper watershed and less than an inch in the lower watershed. Flows prior to the rain event were well below average for September and receded quickly to the low flow event targets. The three days preceding the sampling event had no reported precipitation. See Figure 4-5.

Table 4-13: Precipitation Totals for Low Flow Event #2

Date	Total Daily Precipitation (inches)			
	Location			
	Woodstock, NH	Franklin, NH	Concord, NH	Manchester, NH
	Gage ID: MNHWOD	Gage ID: KNHNORTH4	Gage ID: KNHCONCO5	Gage ID: MNHMCH
	Source: NHDOT	Source: Franklin Falls Dam	Source: NOAA	Source: NHDOT
9/14/2010	0.01	0.01	0.01	0.00
9/15/2010	0.01	0.00	0.00	0.00
9/16/2010	1.88	0.68	0.37	0.10
9/17/2010	0.04	0.04	0.01	0.33
9/18/2010	0.00	0.00	0.00	0.00
9/19/2010	0.00	0.00	0.00	0.00
9/20/2010	0.00	0.00	0.00	0.00
9/21/2010	0.00	0.00	0.00	0.00
7 Day Total	1.94	0.73	0.39	0.43
3 Day Total	0.00	0.00	0.00	0.00



Total Precipitation (in) from September 15, 2009 through September 21, 2009

Merrimack River Basin Precipitation (in)
Low Flow Sampling Event 2
7-Day Total Precipitation September 15 - September 21, 2009

Figure 4-4

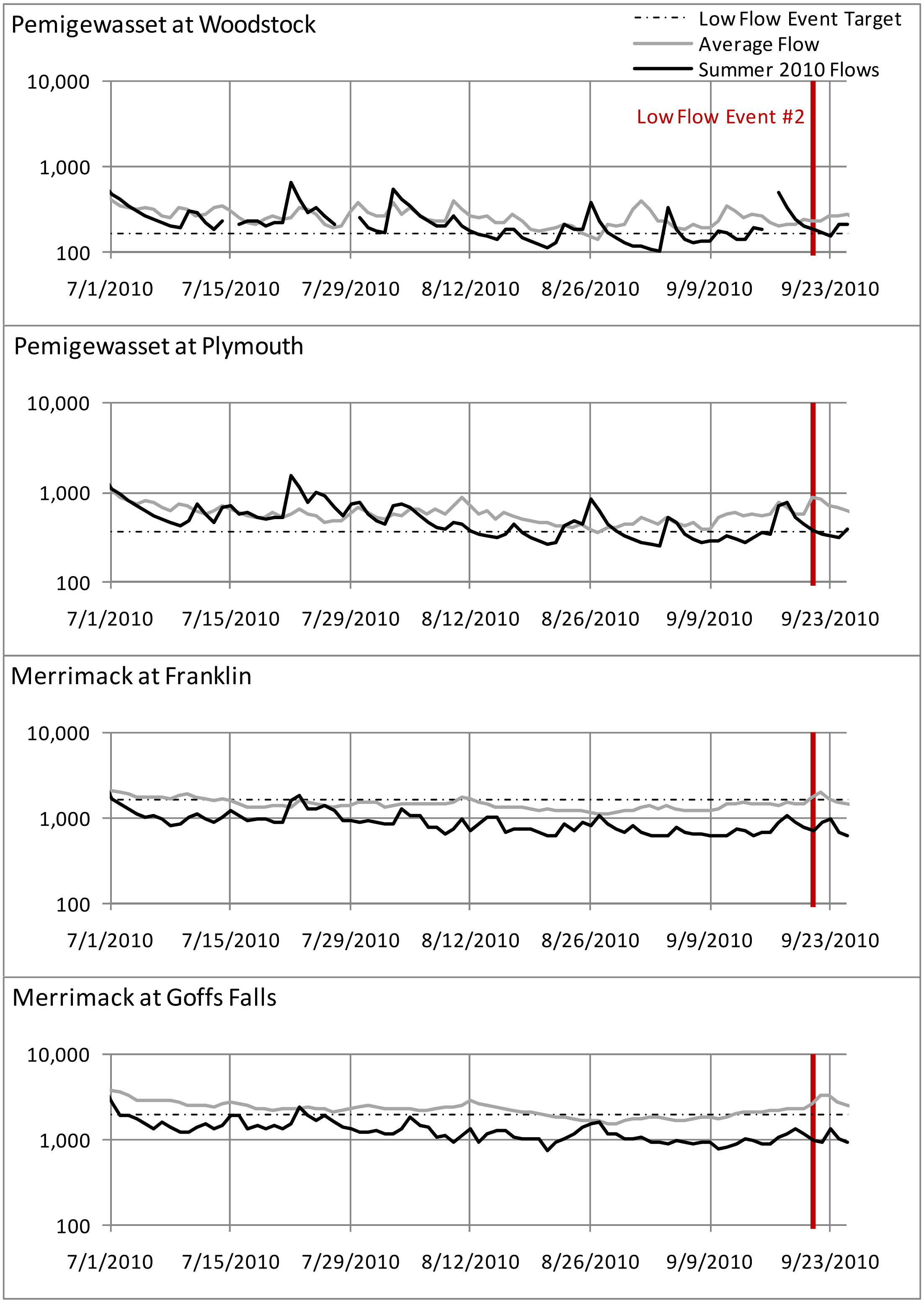
The decision to conduct the second low flow sampling event was made by NHDES and USACE based on data review and interpretation from CDM. Streamflows in the late summer of 2010 continued to be low and the weather relatively dry. While collecting date later in the summer generally results in higher dissolved oxygen readings due to cooler water temperatures, trends related to nutrients and algae should still be apparent. Table 4-14 shows the average flows on the day of the first low flow event with comparisons to the target flow and the 7Q10 value for each gage. Target flows were met at three of the four gages, were very near target flows at the Woodstock gage.

Table 4-14: Daily Average Flow at Mainstem USGS Gages for Low Flow Event #2

Gage	Daily Average Flow 9/21/2010, cfs	7Q10 Flow, cfs	Low Flow Target (3x7Q10), cfs	Daily Average Flow Compared to 7Q10
Pemigewasset at Woodstock	180	56	168	3.2 x 7Q10
Pemigewasset at Plymouth	369	121	364	3.0 x 7Q10
Merrimack at Franklin	719	551	1,653	1.3 x 7Q10
Merrimack at Goffs Falls	978	644	1,932	1.5 x 7Q10

Figure 4-5 shows the summer 2010 streamflow time series at each gage and the date when the second low flow event took place. Flows remained generally low, less than average and near the low flow event targets, for the end of the summer. A few rain events in August caused flows in the upper watershed, which responds more dramatically to precipitation, to increase and recede within a day or two. The second low flow event took place on the receding limb of the hydrographs at all gage locations.

Figure 4-5: Streamflow Conditions for Summer 2010, cfs



Flows at each of the major tributaries were calculated in one of two ways: 1) using basin area to transpose upstream USGS gage flows to the point of confluence with the mainstem, or 2) field measurements of stream velocity and cross sectional area collected on the day of sampling. Table 4-15 shows the calculated flows at each tributary for September 21, 2010. The Contoocook drainage area is the largest subbasin within the study area watershed; the Winnipesaukee River contributed the largest volume of flow on the day of the first low flow sampling event.

Table 4-15: Measured and Gaged Tributary Flows During Low Flow Event #1

Location	Station ID	Drainage Area	Flow		Method
		square miles	cfs	mgd	
Winnipesaukee River	T028	485.8	239.3	154.7	Gage Transposition
East Branch Pemigewasset River	T004	116.7	155.3	100.3	Gage Transposition
Baker River	T011	213.4	56.7	36.7	Gage Transposition
Squam River	T015	65.18	54.3	35.1	Flow Meter
Contoocook River	T035	764.0	51.9	33.5	Gage Transposition
Nashua River	T068	416.1	51.6	33.3	Flow Meter
Newfound River	T021	98.67	37.9	24.5	Flow Meter
Souhegan River	T064	219.6	25.7	16.6	Gage Transposition
Mad River	T010	62.17	23.9	15.5	Flow Meter
Piscataquog River	T056	217.5	10.3	6.7	Gage Transposition
Smith River	T022	87.84	9.2	6.0	Gage Transposition
Soucook River	T044	91.38	6.7	4.3	Gage Transposition
Cohas Brook	T059	69.92	4.5	2.9	Flow Meter
Suncook River	T046	255.9	2.4	1.6	Flow Meter
Salmon Brook	T069	30.74	1.8	1.2	Flow Meter
Chance Pond Brook	T027	18.50	0.5	0.3	Flow Meter

Average flows exiting the WWTPs were taken from September 2010 Monthly Operating Reports for each of the 14 plants. Table 4-16 below lists the average flow for the day of Low Flow Event #2 in cubic feet per second and million gallons per day.

Table 4-16: Average WWTP Discharges During Low Flow Event #2

WWTP	Average Flow – Sept 21, 2010	
	cfs	Mgd
Manchester WWTP	17.1	11.0
Nashua WWTP	11.5	7.4
Hall St WWTP	6.3	4.1
Winnipesaukee WWTP	4.1	2.7
Merrimack WWTP	2.7	1.8
Derry WWTP	1.4	0.9
Hooksett WWTP	0.8	0.5
Lincoln WWTP	0.7	0.4
Plymouth Village WWTP	0.6	0.4
Allenstown/Suncook WWTP	0.6	0.4
Penacook WWTP	0.4	0.3
Bristol WWTP	0.3	0.2
Woodstock WWTP	0.2	0.1
Merrimack County WWTP	0.1	0.0

Source: MOR Reports for September 2010

4.2.2 QAPP and Field Sampling Plan Deviations

The EPA NERL provided laboratory services to analyze the bacteria samples. Volume of samples and timing required that the bacteria sampling plan be reduced so that only *E. coli* analysis was performed and that samples not be brought to the laboratory after 2:30 pm. Table 4-17 lists the sampling stations that were intended to have bacteria analyses, but were not transported to NERL before the cut-off. Water samples from 54 of the 70 sampling stations were received by the lab and analyzed for *E. coli*. Table 4-18 lists the bacteria samples that, according to the NERL lab report, missed the 6 hour hold time.

Table 4-17: Missed Bacteria Samples for Low Flow Event #2

Station	NHDES ID	Location
M007	22M-PMI	D/S Woodstock WWTF 2
M008	21P-PMI	Woodstock Gage
M014	14-PMI	D/S Plymouth Village WWTF 2
T015	00E-SQM	Squam River
T021	01-NFD	Newfound River
T022	00P-SMT	Smith River
M024	02-PMI	D/S Franklin Falls, U/S Eastman Falls 1
M026	01D-PMI	D/S Eastman Falls
T027	01-CPB	Chance Pond Brook
T028	01-WIN	Winnipesaukee River
M032	31A-MER	U/S Merrimack County WWTF
M036	28A-MER	U/S Penacook WWTF
T044	01-SCK	Soucook River
T046	00G-SNK	Suncook River
M049	16E-MER	U/S Hooksett 2, D/S Suncook WWTF 2
M050	16-MER	D/S Hooksett Dam
M055	12-MER	D/S Amoskeag
M057	09-MER	U/S Manchester WWTF
M063	06D-MER	D/S Derry WWTF 2

Table 4-18: Missed Bacteria Hold Times for Low Flow Event #2

Station	NHDES ID	Location
M020	07-PMI	D/S Bristol WWTF 2
M042	20-MER	D/S Hall Street WWTF 2, U/S Garvins Falls
M053	14X-MER	D/S Hooksett WWTF 2, U/S Amoskeag 1
M054	14B-MER	U/S Amoskeag 2
M060	07AX-MER	D/S Manchester WWTF 2
M062	06K-MER	D/S Derry WWTF 1
M066	04AJ-MER	D/S Merrimack WWTF 1
M034	30J-MER	D/S Merrimack County WWTF 2
T002	03-EBP	U/S Lincoln WWTF
T059	01E-COH	Cohas Brook

A few Winkler dissolved oxygen samples were not analyzed due to field error or broken bottles; the sample stations that were missed are listed in Table 4-19

Table 4-19: Missed Winkler Dissolved Oxygen Samples for Low Flow Event #2

Station ID	NHDES ID	Location
M058	08-MER	D/S Manchester WWTF 1
M066	04AJ-MER	D/S Merrimack WWTF 1
T035	01G-CTC	Contoocook River

4.3 High Flow Event #1

The first high flow sampling event was conducted on May 17, 2012. Field crews collected samples and field readings from approximately 7:30am to 5:00pm. Sample runners from EAI transported *E. coli* bacteria samples throughout the day from the sampling central coordination in Bow, NH to their lab in Concord, NH in order to meet the six hour hold time for those samples. Samples for chlorophyll-a, TSS, and CBOD were also transported to EAI, while the remaining samples were transported to SMAST at the conclusion of the day of sampling.

Due to safety and access concerns related to high flow sampling conditions, reconnaissance was performed prior to the start of the high flow event during a period of high flow comparable to that anticipated during the sampling event. The purpose of the reconnaissance was to evaluate high flow conditions along the river and establish whether the existing river access points were acceptable or if new locations would be required. Most access points remained accessible during high flow conditions, and in the few instances where those access points were unsafe or inaccessible, alternate access was established. It is important to note that the list of sample locations was reduced when compared to the low flow events to include only critical locations and to minimize redundancy. These reduced locations generally consisted of the sampling locations downstream of wastewater treatment plants. Instead of two downstream sample locations in relatively close proximity, one sample was collected between the original two locations.

QA/QC samples were collected at three locations to achieve >5% frequency (or 3 out of 50 samples), consisting of field blanks, field duplicates, and field equipment blanks. Table 4-20 lists the sample times and analyses for each of the sample stations and WWTP effluent composites.

Table 4-20: High Flow Event #1 Sampling Details

Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	CBOD$_5$	CBOD$_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
M001	24C-PMI	Headwaters	mainstem riverine	grab	9:30 AM	X		X		X					
T002	03-EBP	U/S Lincoln WWTF	tributary	grab	11:00 AM	X		X		X					
T003	01-EBP	D/S Lincoln WWTF 1	tributary	grab	11:40 AM	X		X		X					
T004	00F-EBP	D/S Lincoln WWTF 2	tributary	grab	2:00 PM	X	X	X		X					
M006	23-PMI	D/S Woodstock WWTF1	mainstem riverine	grab	3:05 PM	X		X		X					
M008	21P-PMI	Woodstock Gage	mainstem riverine	grab	4:15 PM	X		X		X		X	X	X	X
M009	19-PMI	Campton	mainstem riverine	grab	9:45 AM	X	X	X		X	X				
T010	01-MAD	Mad River	tributary	grab	10:25 AM	X		X		X					
T011	01-BKR	Baker River	tributary	grab	11:00 AM	X		X		X					
M012	14X-PMI	U/S Plymouth Village WWTF	mainstem riverine	grab	10:00 AM	X		X		X					
M013	14J-PMI	D/S Plymouth Village WWTF 1	mainstem riverine	grab	10:25 AM	X		X		X					
T015	00E-SQM	Squam River	tributary	grab	12:00 PM	X		X		X					
M017	08J-PMI	U/S Ayers Island 2	mainstem impoundment	grab	12:15 PM	X	X	X		X	X				
M018	07R-PMI	D/S Ayers Island, U/S Bristol WWTF	mainstem riverine	grab	1:05 AM	X		X		X					
M020	07-PMI	D/S Bristol WWTF 2	mainstem riverine	grab	2:10 PM	X	X	X		X					
T021	01-NFD	Newfound River	tributary	grab	2:50 PM	X		X		X					
T022	00P-SMT	Smith River	tributary	grab	3:20 PM	X		X		X					
M023	04-PMI	U/S Franklin Falls 1	mainstem impoundment	grab	2:47 PM	X		X		X	X				
M024	02-PMI	D/S Franklin Falls, U/S Eastman Falls 1	mainstem impoundment	grab	4:02 PM	X		X		X	X				
M026	01D-PMI	D/S Eastman Falls	mainstem riverine	grab	9:10 AM	X		X		X					
T027	01-CPB	Chance Pond Brook	tributary	grab	4:58 PM	X		X		X			X	X	X
T028	01-WIN	Winnipesaukee River	tributary	grab	3:20 PM	X		X		X		X			
M030	32-MER	D/S Winnipesaukee WWTF 1	mainstem riverine	grab	11:26 AM	X	X	X	X	X					
M032	31A-MER	U/S Merrimack County WWTF	mainstem riverine	grab	1:48 PM	X		X		X					
M033	30X-MER	D/S Merrimack County WWTF 1	mainstem riverine	grab	2:06 PM	X		X		X					
T035	01G-CTC	Contoocook River	tributary	grab	8:40 AM	X		X		X					
M036	28A-MER	U/S Penacook WWTF	mainstem riverine	grab	9:15 AM	X		X	X[1]	X			X	X	X
M037	27X-MER	D/S Penacook WWTF 1	mainstem riverine	grab	9:55 AM	X		X	X	X					
M039	26-MER	U/S Concord	mainstem impoundment	grab	11:55 AM	X		X		X					
M041	22-MER	D/S Hall Street WWTF 1, U/S Garvins Falls 1	mainstem impoundment	grab	12:58 PM	X	X	X	X	X	X	X			
T044	01-SCK	Soucook River	tributary	grab	10:00 AM	X		X		X					
M045	18-MER	U/S Hooksett 1	mainstem impoundment	grab	9:25 AM	X		X		X	X				
T046	00G-SNK	Suncook River	tributary	grab	8:55 AM	X		X		X					
M048	16J-MER	D/S Suncook WWTF 1	mainstem riverine	grab	10:40 AM	X		X		X					
M051	15J-MER	U/S Hooksett WWTF	mainstem impoundment	grab	11:55 AM	X		X		X					
M052	15E-MER	D/S Hooksett WWTF 1	mainstem impoundment	grab	12:25 PM	X	X	X	X	X					
M054	14B-MER	U/S Amoskeag 2	mainstem impoundment	grab	1:05 PM	X		X		X	X				
M055	12-MER	D/S Amoskeag	mainstem riverine	grab	2:35 PM	X		X		X		X			
T056	03-PQG	Picataquog River	tributary	grab	7:40 AM	X		X		X					

Table 4-20: High Flow Event #1 Sampling Details (continued)

Station ID	NHDES ID	Location	Station Type	Sample Type	Sample Time	Nutrients	Winkler DO	$CBOD_5$	$CBOD_{20}$	Total Suspended Solids	Chlorophyll-a	E. coli	Field Blank	Field Duplicate	Field Equip. Blank
M058	08-MER	D/S Manchester WWTF 1	mainstem riverine	grab	8:50 AM	X	X	X	X	X					
T059	01E-COH	Cohas Brook	tributary	grab	10:00 AM	X		X		X					
M061	07A-MER	U/S Derry WWTF	mainstem riverine	grab	11:10 AM	X		X		X	X				
M062	06K-MER	D/S Derry WWTF 1	mainstem riverine	grab	12:50 PM	X	X	X	X	X					
T064	01-SHG	Souhegan River	tributary	grab	2:05 PM	X		X		X		X			
M065	04AM-MER	U/S Merrimack WWTF	mainstem riverine	grab	9:57 AM	X		X		X	X				
M066	04AJ-MER	D/S Merrimack WWTF 1	mainstem riverine	grab	10:54 AM	X		X	X	X					
T068	01P-NSH	Nashua River	tributary	grab	3:20 PM	X		X		X		X			
T069	00-SMN	Salmon Brook	tributary	grab	12:02 PM	X		X		X					
M070	02M-MER	U/S Nashua WWTF	mainstem riverine	grab	1:00 PM	X		X		X	X		X	X	X
M071	02K-MER	D/S Nashua WWTF 1	mainstem riverine	grab	2:08 PM	X		X	X	X					
Lincoln WWTP	NH0100706	WWTP	WWTP effluent	24-hr composite	9:00 AM	X		X	X	X					
Woodstock WWTP	NH0100293	WWTP	WWTP effluent	24-hr composite	8:50 AM	X		X	X	X					
Plymouth WWTP	NH0100242	WWTP	WWTP effluent	24-hr composite	7:00 AM	X		X	X	X					
Bristol WWTP	NHG580021	WWTP	WWTP effluent	24-hr composite	12:05 PM	X		X	X	X					
Franklin/Winnipesaukee WWTP	NH0100960	WWTP	WWTP effluent	24-hr composite	1:15 PM	X		X	X	X					
Merrimack Co. WWTP	NHG580935	WWTP	WWTP effluent	24-hr composite	8:40 AM	X		X	X	X					
Penacook WWTP	NH0100331	WWTP	WWTP effluent	24-hr composite	7:30 AM	X		X	X	X					
Hall St WWTP	NH0100901	WWTP	WWTP effluent	24-hr composite	8:00 AM	X		X	X	X					
Suncook/Allenstown WWTP	NHG580714	WWTP	WWTP effluent	24-hr composite	8:55 AM	X		X	X	X					
Hooksett WWTP	NH0100129	WWTP	WWTP effluent	24-hr composite	8:30 AM	X		X	X	X					
Manchester WWTP	NH0100447	WWTP	WWTP effluent	24-hr composite	6:45 AM	X		X	X	X					
Derry WWTP	NH0100056	WWTP	WWTP effluent	24-hr composite	11:16 AM	X		X	X	X					
Merrimack WWTP	NH0100161	WWTP	WWTP effluent	24-hr composite	7:46 AM	X		X	X	X					
Nashua WWTP	NH0100170	WWTP	WWTP effluent	24-hr composite	9:00 AM	X		X	X	X					

Notes:
1) The field blank, field duplicate, and equipment blank were analyzed for $CBOD_{20}$; however, due to a COC error, the parent sample (M036) was not.

4.3.1 Precipitation and Streamflow Conditions

The precipitation totals for four locations within the watershed are shown in Table 4-21. Rain events occurred in the watershed seven days and three days before the sampling event, resulting in up to approximately an inch and a half of precipitation locally in the upper watershed and up to almost 2 inches in the lower watershed. Flows in the spring of 2012 prior to the rain event were below the seasonal average but a few select rain storms in April and May increased flows to the desired high flow ranges. See Figure 4-6.

Table 4-21: Precipitation Totals for High Flow Event #1

	Total Daily Precipitation (inches)			
	Location			
	Woodstock, NH	**Franklin, NH**	**Concord, NH**	**Manchester, NH**
	Gage ID: MNHWOD	Gage ID: KNHNORTH4	Gage ID: Concord Airport	Gage ID: MNHMCH
Date	Source: NHDOT	Source: Franklin Falls Dam	Source: NOAA	Source: NHDOT
5/10/2012	0.27	0.39	0.69	0.50
5/11/2012	0.00	0.00	0.00	0.00
5/12/2012	0.00	0.00	0.00	0.00
5/13/2012	0.00	0.00	0.00	0.00
5/14/2012	0.08	0.36	0.25	0.10
5/15/2012	0.46	0.47	0.56	0.40
5/16/2012	0.03	0.30	0.48	0.20
5/17/2012	0.00	0.01	0.00	0.00
7 Day Total	0.84	1.53	1.98	1.20
3 Day Total	0.57	1.14	1.29	0.70

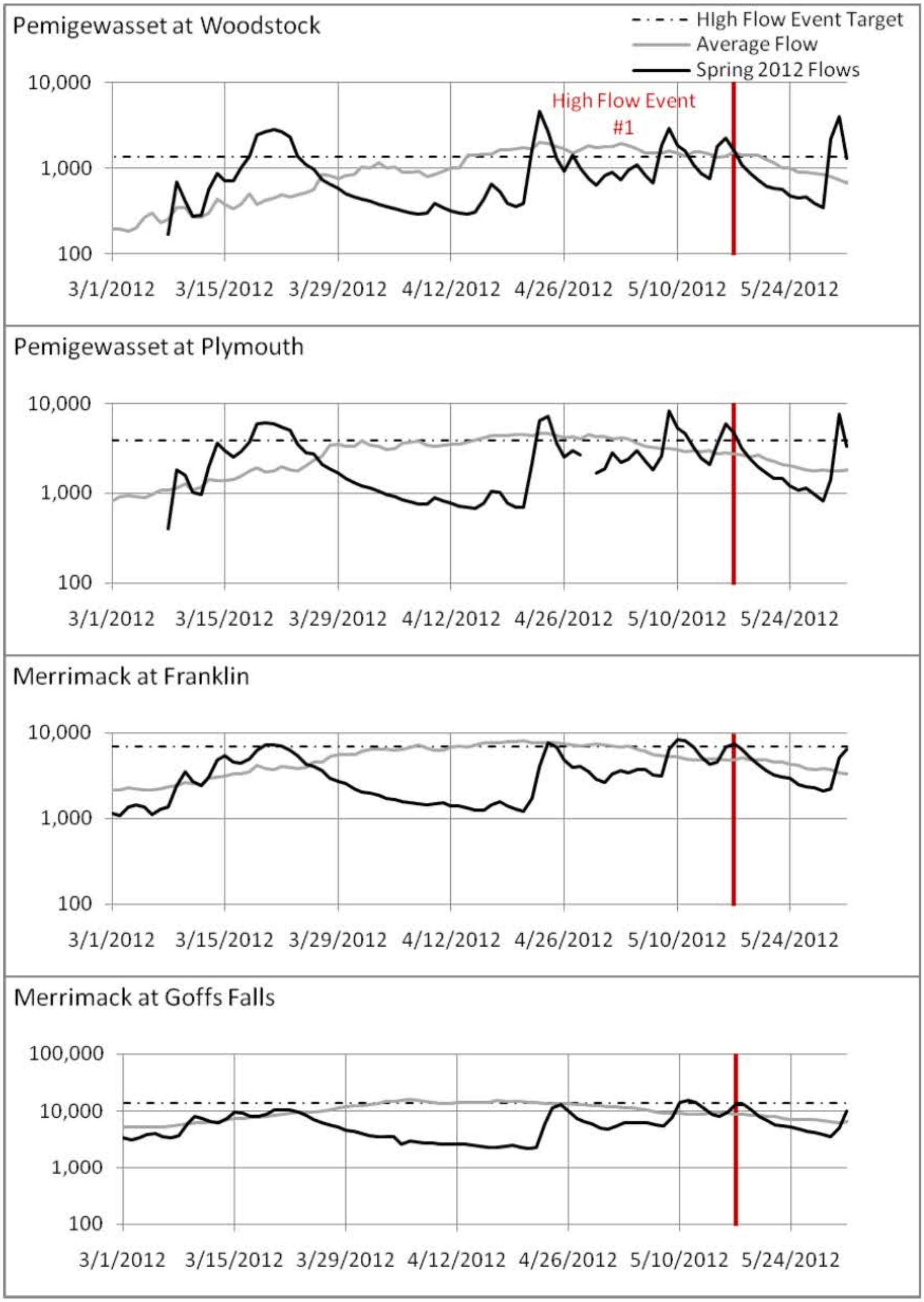
The decision to conduct the high flow sampling event was made by NHDES and USACE based on data review and interpretation from CDM Smith. Streamflows in the spring of 2012 continued to be low with the exception of a period of snow melt in 2012 and the weather relatively dry; however, a few major rain events in April and May 2012 increased flows to above the high flow targets. The target flows were established as greater than or equal to the monthly average for the wettest month of the year at each gage based on historical data since the early to mid 1900s. April was historically the wettest month at each gage, with the exception of the Woodstock gage, which historically peaked in May. Table 4-22 shows the average flows on the day of the first high flow event with comparisons to the target flow. Target flows were met at three of the four gages and were very near target flows at the Goffs Falls gage.

Table 4-22: Daily Average Flow at Mainstem USGS Gages for High Flow Event #1

Gage	Daily Average Flow 5/17/2012, cfs	High Flow Target, cfs
Pemigewasset at Woodstock	1,590	1,350
Pemigewasset at Plymouth	4,700	3,920
Merrimack at Franklin	7,530	7,030
Merrimack at Goffs Falls	12,900	13,900

Figure 4-6 shows the Spring 2012 streamflow time series at each gage and the date when the high flow event took place. With the exception of a period of snow melt in March, flows remained generally low in Spring 2012, however increased after rain events in April to near and above the high flow event targets. As shown in the graphs, since the upper watershed responds more dramatically to precipitation flows tend to increase and recede within a day or two. The high flow event took place just near the peak of the hydrographs at all gage locations.

Figure 4-6: Streamflow Conditions for Spring 2012, cfs



Flows at each of the major tributaries were calculated in one of two ways: 1) using basin area to transpose upstream USGS gage flows to the point of confluence with the mainstem, or 2) field measurements of stream velocity and cross sectional area collected on the day of sampling. Table 4-23 shows the calculated flows at each tributary for May 17, 2012. The Contoocook drainage area is the largest subbasin within the study area watershed and contributed the largest volume of flow on the day of the first high flow sampling event.

Table 4-23: Measured and Gaged Tributary Flows During High Flow Event #1

Location	Station ID	Drainage Area	Flow		Method
		square miles	cfs	mgd	
Winnipesaukee River	T028	485.8	1568	1013	Gage Transposition
East Branch Pemigewasset River	T004	116.7	838	542	Gage Transposition
Baker River	T011	213.4	924	597	Gage Transposition
Squam River	T015	65.18	22	14	Flow Meter
Contoocook River	T035	764.0	2070	1338	Gage Transposition/ Estimate
Nashua River	T068	416.1	1415	914	Comparison
Newfound River	T021	98.67	296	191	Comparison
Souhegan River	T064	219.6	684	442	Gage Transposition
Mad River	T010	62.17	187	121	Comparison
Piscataquog River	T056	217.5	668	431	Gage Transposition
Smith River	T022	87.84	332	214	Gage Transposition
Soucook River	T044	91.38	397	257	Gage Transposition
Cohas Brook	T059	69.92	287	185	Comparison
Suncook River	T046	255.9	1049	678	Comparison
Salmon Brook	T069	30.74	34	22	Flow Meter
Chance Pond Brook	T027	18.50	77	50	Flow Meter

Average flows exiting the WWTPs were taken from May 2012 Monthly Operating Reports for each of the 14 plants. Table 4-24 below lists the average flow for the day of High Flow Event #1 in cubic feet per second and million gallons per day.

Table 4-24: Average WWTP Discharges During High Flow Event #1

WWTP	Average Flow – May 17, 2012	
	cfs	Mgd
Manchester WWTP	85	55
Nashua WWTP	16	10
Hall St WWTP	6.2	4.0
Winnipesaukee WWTP	12	7.8
Merrimack WWTP	2.5	1.6
Derry WWTP	2.6	1.7
Hooksett WWTP	1.4	0.9
Lincoln WWTP	0.9	0.6
Plymouth Village WWTP	0.9	0.6
Allenstown/Suncook WWTP	1.2	0.8
Penacook WWTP	1.1	0.7
Bristol WWTP	0.3	0.2
Woodstock WWTP	0.2	0.13
Merrimack County WWTP	0.1	0.06

Source: MOR Reports for May 2012

4.3.2 QAPP and Field Sampling Plan Deviations

High Flow Event #1 was conducted with strict adherence to the QAPP and Field Sampling Plan. All analytical hold times were met and samples were collected from all intended locations. One minor error occurred with analysis of CBOD20 at M036. Though a duplicate sample was collected at this location, a parent sample was not collected from M036 for comparison, as required by the QAPP's field precision objectives.

Additionally, one Winkler dissolved oxygen sample could not be analyzed as the bottle was broken during shipment; the sample station that was missed is listed in Table 4-25

Table 4-25: Missed Winkler Dissolved Oxygen Sample for High Flow Event #1

Station ID	NHDES ID	Location
M071	02K-MER	D/S Nashua WWTF 1

4.4 Low Flow Data Summary and Observations

The following sections offer summaries of the data collected during the low flow events and preliminary observations. Fold-out panels containing plots of the data described herein can be found at the end of Section 4; complete data tables can be found in Appendix B.

4.4.1 Carbonaceous Biological Oxygen Demand

Concentrations of $CBOD_5$ in the river were mostly non-detect (detection limits: 2.0 and 3.0 mg/L; see Figure 4-7). The exceptions were during the first event, at sampling locations in Concord downstream of the WWTPs and upstream of Garvins Falls Dam (2.4-3.9 mg/L) and downstream of the Nashua WWTP (2.9 mg/L). There is no clear connection to the WWTPs immediately upstream of these higher concentrations based on the 24-hour composite effluent concentrations at those plants, which were not unusually high. Concentrations of $CBOD_5$ in the WWTP effluents were generally in the range that would be expected from permitted wastewater discharges: from approximately 4.0 mg/L to 20 mg/L (when detected).

$CBOD_{20}$ concentrations ranged from non-detect to 41 mg/L at one station during the first event, also downstream of the Concord WWTPs and upstream of Garvins Falls Dam (Figure 4-8). Concentrations of $CBOD_{20}$ in the WWTP effluents ranged from 5.5 mg/L to 60 mg/L. Again, no correlation could be seen between the higher $CBOD_{20}$ in the river downstream of Concord and the WWTP effluent immediately upstream.

The Hooksett WWTP effluent had notably greater $CBOD_5$ and $CBOD_{20}$ than the other plants: $CBOD_5$ of 18- 19 mg/L for the two events, as compared with medians of 4.0-8.5 mg/L for all the plants and 6-11 mg/L greater than the next highest concentration; and $CBOD_{20}$ of 39-60 mg/L, as compared with a median of 10.5-16 mg/L for all the plants and 15-40 mg/L greater than the next highest concentration.

4.4.2 Chlorophyll-a

Chlorophyll-a concentrations generally increased from upstream to downstream along the Pemigewasset and Upper Merrimack Rivers during the first low flow event (Figure 4-9). This trend was also observed in the impoundments studies of 2009 and in the data collected on the Lower Merrimack River as part of the 2006 Merrimack River Watershed Assessment Study. Concentrations range from 1 to 12 ug/L within impoundments, 0.4 to 21 ug/L in mainstem riverine samples, and 0.2 to 4 ug/L in tributary samples. The greatest impoundment chlorophyll-a concentrations were observed in the Hooksett Falls impoundment at 5 to 12 ug/L. The chlorophyll-a concentrations were lower during the second low flow event. This could be the result of cooler water temperatures and system flushing at the end of the summer. The chlorophyll-a levels observed during the first event were generally higher than the second, with the exception of within the Ayers Island impoundment, indicating that this impoundment is slower to change over from summer to fall conditions than the rest of the river system.

During the first low flow event, in the most downstream reach of the study area, south of the Souhegan River confluence, chlorophyll-a concentrations rose from the 5-10 ug/L that were observed consistently downstream of Concord to above the NH state guidance threshold of 15 ug/L, reaching a peak concentration of 21 ug/L just upstream of the Nashua WWTP.

Chlorophyll-a levels generally decline after dams, indicating that while there is growth in the impoundments, the system is flushing itself in ways that prevents long term accumulation. This decline was not observed downstream of Franklin Falls Dam or Garvins Falls Dam, possibly because these dams spill directly into the next downstream impoundment where algal growth is occurring.

4.4.3 Dissolved Oxygen and Temperature

Dissolved Oxygen

Dissolved oxygen levels in the river were measured *in situ* using YSI field meters and in the lab using Winkler titration. Winkler titration values are typically more accurate that field meters, providing the sampler does not introduce additional air into the water sample while filling the bottle. Field crews were trained in this sampling procedure, but inadvertent air introduction is a risk when filling Winkler bottles in the field. Both the field measured values and the Winkler titration values are shown in Figures 4-10 and 4-11 to give a comprehensive portrayal of the dissolved oxygen conditions in the river.

Concentrations of dissolved oxygen measured during the two events ranged from 5.7-5.8 mg/L (66-67%) to above 100% air saturation (Figures 4-10 and 4-11). No field readings or Winkler samples showed concentrations less than the NH Class B water standard of 5 mg/L. In two locations during the first event the dissolved oxygen concentration was measured to be lower that the NH Class B saturation standard of 75%[2]: M034 Downstream Merrimack County Facilities WWTP, 67% (Winkler method), and at M042 Downstream Hall Street WWTP and Upstream Garvins Falls, 73% (field measurement). There were several locations with saturation percentages below 75% during the second low flow event: M029 Upstream Winnipesaukee WWTP, 70% (Winkler method); M047 Upstream Suncook WWTP, 72% (field measurement); M049 Upstream Hooksett Dam, Downstream Suncook WWTP, 66% (field measurement); and T046 Suncook River, 72% (field measurement)

Field teams took profile measurements *in situ* when sampling at locations where the water was slow moving and deep (Figures 4-12a to 4-12g). These measurements of temperature and dissolved oxygen show evidence of stratification in two impoundments during the first event: Eastman Falls and Garvins Falls. Dissolved oxygen concentration at the surface in Eastman Falls impoundment (M025) was low at 5.8 mg/L (67%) and dropped suddenly to 5.3 mg/L (63%) at a depth of 12 feet. The temperature at this location was 25.2°C at the surface and declined steadily with depth to 23.3°C near the bottom. Dissolved oxygen concentration at the surface in Garvins Falls impoundment (M042) was 7.3 mg/L (86%), dropped to 6.6 mg/L (82%) at a depth of 5 feet, and fluctuated near the bottom of the water column. The temperature at the bottom of the water column in the Ayers Island impoundment (M017) was significantly colder than at the top: 22.3°C and 25.4°C respectively.

[2] The percent saturation standard is for daily average dissolved oxygen readings, not single point measurements as were taken during the low flow events.

However, dissolved oxygen measurements did not show evidence of low levels deeper in the water column.

There was no evidence of stratification found in the profiles readings taken during the second low flow event.

During the first event, field teams measured dissolved oxygen in the river during the early morning (5:00 am to 8:00 am) and later afternoon (2:00 pm to 7:00 pm) at select stations (listed in Table 4-1) in order to evaluate diurnal fluctuation. Figure 4-13 shows the observed dissolved oxygen difference between the morning and afternoon readings at these stations. Locations upstream of the Hooksett Dam (M045) and downstream of the Merrimack WWTP (M066) showed significant diurnal fluctuations when continuous metering data was collected in summer 2009 (see Section 3), and also showed fluctuations of greater than 1.0 mg/L in dissolved oxygen during the low flow sampling in July 2010. Low dissolved oxygen readings were observed downstream of the Merrimack County Facilities WWTP (M033) and downstream of the Nashua WWTP (M071) during the morning readings as compared with the afternoon readings.

Temperature
During both low flow events, temperatures in the upstream reaches of the study area were lower than in the downstream reaches where the lesser streambed slope results in a wider, slower moving river (Figure 4-14). The average mainstem water temperature upstream of the Pemigewasset and Winnipesaukee Rivers confluence was 22.5°C during sampling in July and 14.9°C during sampling in September. The average water temperature downstream of the confluence was 25.8°C in July and 19.2°C in September. Tributaries entering the mainstem upstream of the Winnipesaukee River were also colder on average than those entering downstream: 22.1°C/25.1°C in Jul, 13.8°C/17.2°C in September, respectively.

Temperatures decreased one to two degrees immediately downstream of four dams: Ayers Island, Franklin Falls, Eastman Falls, and Garvins Falls. For the hydropower dams (Ayers Island, Eastman Falls, and Garvins Falls), this indicates that there is a low flow release or turbine intake from either mid-depth or near the bottom of the impoundment, where water temperatures are cooler than at the surface spillway.

A notable temperature increase (approximately 3°C in July and 6°C in September) occurs within the Hooksett Falls impoundment from station M045 to M047. This is likely due to a cooling water discharge at the PSNH power plant adjacent to the river between those two stations. Depth profiles of temperature at station M047 show significant variation from the surface to the bottom of the water column (Figure 4-12e).

Figure 4-12a: Dissolved Oxygen and Temperature Profiles at Ayers Island

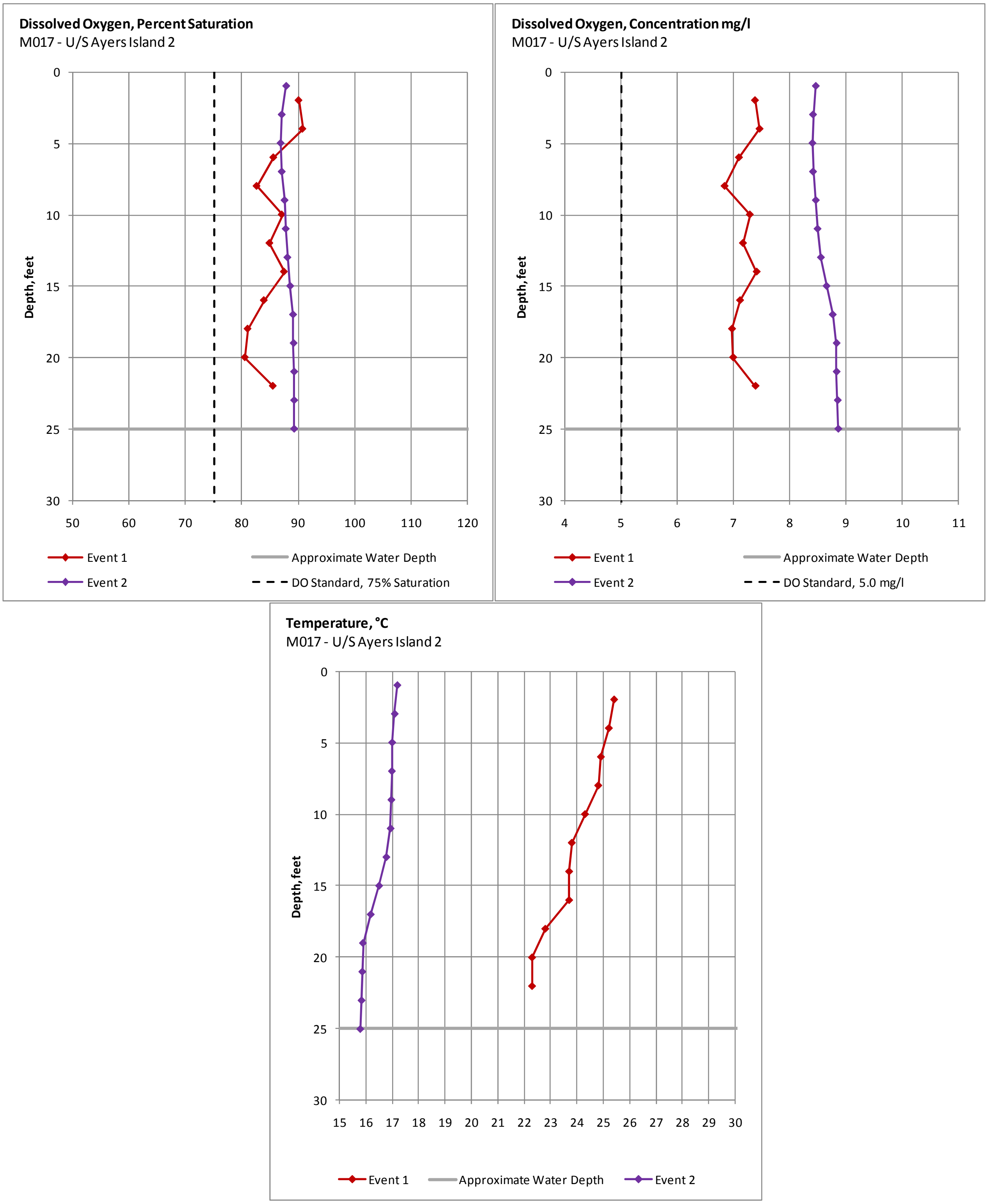


Figure 4-12b: Dissolved Oxygen and Temperature Profiles at Franklin Falls

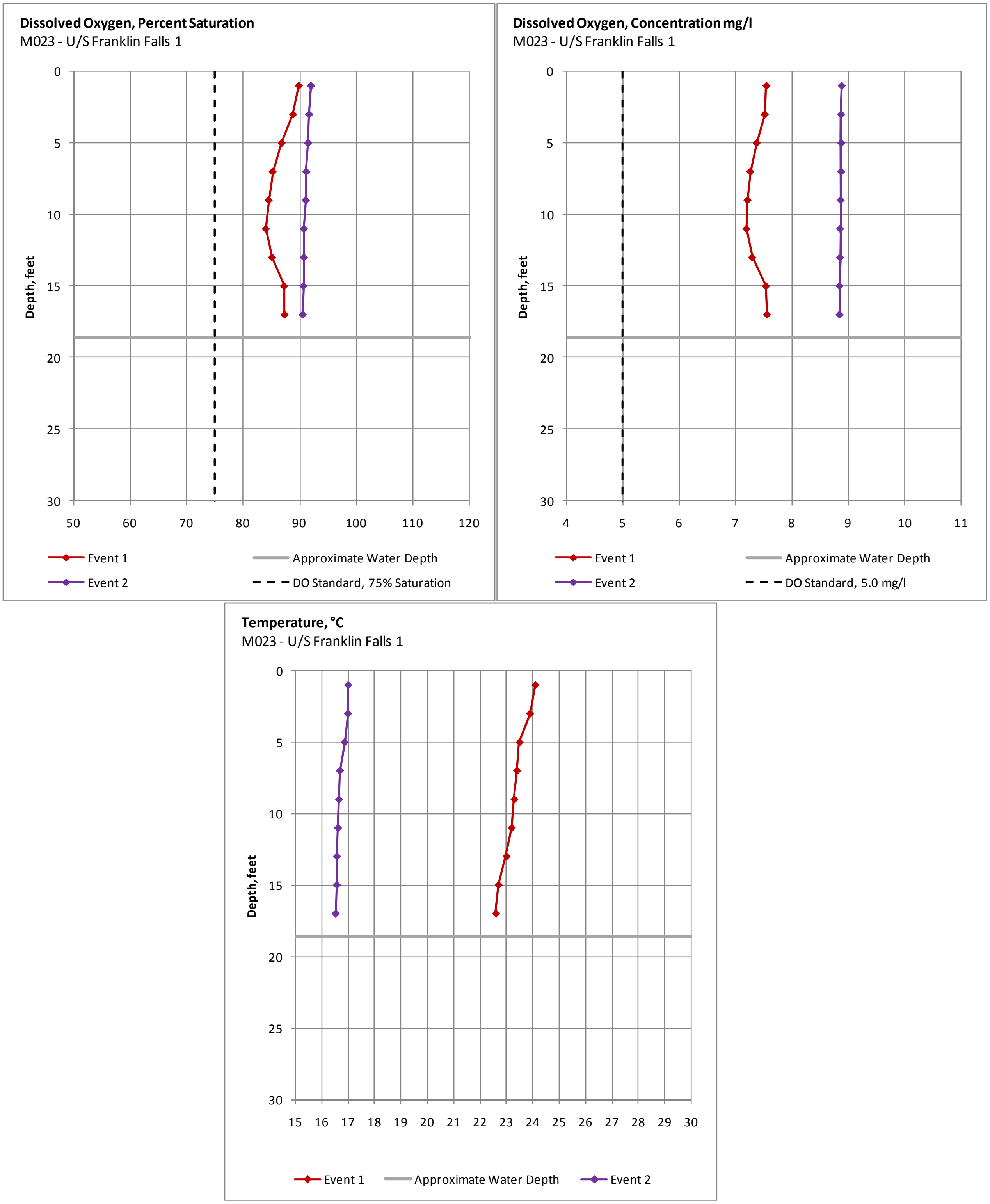
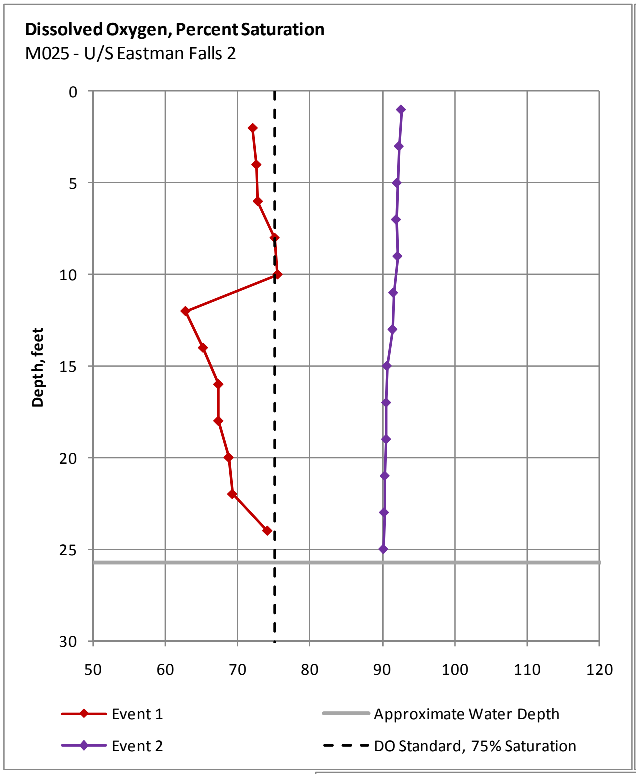
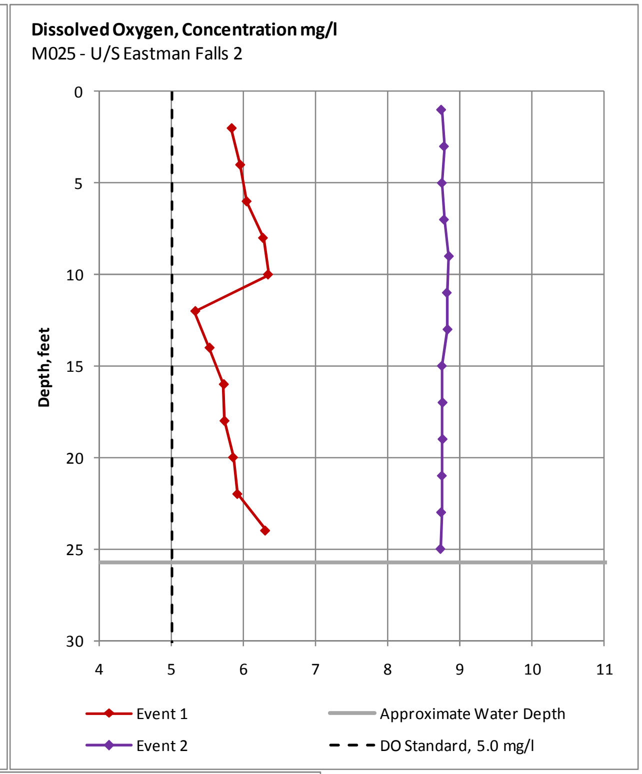


Figure 4-12c: Dissolved Oxygen and Temperature Profiles at Eastman Falls





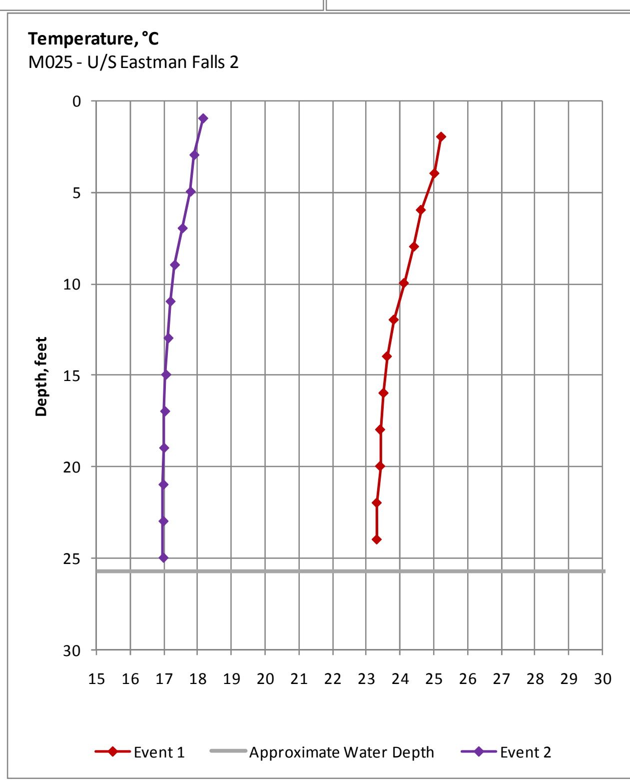


Figure 4-12d: Dissolved Oxygen and Temperature Profiles at Garvins Falls

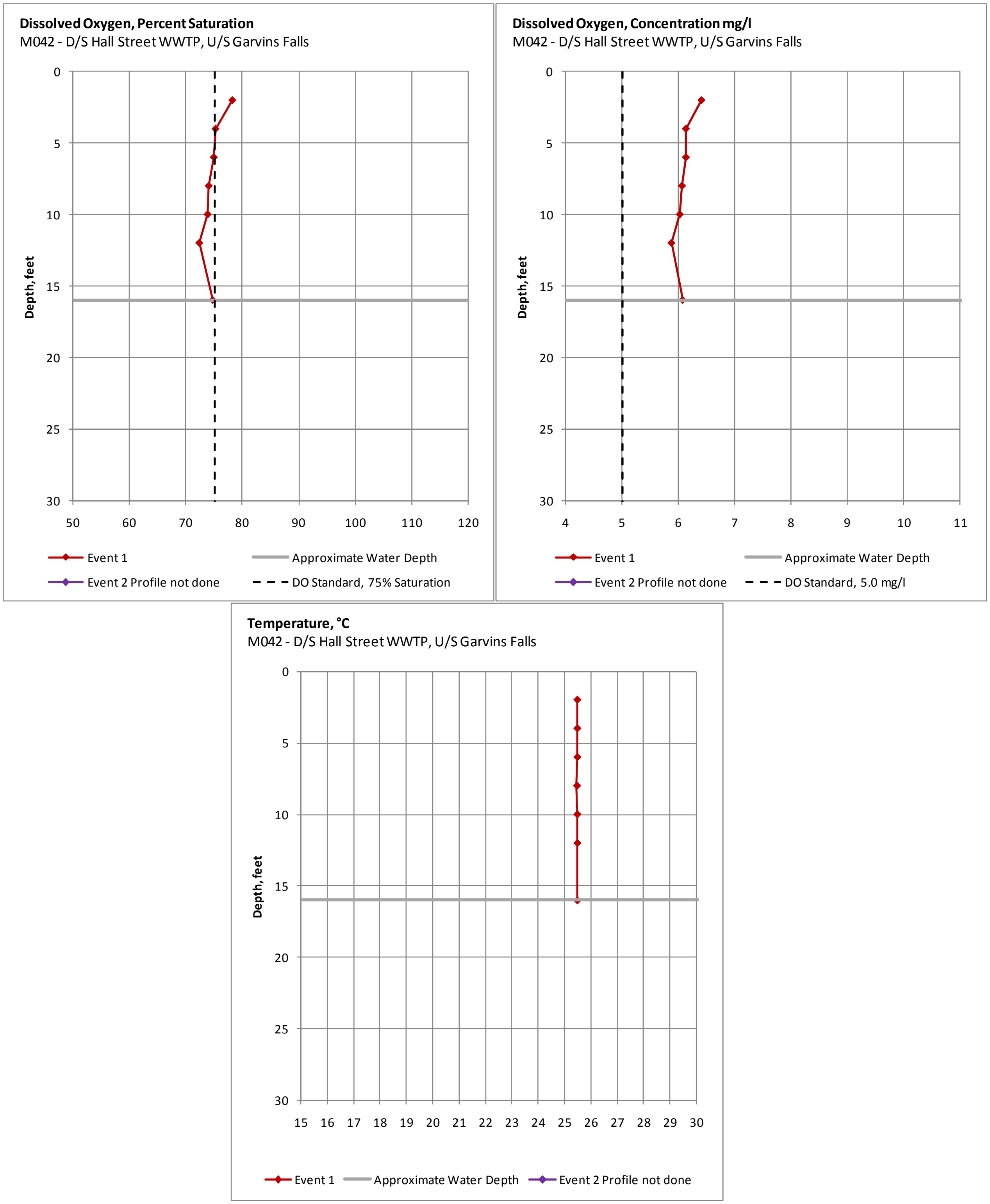
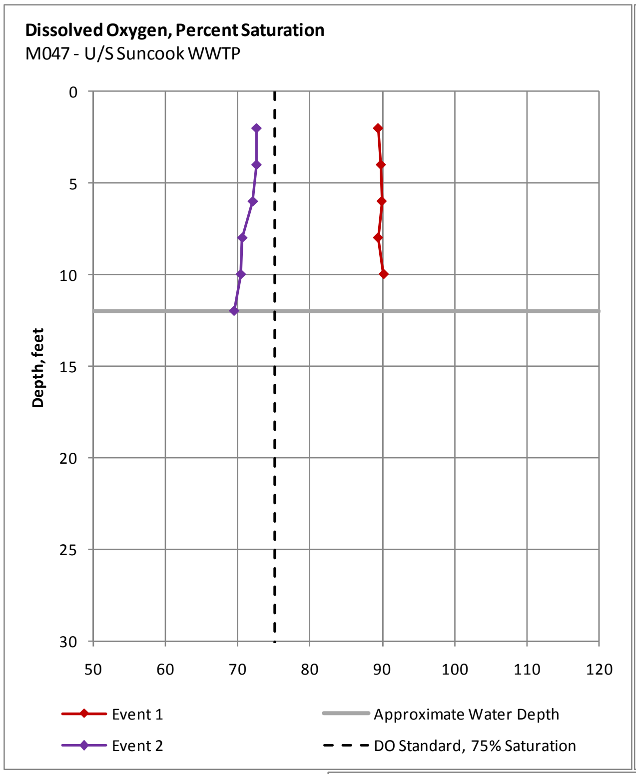
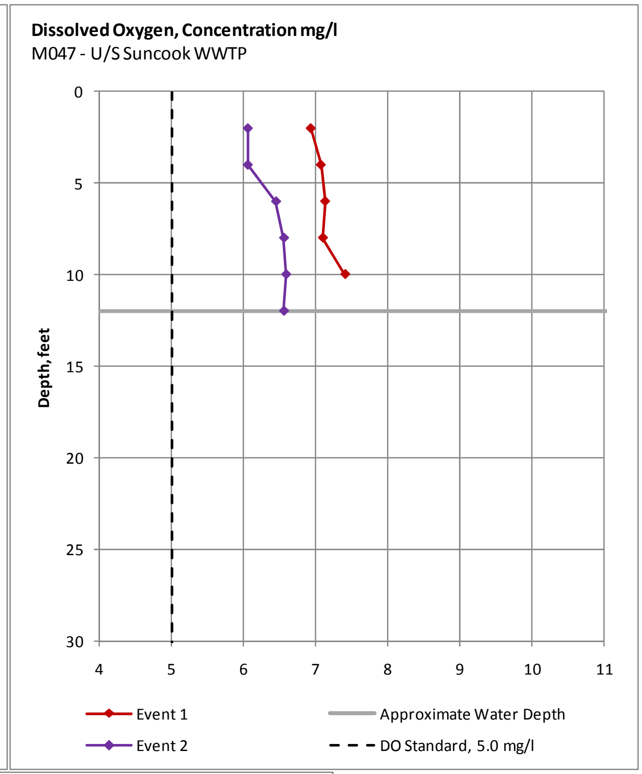


Figure 4-12e: Dissolved Oxygen and Temperature Profiles at Hooksett Power Plant





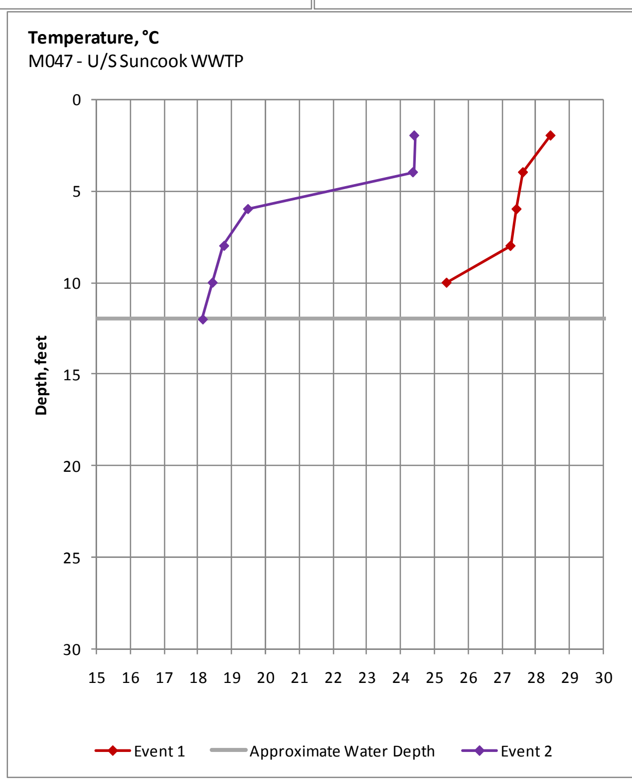
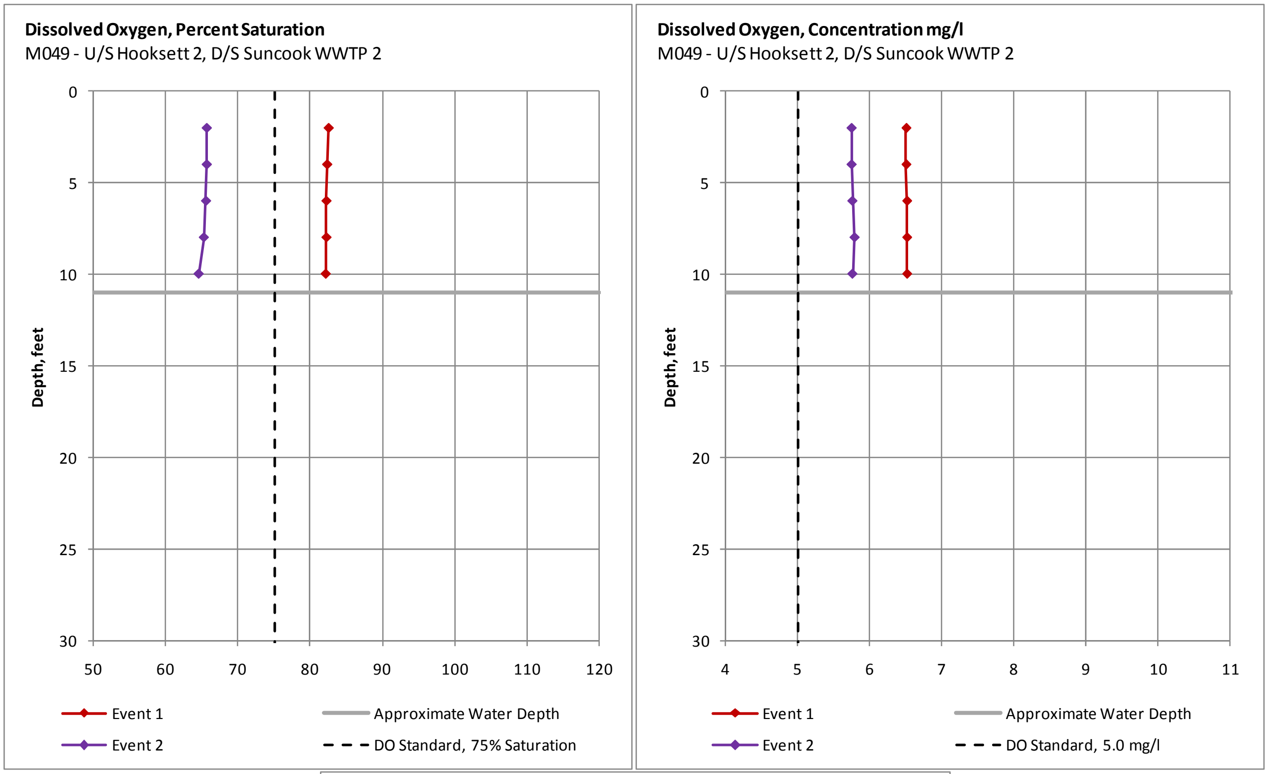


Figure 4-12f: Dissolved Oxygen and Temperature Profiles at Hooksett Falls



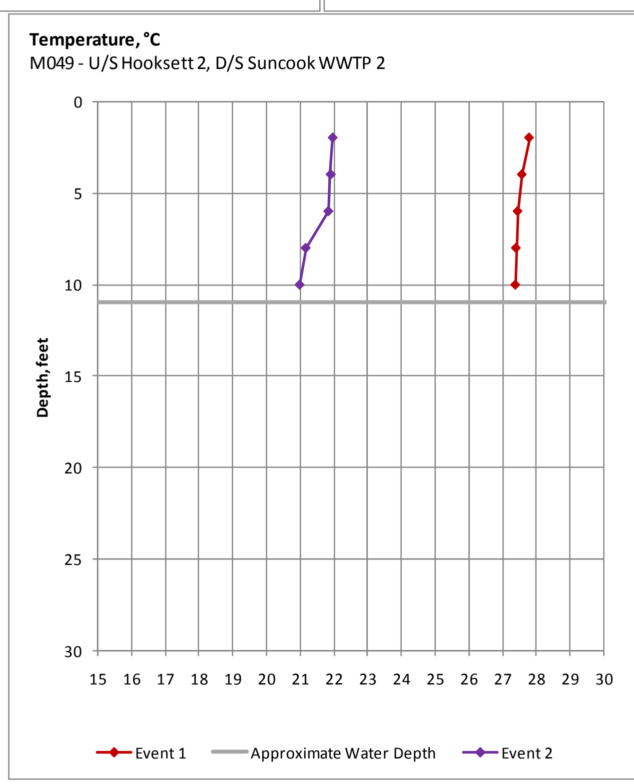


Figure 4-12g: Dissolved Oxygen and Temperature Profiles at Amoskeag

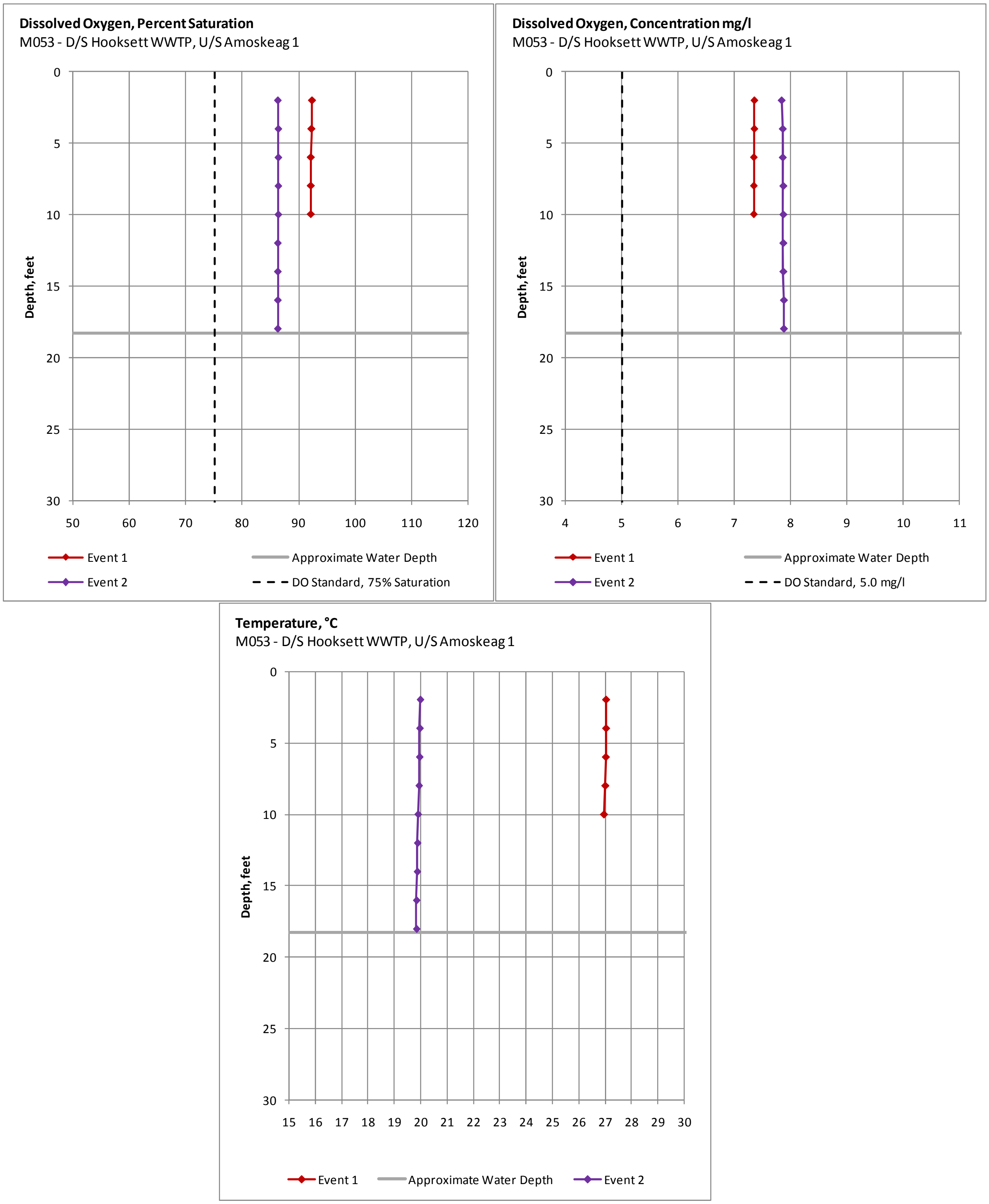
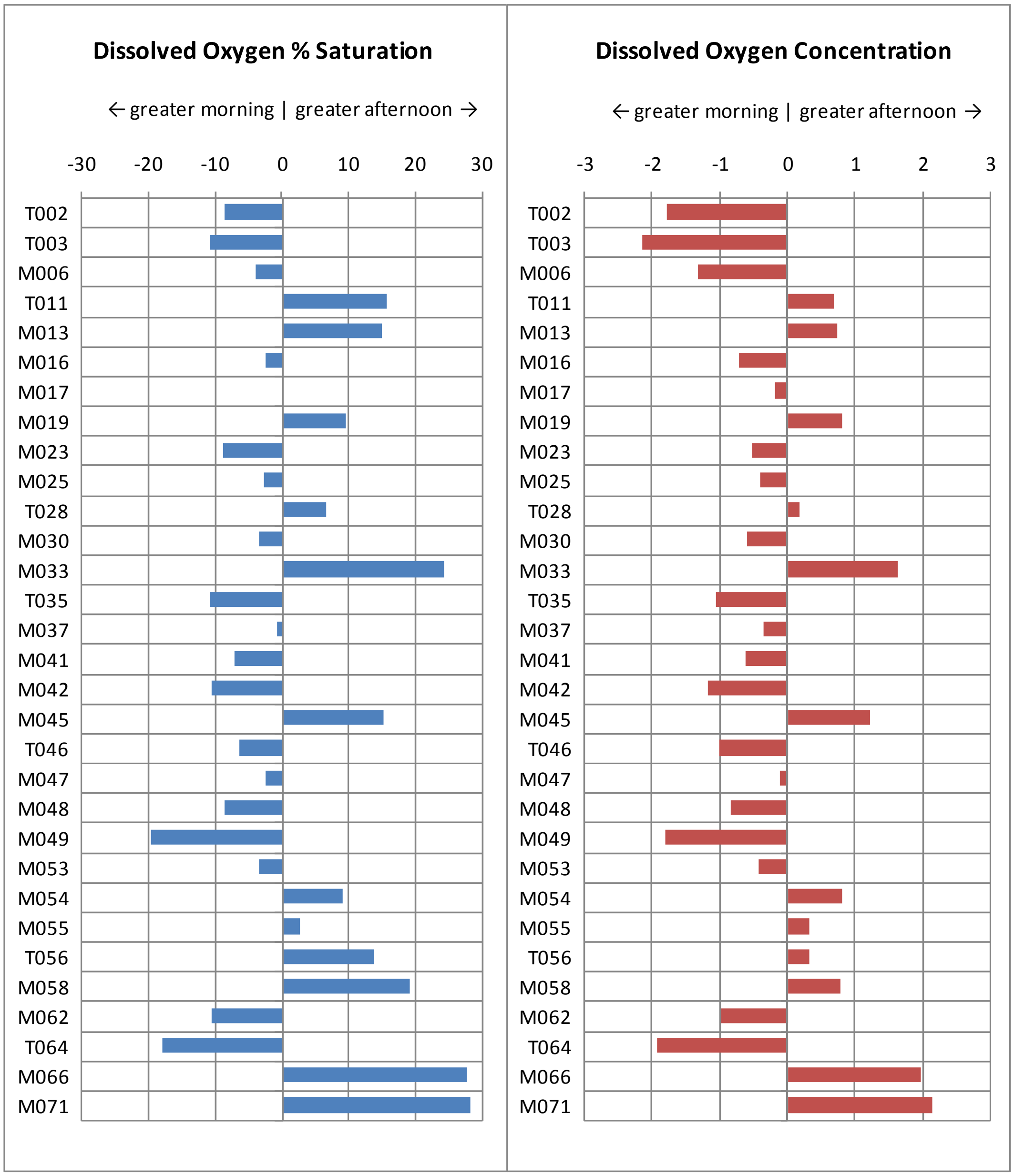


Figure 4-13: Difference in Morning and Afternoon Dissolved Oxygen Readings for Low Flow Event #1



4.4.4 Nitrogen

Total nitrogen concentrations generally increased from upstream to downstream within the study area (Figure 4-15). The range of observed total nitrogen concentrations are presenting in Table 4-26 and 4-27.

Low Flow Event #1

In several locations total nitrogen concentrations increased significantly (> 0.2 mg/L): downstream of Franklin Falls Dam (0.44 to 0.76 mg/L); downstream of Winnipesaukee WWTP (0.43 to 1.05 mg/L); between two locations upstream of Concord (0.45 to 0.90 mg/L); between two locations in Garvins Falls impoundment (0.82 to 1.25 mg/L); downstream of Cohas Brook (0.65 to 1.02 mg/L); downstream of Nashua WWTP (0.89 to 1.16 mg/L). Nitrogen levels decreased from upstream to downstream of the Garvins Falls Dam and the Amoskeag Dam. The Winnipesaukee, Nashua, and Hall Street WWTPs recorded the highest total nitrogen concentrations, at 36.0, 32.4, and 28.8 mg/L respectively.

Table 4-26: Total Nitrogen Concentrations for Low Flow Event #1 (mg/L)

Location Type	Minimum	Maximum	Average
Mainstem Impoundment	0.35	1.25	0.65
Mainstem Riverine	0.33	1.16	0.65
Tributary	0.29	1.15	0.51
WWTP Effluent	5.41	36.0	20.1

Note: Detection Limit = 0.01 mg/L

Low Flow Event #2

Nitrogen concentrations increased significantly from upstream to downstream of the Eastman Falls Dam (0.36 to 0.60 mg/L); within the Garvins Falls impoundment (0.44 to 0.68 mg/L); downstream of Amoskeag Dam (0.78 to 1.0 mg/L); and downstream of the Nashua WWTP (1.1 to 1.7 mg/L. There were few significant decreases in nitrogen along the river, and generally the concentrations were more consistent than during the first low flow event, following an increasing trend from upstream to downstream. The Nashua, Winnipesaukee, and Hooksett WWTPs recorded the highest total nitrogen concentrations, at 37.9, 31.7, and 30.5 mg/L, respectively

Table 4-27: Total Nitrogen Concentrations for Low Flow Event #2 (mg/L)

Location Type	Minimum	Maximum	Average
Mainstem Impoundment	0.34	0.79	0.60
Mainstem Riverine	0.35	1.71	0.72
Tributary	ND	1.52	0.55
WWTP Effluent	5.13	37.9	21.4

Note: Detection Limit = 0.01 mg/L

4.4.5 Phosphorus

Total phosphorus concentrations generally increase from upstream to downstream within the study area, as was observed during the 2009 impoundment studies. Figure 4-16 shows the total phosphorus concentrations along the river as well as guidance values provided by EPA for streams (0.10 mg/L), streams flowing into impoundments (0.05 mg/L), and waters within impoundments (0.025 mg/L); the value used by New Hampshire for lakes (0.012 mg/l); and the value used in Maine for wadeable streams (0.03 mg/l). These values are not NH state standards and are meant for only comparative purposes. A summary of the observed total phosphorus concentrations is shown in Tables 4-28 and 4-29.

Low Flow Event #1

Phosphorus levels upstream of the Winnipesaukee and Pemigewasset confluence were generally below 0.025 mg/L, with the exception of the headwaters in Lincoln. The observed total phosphorus in the East Branch Pemigewasset was high (0.068 mg/L) compared with the average for tributaries (0.021 mg/L) and compared with other concentrations observed in that area (0.009 mg/L upstream of the confluence on the West Branch Pemigewasset, and 0.004 mg/L at the most upstream station on the East Branch Pemigewasset).

The phosphorus concentration increased from below 0.025 mg/L to above 0.05 mg/L downstream of the Winnipesaukee River confluence and Winnipesaukee WWTP. Another dramatic increase in phosphorus concentration occurred downstream of the Cohas Brook confluence and Manchester WWTP. In both of these locations lower concentrations of dissolved oxygen were also observed on the day of the first low flow event.

Table 4-28: Total Phosphorus Concentrations for Low Flow Event #1 (mg/L)

Location Type	Minimum	Maximum	Average
Mainstem Impoundment	0.012	0.033	0.020
Mainstem Riverine	0.009	0.074	0.032
Tributary	0.004	0.068	0.021
WWTP Effluent	2.10	10.9	5.06

Note: Detection Limit = 0.0016 mg/L

Low Flow Event #2

Total phosphorus concentration patterns were similar during the second low flow event as compared with the first. Concentrations were slightly lower in the upper watershed and higher in the lower watershed. As in the first event, the total phosphorus increased downstream of the Winnipesaukee River and Winnipesaukee WWTP, and downstream of Manchester WWTP and Cohas Brook. Another spike in total phosphorus concentration was observed downstream of the Hall St WWTP, within the Garvins Falls impoundment.

As compared to the first event, total phosphorus concentrations were higher during the second event within and downstream of Garvins Falls impoundment and Concord. This pattern is in agreement with the pattern observed during the 2009 impoundment studies: that phosphorus levels increase throughout the summer. Downstream of Concord, all main stem (riverine and impoundment sections) concentrations of total phosphorus during the second low flow event were above the EPA recommended level for impoundments (0.025 mg/l). Tributary levels were generally the same as the first low flow event.

Table 4-29: Total Phosphorus Concentrations for Low Flow Event #2 (mg/L)

Location Type	Minimum	Maximum	Average
Mainstem Impoundment	0.007	0.069	0.032
Mainstem Riverine	0.006	0.102	0.036
Tributary	0.004	0.043	0.016
WWTP Effluent	0.827	9.04	4.58

Note: Detection Limit = 0.0016 mg/L

Orthophosphates

Measuring orthophosphates along with total phosphorus in the river gives an idea of how much of the nutrient is bioavailable for algal growth (Figure 4-17). Orthophosphate is the inorganic, dissolved portion of phosphorus, and is bioavailable. Typically the fraction of total phosphorus that is orthophosphate in rivers is 0.5, but it can vary depending on the sources of phosphorus and the algal activity.

Orthophosphates in the river and wastewater effluent were generally observed higher in the second low flow event than the first. The Garvins Falls, Hooksett Falls, and Amoskeag impoundments had significantly higher orthophosphate concentrations during the second event – as compared to those locations during the first event and to the rest of the river samples. There were also higher concentrations of orthophosphates in the most downstream reach of the study area during the second event. This area had much less algae observed at that time, indicating that algal growth was otherwise inhibited in September (perhaps by cooler temperatures, but not by lack of bioavailable phosphorus).

The ratio of orthophosphates to total phosphorus (Figure 4-18) in the main stem river and tributaries was generally less than 0.5 (average of 0.26) during the first event, and variable between 0.2 and 0.8 (average of 0.53) during the second event. The ratio for the wastewater plants was greater for both events, averaging 0.76 and 0.9 for the first and second events, respectively.

Phosphorus Loading

Total phosphorus loading to the river from tributaries and WWTPs was calculated using the gaged and measured tributary flows and the average WWTP discharges (based on values in monthly operating reports). Figure 4-19 shows the total phosphorus loading from each source, for each event. Overall, during the low flow sampling, the WWTPs generally contributed more total phosphorus loading to the river than the tributaries.

The WWTPs with the highest average discharge also contributed the greatest total phosphorus loading: Manchester, Nashua, Concord Hall Street, and Winnipesaukee. This is also the case with tributaries: East Branch Pemigewasset River, Winnipesaukee River , and Nashua River. The four largest total phosphorus load contributions were greater than the others by a substantial amount, ranging from 137 to 377 lbs/day as compared with an overall average and median load of 35.7 and 9.12 lb/day, respectively. A discussion of the high flow event loading (also shown in Figure 4-19) is included in Section 4.5.5.

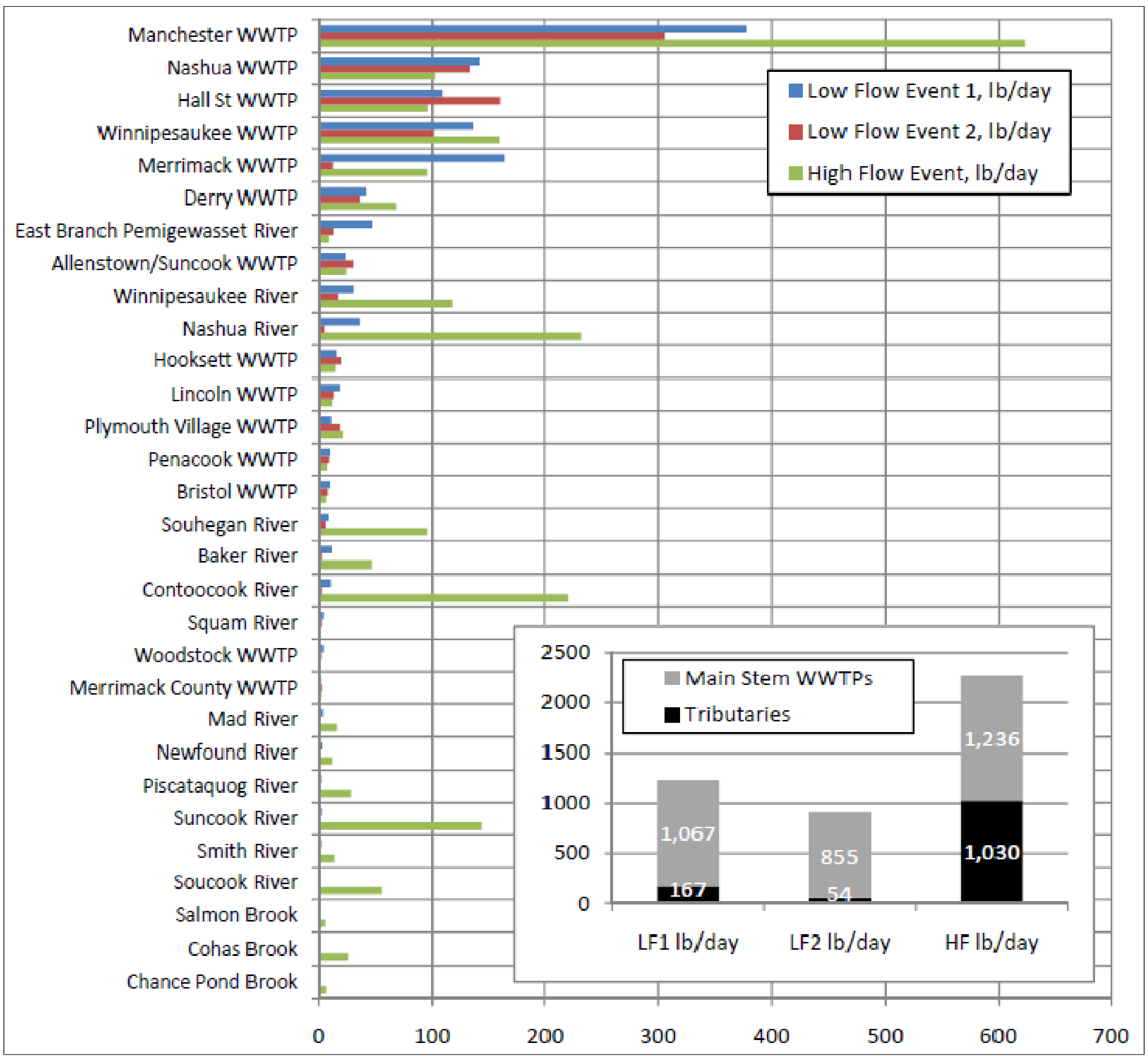


Figure 4-19: WWTP and Tributary Loading of Total Phosphorus During Low Flow Sampling

4.4.6 pH

Field readings of pH in the river were generally at neutral (7.0) upstream of the Winnipesaukee River confluence (Figure 4-20). Values in the WWTP effluent samples ranged from 6.5 to 7.6. PH dropped dramatically from 7.1 to 5.3 downstream of the Contoocook River confluence and Penacook WWTP, during the first low flow event. The Contoocook River had the lowest pH reading of all the tributaries and was lower than most of the mainstem readings at 5.6 during the first event. Also during the first event, levels of pH in the mainstem increased to above 8.0 within the Hooksett Falls impoundment, remained high until near the Souhegan River confluence, and increased again to over 9.0 downstream of Nashua River and Salmon Brook. Neither of those tributaries recorded high pH (7.2 and 7.4 respectively). PH levels during the second event were generally less variable.

4.4.7 Bacteria

New Hampshire Class B water quality standards for bacteria in freshwater are as follows: not more than either a geometric mean based on at least 3 samples obtained over a 60-day period of 126 *E. coli* per 100 mL, or greater than 406 *E. coli* per 100 mL in any one sample; and for designated beach areas not more than a geometric mean based on at least 3 samples obtained over a 60-day period of 47 *E. coli* per 100 mL, or 88 *E. coli* per 100 mL in any one sample (RSA 485-A:8).

Most river samples collected and analyzed for *E. coli* during the both low flow events had concentrations below all of the aforementioned state standards. Table 4-30 shows the frequency of samples that were above each of the four criteria.

Table 4-30: Frequency of *E. coli* Concentrations Above State Water Quality Criteria-Low Flow Events

Station Type	Number of Samples	60-Day Mean, Freshwater Beach	Single Sample, Freshwater Beach	60-Day Mean, Class B Freshwater	Single Sample, Class B Freshwater
		47 mpn/100 mL	88 mpn/100 mL	126 mpn/100 mL	406 mpn/100 mL
Mainstem	81	22%	1%	0%	0%
Tributary	21	57%	38%	24%	5%

The highest bacteria concentration was observed in the Souhegan River sample during the second low flow event: 2,190 mpn/100mL. This sample was an order of magnitude above all other samples.

4.5 High Flow Data Summary and Observations

The following sections offer summaries of the data collected during the high flow event and preliminary observations. Fold-out panels containing plots of the data described herein can be found at the end of Section 4 along with the low flow data; complete data tables can be found in Appendix B.

4.5.1 Carbonaceous Biological Oxygen Demand

Concentrations of $CBOD_5$ in the river were mostly non-detect (detection limit 3.0 mg/L; see Figure 4-7). The exceptions were at sampling locations in the Soucook River (4.0 mg/L) and upstream of the Hooksett WWTP/downstream of the Soucook River (4.0 mg/L).The slightly elevated $CBOD_5$ in the Soucook River likely caused the elevated concentration downstream in the main stem. There are no known point sources of CBOD on the Soucook River. Concentrations of $CBOD_5$ in the WWTP effluents were generally in the range that would be expected from permitted wastewater discharges and generally less than the concentrations measured during the 2010 low flow events: from approximately 3.0 mg/L to 9.0 mg/L (when detected).

$CBOD_{20}$ concentrations at all stations were nondetect (detection limit 3.0; see Figure 4-8). Concentrations of $CBOD_{20}$ in the WWTP effluents ranged from 7.0 mg/L to 20 mg/L.

During the low flow events, the Hooksett WWTP had notably higher levels of CBOD than the other main stem WWTPs. This was not the case during the high flow sampling. As with the other plants, Hooksett showed less than 9.0 mg/l $CBOD_5$ and less than 20 mg/l $CBOD_{20}$.

4.5.2 Chlorophyll-a

Samples were analyzed for chlorophyll-a only at select locations because the project team did not anticipate high algal growth during high flow or during the cooler season in which high flow sampling was conducted. Chlorophyll-a concentrations increased slightly from upstream to downstream along the Pemigewasset and Upper Merrimack Rivers during the high flow event (Figure 4-9). This trend was also observed in the impoundments studies of 2009, the low flow events in 2010, and in the data collected on the Lower Merrimack River as part of the 2006 Merrimack River Watershed Assessment Study. Concentrations ranged from 0.5 to 2.6 ug/L in the mainstem riverine samples; levels well below the NH state guidance threshold and what would be considered significant algal growth.

4.5.3 Dissolved Oxygen and Temperature

Dissolved Oxygen

Dissolved oxygen levels in the river were measured *in situ* using YSI field meters and in the lab using Winkler titration. Winkler titration values are typically more accurate that field meters, providing the sampler does not introduce additional air into the water sample while filling the bottle. Field crews were trained in this sampling procedure, but inadvertent air introduction is a risk when filling Winkler bottles in the field. Both the field measured values and the Winkler titration values are shown in Figures 4-10 and 4-11 to give a comprehensive portrayal of the dissolved oxygen conditions in the river.

Concentrations of dissolved oxygen measured during the high flow event in the main stem river were generally at or near saturation, ranging from 8.3 mg/L (88% saturation) to above 100% air saturation (Figures 4-10 and 4-11). The concentrations measured in the tributaries ranged from 6.5 mg/l (67% saturation) to above 100% air saturation. No field readings or Winkler samples showed concentrations less than the NH Class B water standard of 5 mg/L. The lowest percent saturation measurement in the main stem was recorded in the Ayers Island impoundment, directly behind the dam, at 84% (8.4 mg/l). The only measurement below the NH average daily standard of 75% was in the Squam River at 67% (6.5 mg/l).

Temperature

During the high flow, temperatures in the upstream reaches of the study area were lower than in the downstream reaches where the lesser streambed slope results in a wider, slower moving river (Figure 4-14). The temperatures observed through the majority of the river during the high flow event were colder than during the two low flow events. The average mainstem water temperature upstream of the Pemigewasset and Winnipesaukee Rivers confluence was 12.9°C. The average water temperature downstream of the confluence was 15.2°C. Tributaries entering the mainstem upstream of the Winnipesaukee River were also colder on average than those entering downstream: 13.2°C and 17.2°C, respectively.

Temperatures decreased 1.8°C from upstream to downstream of Ayers Island Dam during the high flow sampling event. No other discernible temperature changes were observed at the other dams.

4.5.4 Nitrogen

Total nitrogen concentrations generally increased from upstream to downstream within the study area (Figure 4-15). The range of observed total nitrogen concentrations are presented in Table 4-31.

Nitrogen concentrations increased significantly from upstream to downstream of the Plymouth Village WWTP (0.43 to 0.75 mg/l), downstream of the Winnipesaukee WWTP (0.36 to 0.58 mg/l), and from upstream to downstream of the Hooksett WWTP (0.59 to 0.84 mg/l). Main stem impoundment, main stem riverine, and tributary concentrations were comparable to the low flow events; WWTP discharge concentrations tended to be higher during the high flow sampling.

Table 4-31: Total Nitrogen Concentrations for High Flow Event #1 (mg/L)

Location Type	Minimum	Maximum	Average
Mainstem Impoundment	0.49	0.84	0.59
Mainstem Riverine	0.36	1.00	0.60
Tributary	0.31	1.78	0.65
WWTP Effluent	7.80	50.51	31.0

Note: Detection Limit = 0.01 mg/L.

4.5.5 Phosphorus

Total phosphorus concentrations generally increase from upstream to downstream within the study area, as was observed during the 2009 impoundment studies and two low flow events. Figure 4-16 shows the total phosphorus concentrations along the river as well as guidance values provided by EPA for streams (0.10 mg/L), streams flowing into impoundments (0.05 mg/L), and waters within impoundments (0.025 mg/L); the value used by New Hampshire for lakes (0.012 mg/l); and the value used in Maine for wadeable streams (0.03 mg/l). These values are not NH state standards and are meant for only comparative purposes. A summary of the observed total phosphorus concentrations is shown in Table 4-32.

While the total phosphorus concentrations observed during the high flow event followed the same trend of increasing from upstream to downstream as was observed in the low flow events, the concentrations were lower. Total phosphorus observed in the main stem ranged from 0.003 mg/l to 0.03 mg/l, and from non-detect to 0.031 mg/l in the tributaries.

The increased spring streamflow was caused by a combination of runoff and increased groundwater baseflow. These sources likely diluted the phosphorus concentrations in the river. The high flow event is not an accurate characterization of the watershed runoff, as the event was not conducted during a rain event, background concentrations were not established, and there is no reliable method to separate the instream concentration resulting from runoff versus other sources. The high flow data will be used to validate the water quality model.

Table 4-32: Total Phosphorus Concentrations for High Flow Event #1 (mg/L)

Location Type	Minimum	Maximum	Average
Mainstem Impoundment	0.008	0.019	0.013
Mainstem Riverine	0.003	0.030	0.014
Tributary	ND	0.031	0.017
WWTP Effluent	1.16	7.22	3.30

Note: Detection Limit = 0.00155 mg/L

Orthophosphates

Measuring orthophosphates along with total phosphorus in the river gives an idea of how much of the nutrient is bioavailable for algal growth (Figure 4-17). Orthophosphate is the inorganic, dissolved portion of phosphorus, and is bioavailable. Typically the fraction of total phosphorus that is orthophosphate in rivers is 0.5, but it can vary depending on the sources of phosphorus and the algal activity.

The orthophosphate concentrations observed in the river during the high flow event were generally low, and less than those observed during the low flow events. The ratio of orthophosphate:total phosphorus was also lower at most locations in the main stem during the high flow event than during the low flow events. This ratio was highest throughout the river, and particularly downstream of the Winnipesaukee River confluence and in Concord and Manchester, during the second low flow event. During all three events, the ratio of orthophosphate:total phosphorus was higher in the far upstream reaches of the Pemigewasset River, then decreasing towards the Winnipesaukee River confluence.

The average ratio of orthophosphates to total phosphorus (Figure 4-18) during the high flow event was 0.26 in the main stem river and tributaries. The average ratio for wastewater plants during the high flow event was 0.78, between that of the two low flow events

Phosphorus Loading

Total phosphorus loading to the river from tributaries and WWTPs was calculated using the gaged and measured tributary flows and the average WWTP discharges (based on values in monthly operating reports). Figure 4-19 in Section 4.4 shows the total phosphorus loading from each source, for each event. Overall, during the low flow sampling, the WWTPs generally contributed more total phosphorus loading to the river than the tributaries. However, the contributions were nearly equal during the high flow event. The same four WWTPs contributed the greatest loads, as compared to other plants (Manchester, Winnipesaukee, Nashua, and Concord Hall St. However, large tributaries contributed more significant loads to the main stem during the high flow event than during the low flow event. Five of the top ten phosphorus loads during the high flow event were major tributaries: Nashua River, Contoocook River, Suncook River, Winnipesaukee River, and Souhegan River. The increased tributary loads are attributed to increased flows in the streams during the high flow event; phosphorus concentrations in the streams were generally lower.

4.5.6 pH

Field readings of pH in the river for the high flow event were generally lower than for the low flow events, ranging from 4.9 to 8.1 (Figure 4-20). PH drops were observed downstream of the Eastman Falls Dam and the Souhegan River. An steady increase in pH from approximately 6.5 to 8.1 was observed in Manchester, downstream of the

Amoskeag Dam to downstream of the Manchester WWTP. The lowest pH value (4.9) was observed in the main stem in Campton, upstream of the Mad River.

4.5.7 Bacteria

Fewer bacteria samples were collected during the high flow sampling event than the low flow sampling events. In total, 9 bacteria samples were collected during high flow: 6 main stem and 3 tributary. This sample set is not adequate to develop broad generalizations comparing low flow with high flow bacteria counts.

New Hampshire Class B water quality standards for bacteria in freshwater are as follows: not more than either a geometric mean based on at least 3 samples obtained over a 60-day period of 126 *E. coli* per 100 mL, or greater than 406 *E. coli* per 100 mL in any one sample; and for designated beach areas not more than a geometric mean based on at least 3 samples obtained over a 60-day period of 47 *E. coli* per 100 mL, or 88 *E. coli* per 100 mL in any one sample (RSA 485-A:8).

Most river samples collected and analyzed for *E. coli* during the high flow event had concentrations below all of the aforementioned state standards. Table 4-33 shows the frequency of samples that were above each of the four criteria.

Table 4-33: Frequency of *E. coli* Concentrations Above State Water Quality Criteria- Low Flow Events

Station Type	Number of Samples	60-Day Mean, Freshwater Beach	Single Sample, Freshwater Beach	60-Day Mean, Class B Freshwater	Single Sample, Class B Freshwater
		47 mpn/100 mL	88 mpn/100 mL	126 mpn/100 mL	406 mpn/100 mL
Mainstem	6	17%	0%	0%	0%
Tributary	3	67%	33%	0%	0%

Similar to the second low flow event, the highest bacteria concentration was observed in the Souhegan River sample, 111 mpn/100mL. This result was an order of magnitude less than the concentration measured during the second low flow event, but several hundred mpn greater than the concentration measured during the first low flow event.

Figure 4-7 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
CBOD 5

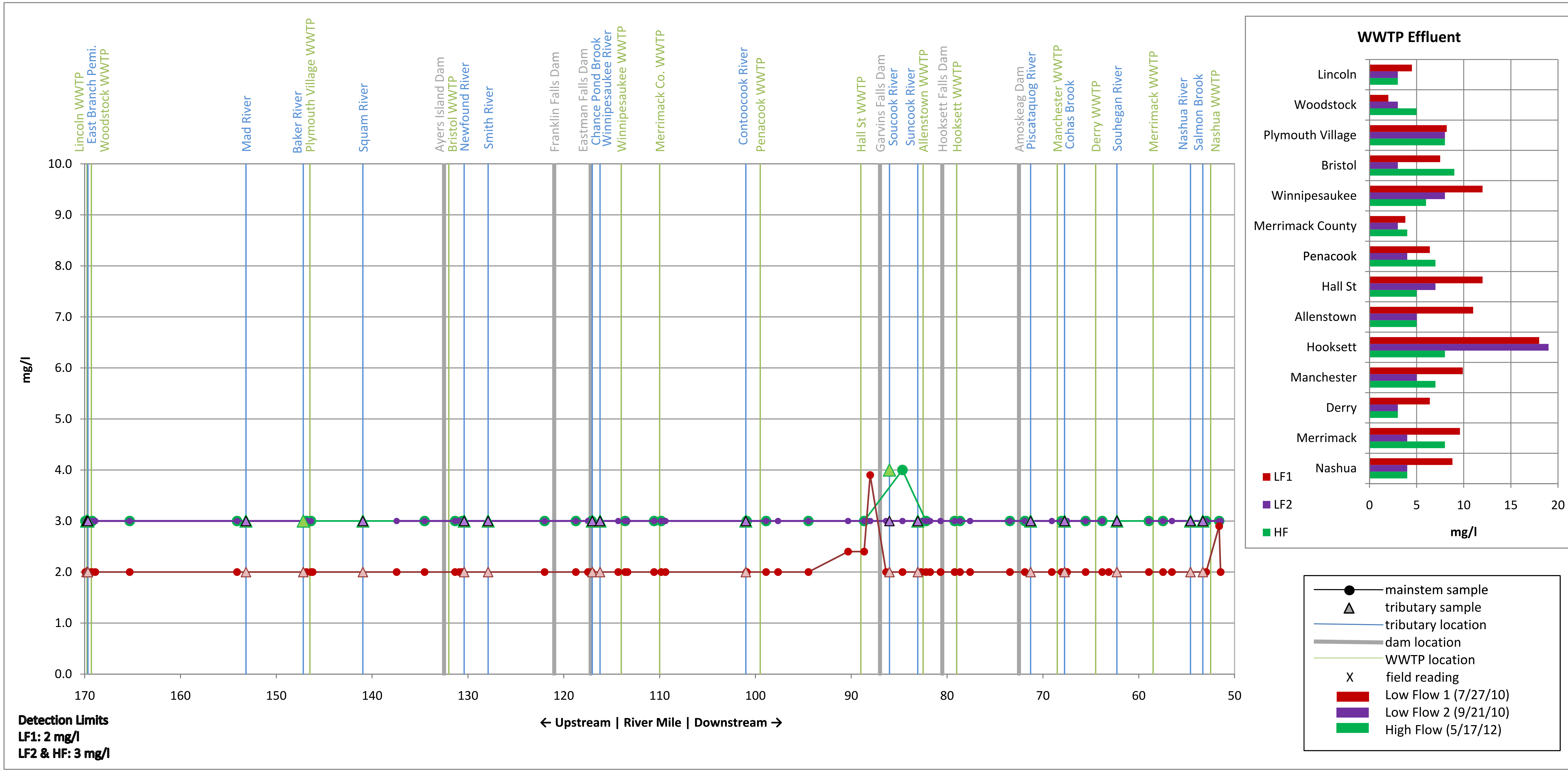


Figure 4-8 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
CBOD 20

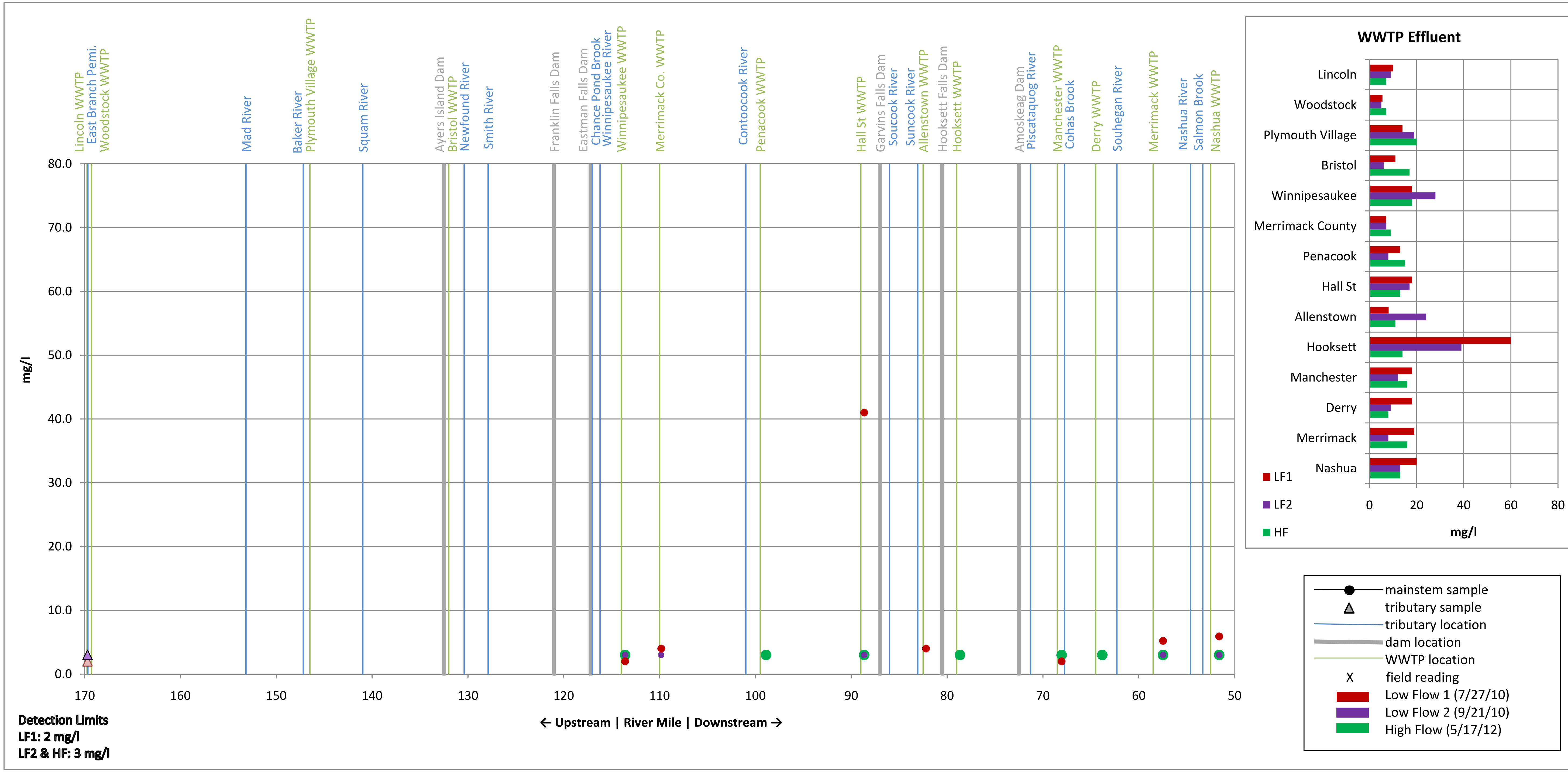


Figure 4-9 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Chlorophyll-a

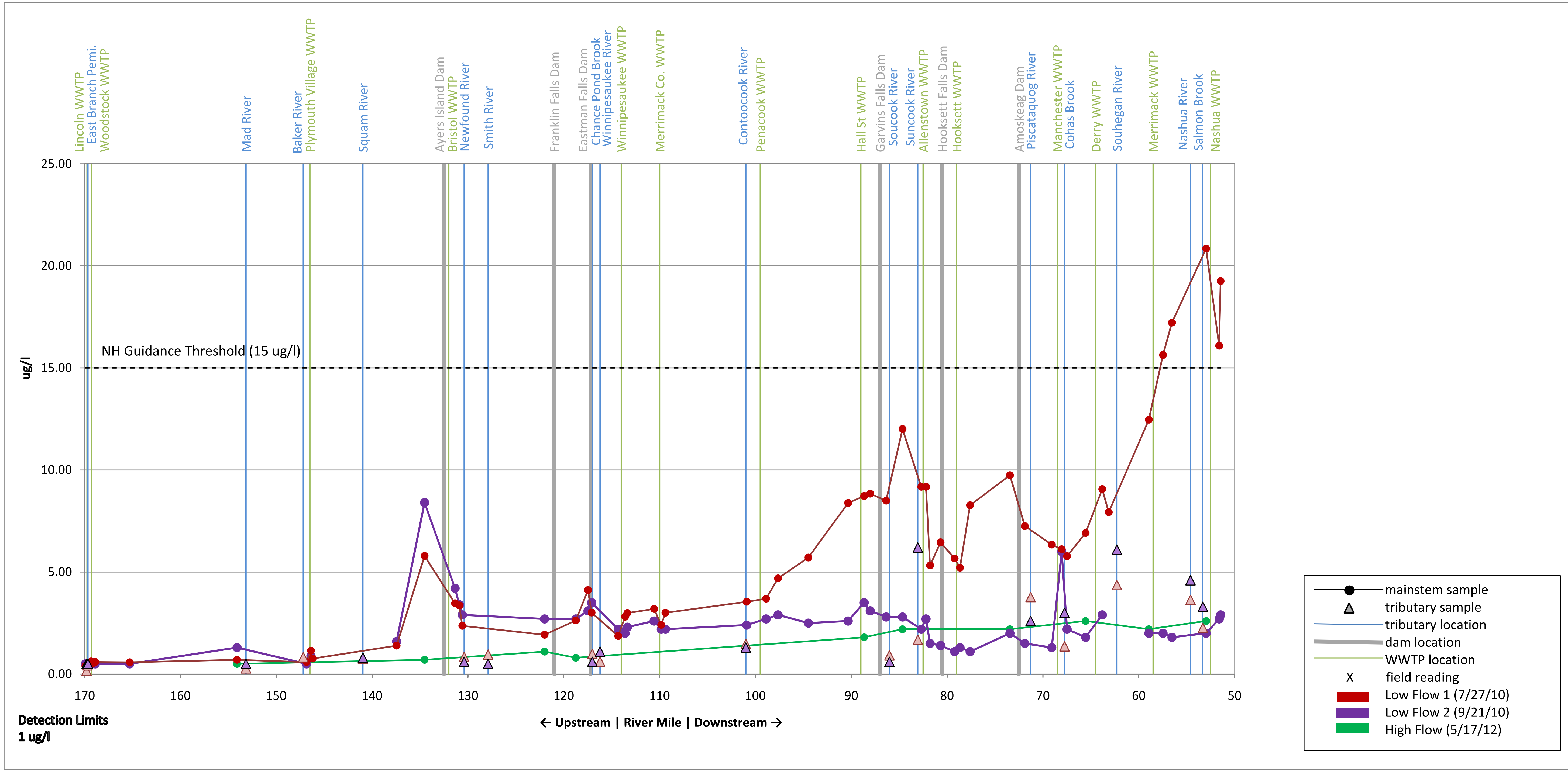


Figure 4-10 Low Flow Event Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Dissolved Oxygen Concentration

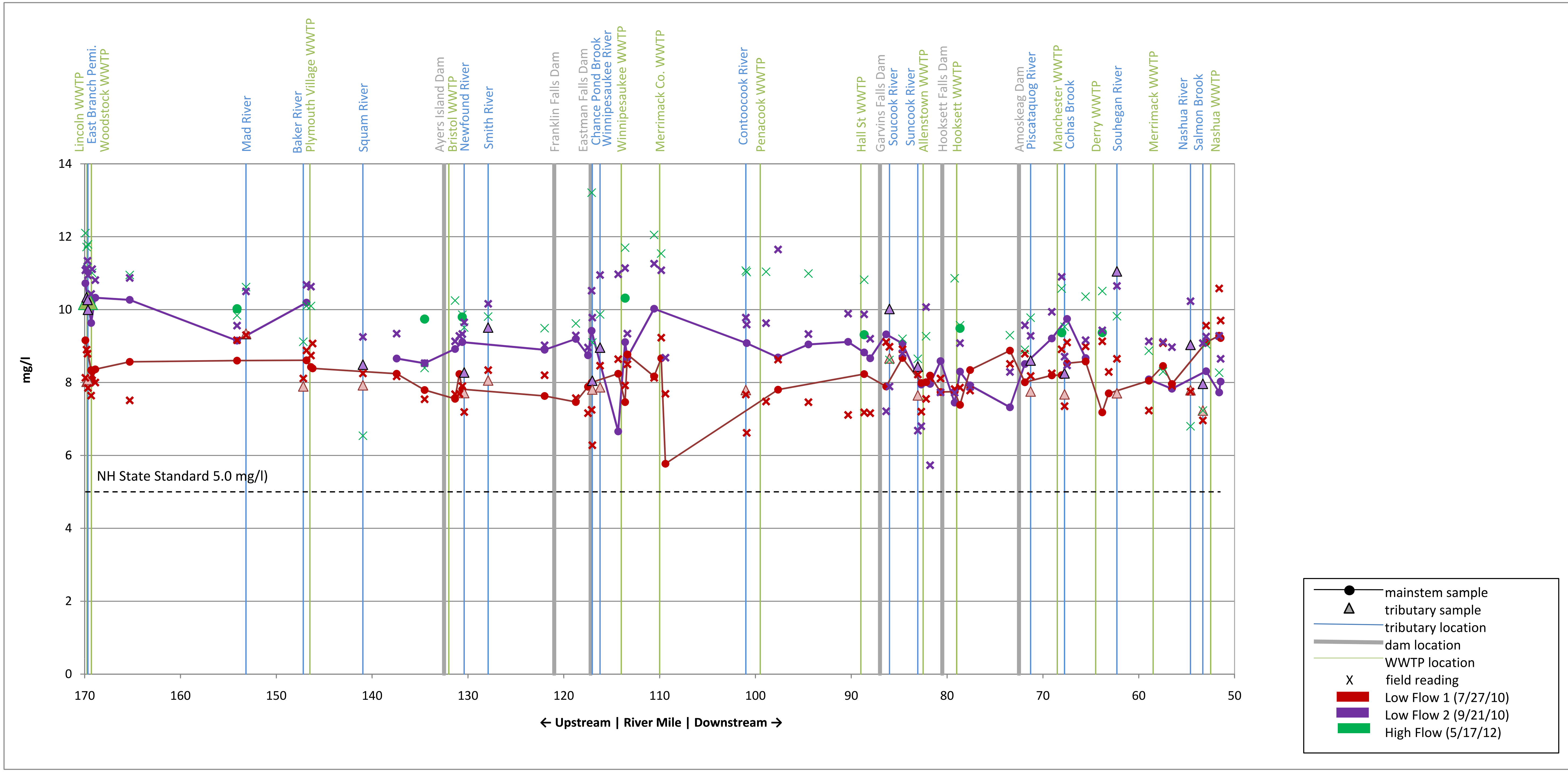


Figure 4-11 Low Flow Event Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Dissolved Oxygen Percent Saturation

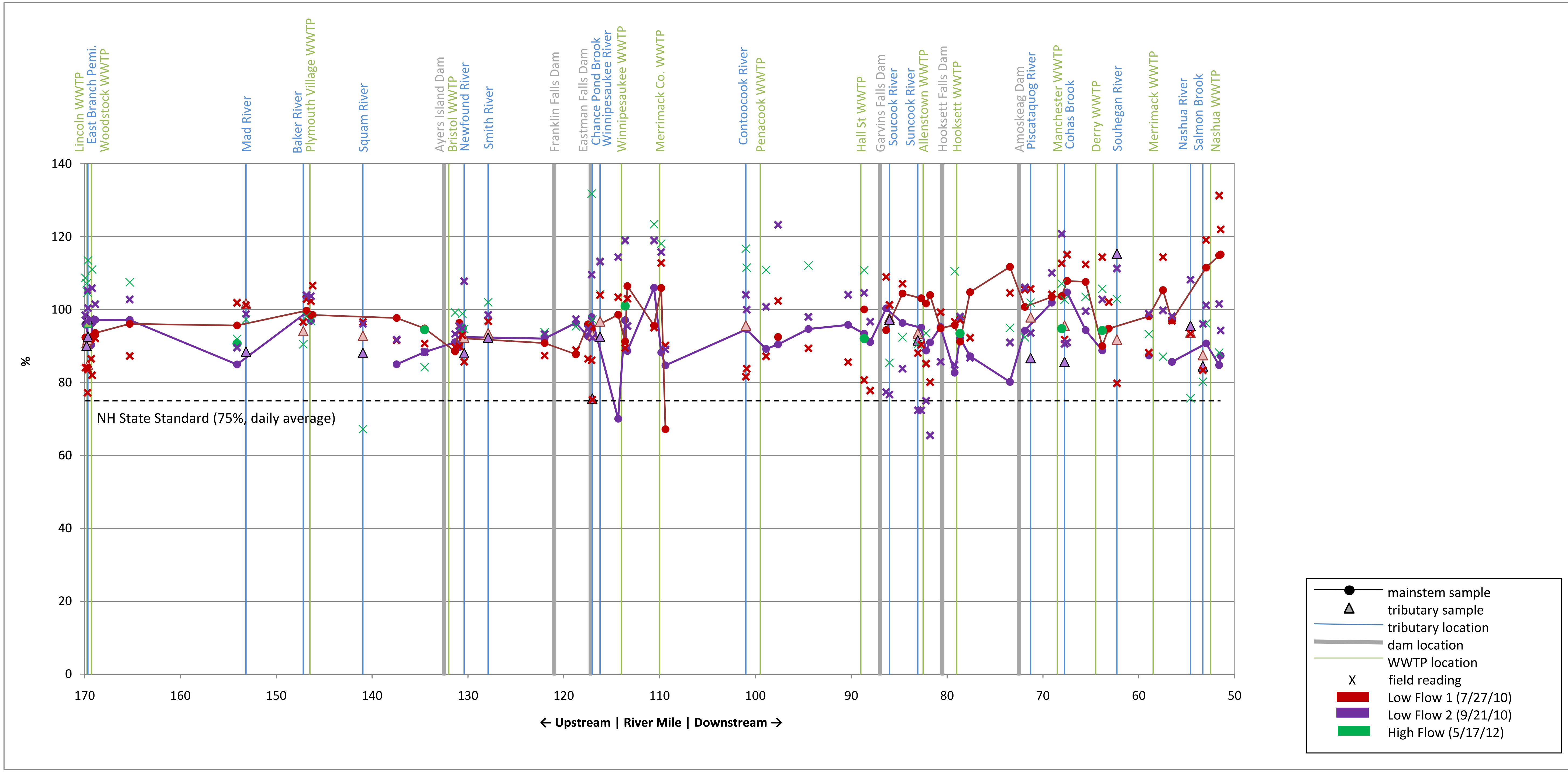


Figure 4-14 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Temperature

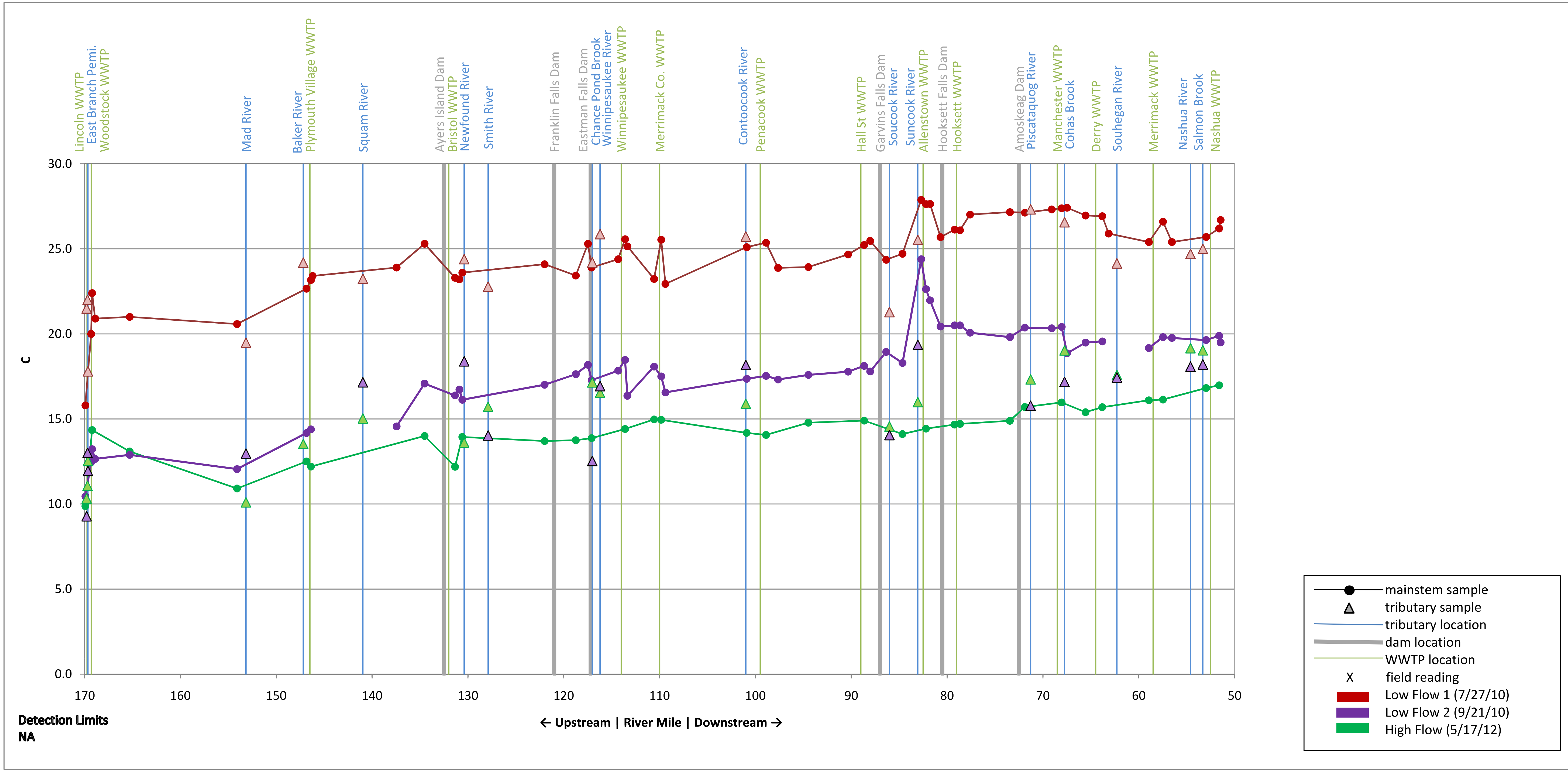


Figure 4-15 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Total Nitrogen

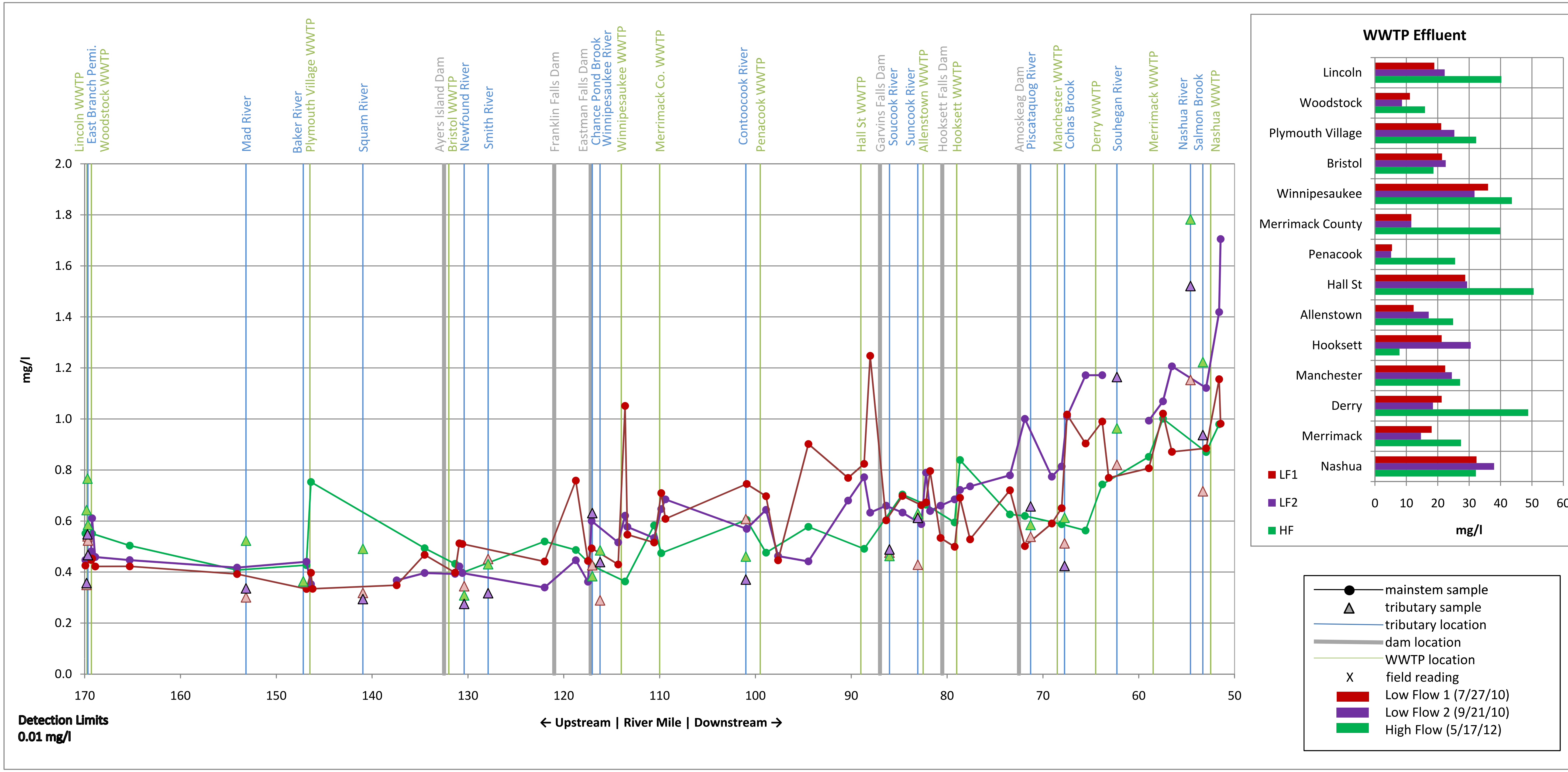
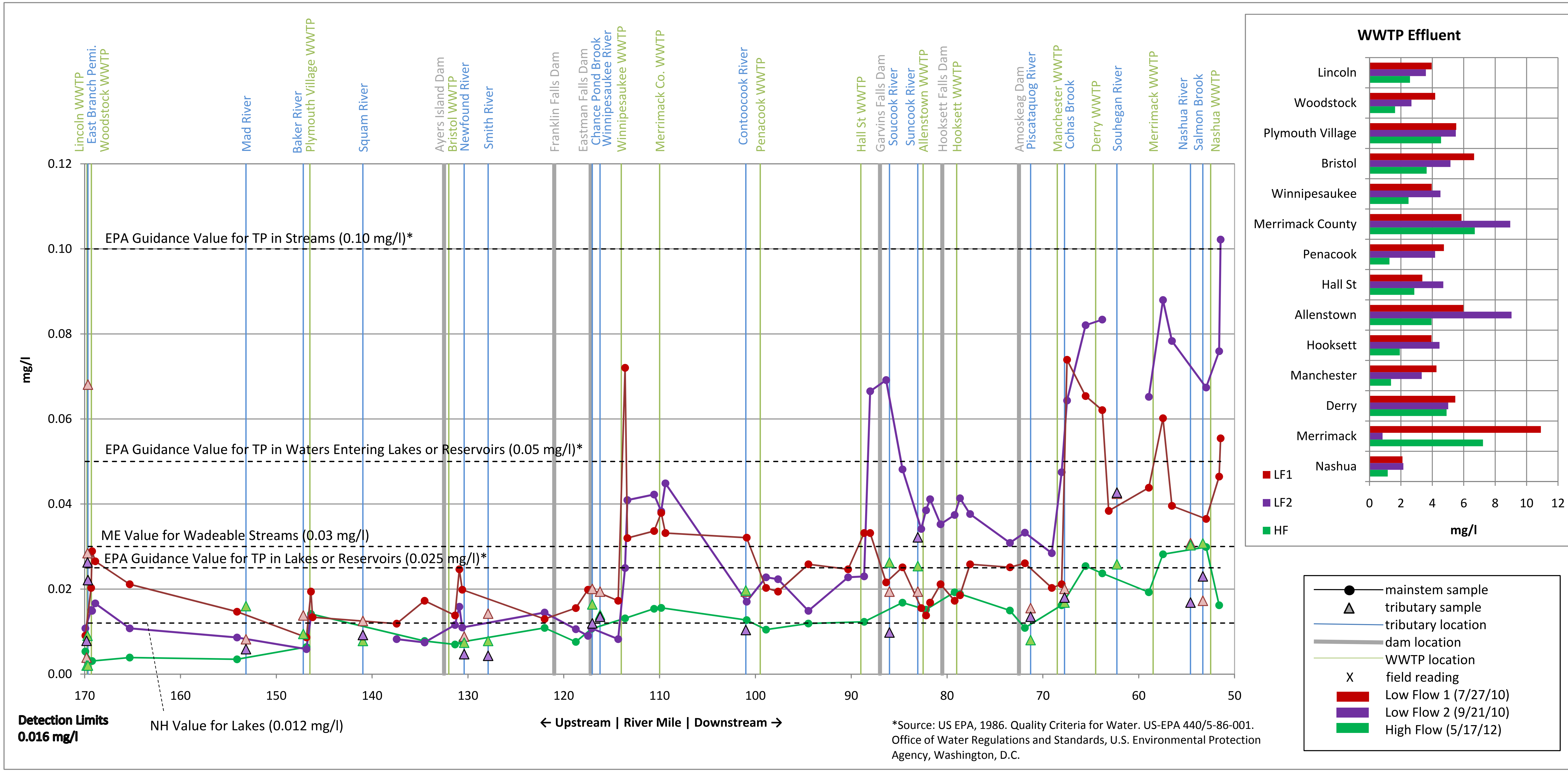


Figure 4-16 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Total Phosphorus



*Source: US EPA, 1986. Quality Criteria for Water. US-EPA 440/5-86-001. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, D.C.

Figure 4-17 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Orthophosphates

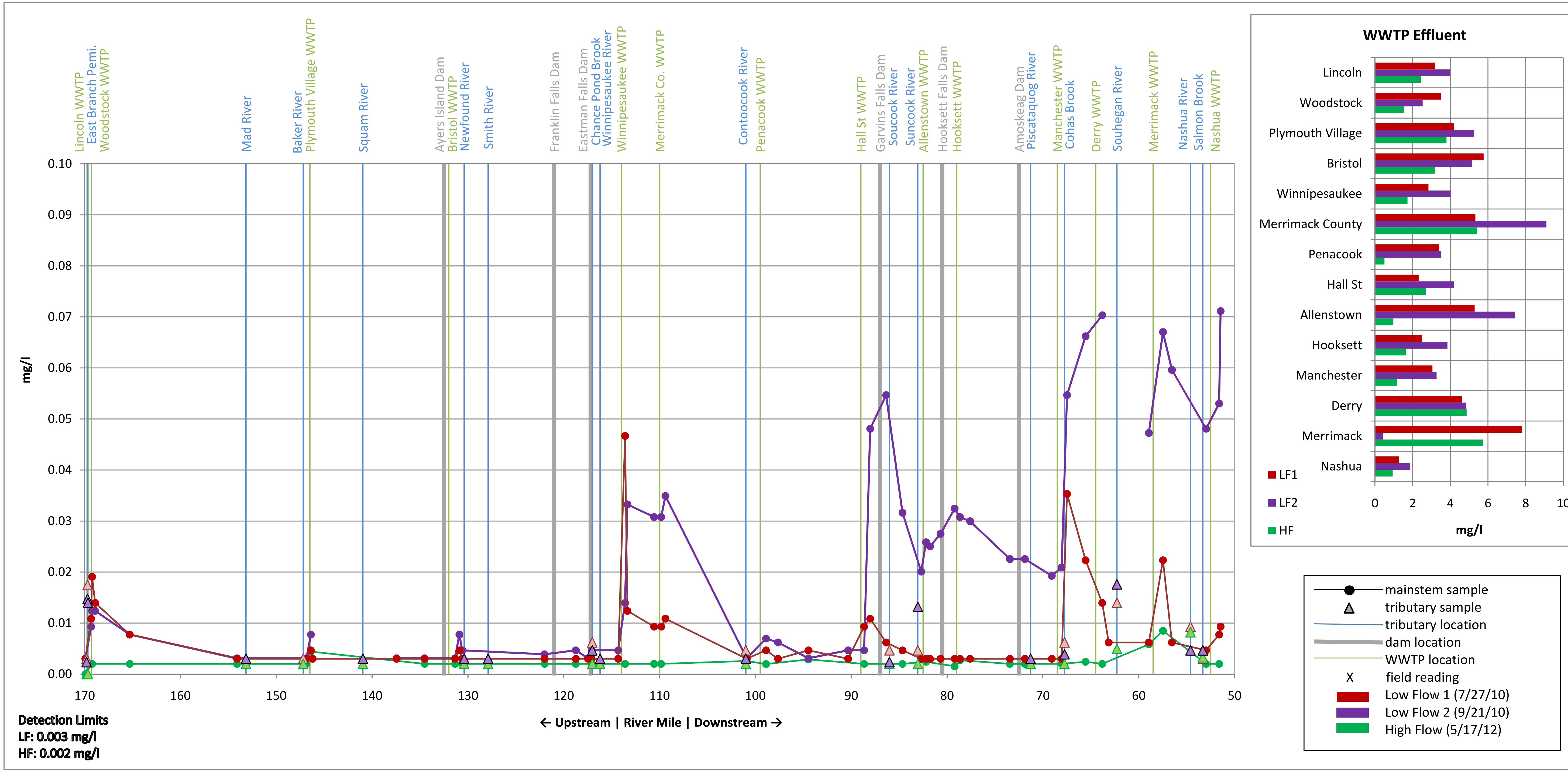


Figure 4-18 Low Flow Event Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
Orthophosphates : Total Phosphorus Ratio

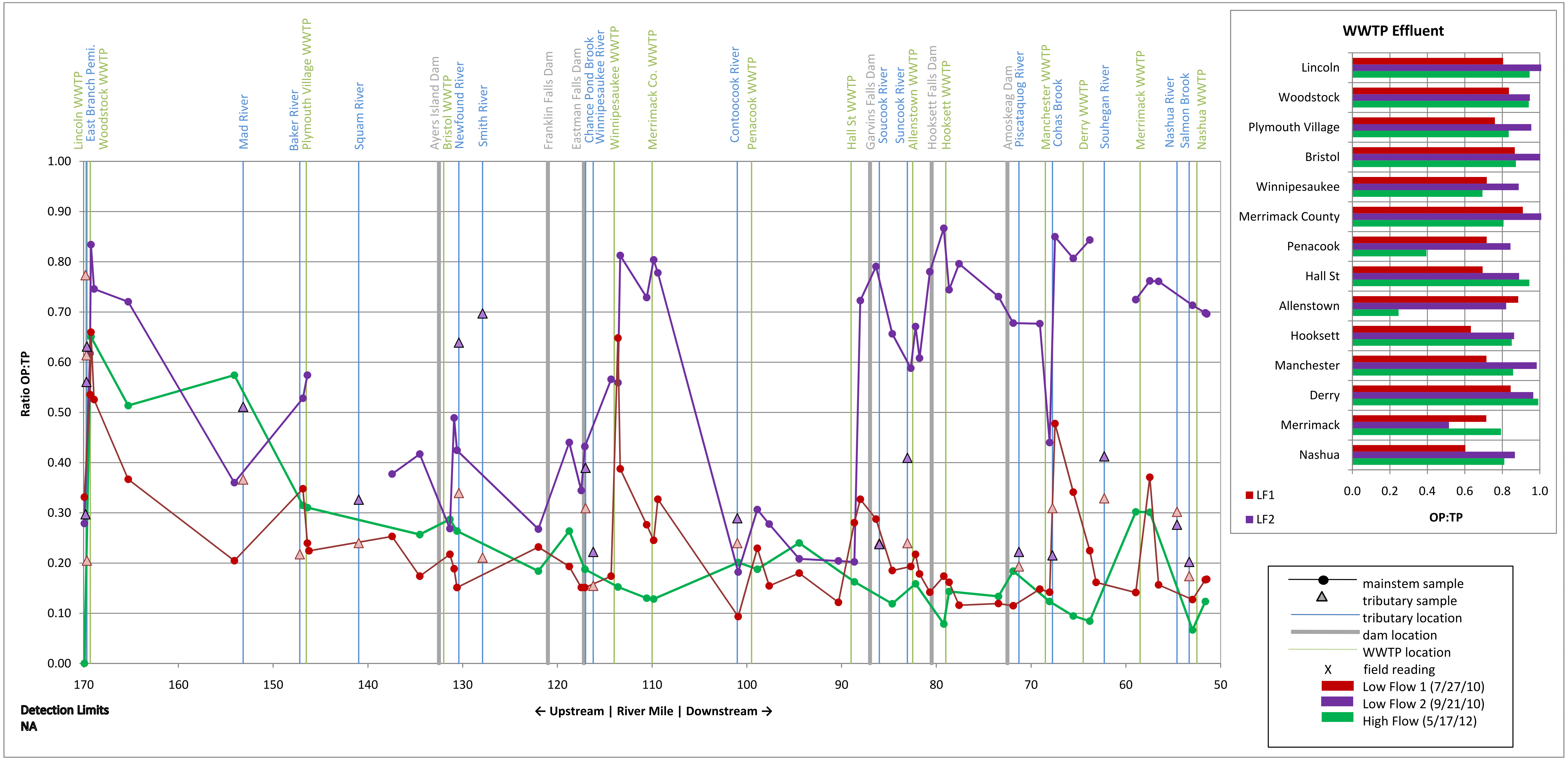
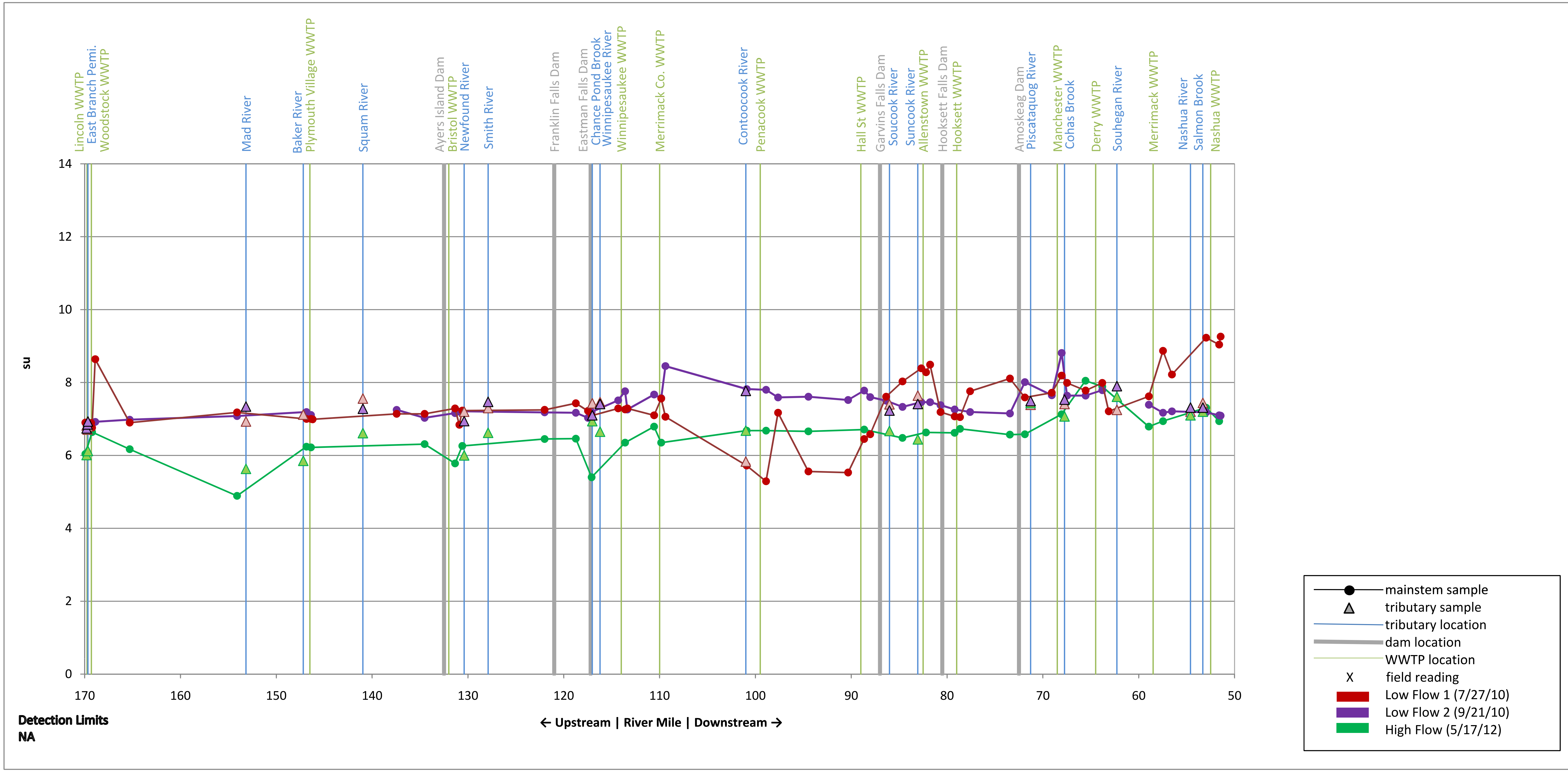


Figure 4-20 Water Quality Results
Mainstem, Tributary, and WWTP Effluent Samples
pH

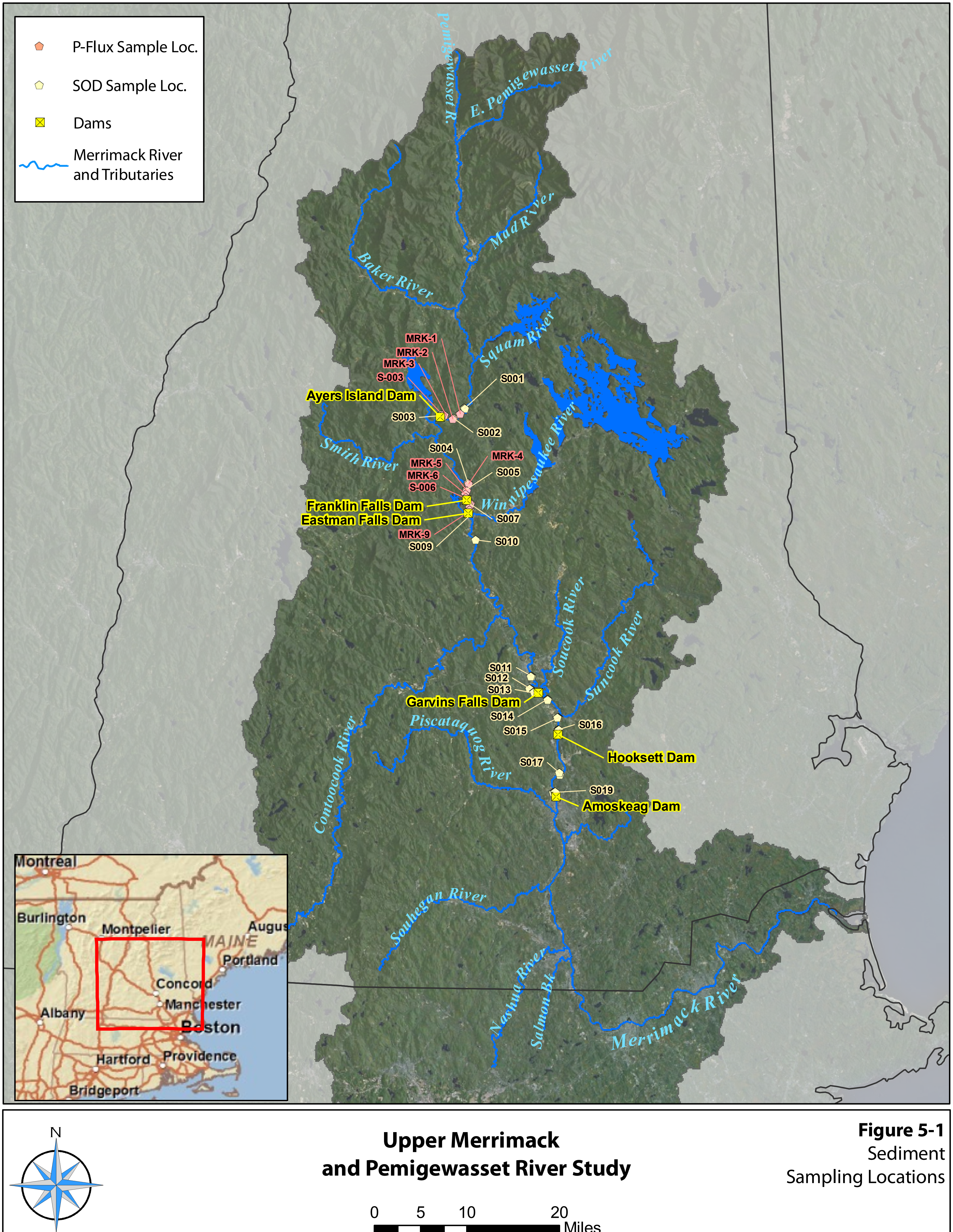


Section 5
Sediment Flux Sampling

Sediment sampling was conducted at the end of summer and early fall of 2009. Sampling cores were collected on September 1 and 2, 2009 for sediment phosphorus flux (p-flux) and in the first two weeks of October 2009 for sediment oxygen demand (SOD). Table 5-1 lists the sediment sampling stations and descriptions of their approximate locations. Figure 5-1 shows the sediment sampling locations within the study area; more detailed maps are provided in Appendix A and in the sediment analysis reports in Appendix E and Appendix F.

Table 5-1: Sediment Sampling Stations

Station ID	Location	SOD Analysis	P-Flux Analysis	Alternative ID
S001	Ayers Island 1	X	X	MRK1
S002	Ayers Island 2	X	X	MRK2
S003	Ayers Island 3	X	X	MRK3
S004	Franklin Falls 1	X	X	MRK4
S005	Franklin Falls 2	X	X	MRK5
S006	Franklin Falls 2		X	MRK6
S007	Eastman Falls 1	X	X	MRK7
S008	Eastman Falls 1		X	MRK8
S009	Eastman Falls 3	X	X	MRK9
S010	D/S Winnipesaukee	X		
S011	Garvins Falls 1	X		
S012	Garvins Falls 2	X		
S013	Garvins Falls 3	X		
S014	Hooksett 1	X		
S015	Hooksett 2	X		
S016	Hooksett 3	X		
S017	Amoskeag 1	X		
S018	Amoskeag 2			
S019	Amoskeag 3	X		
S020	Nashua Impairment	X		
S001	Ayers Island 1	X		



Upper Merrimack and Pemigewasset River Study

Figure 5-1
Sediment Sampling Locations

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5.1 Description of Field Activities

Sediment cores were collected for analysis of SOD and nutrient flux. Two field crews collected and analyzed sediment cores: EPA and SMAST. The EPA-collected cores were collected with a gravity type Wildco K-B Core Sampler. The EPA cores were analyzed for SOD and grain size distribution. The SMAST field crews collected 15 cm diameter cores with SCUBA divers, which were held at ambient water temperature and analyzed for SOD and nutrient flux. SMAST cores with evidence of disturbance were discarded and recollected.

EPA field crews collected cores from the stations listed in Table 5-1 under SOD Analysis. In three of the six impoundments, two stations rather than three were sampled due to access restrictions and proximity to other coring locations. The EPA core locations are shown in Appendix A, labeled with S0## designation.

SMAST field crews collected cores from the upstream impoundments only due to high flow conditions affecting the safety of divers. These locations are listed in Table 5-1 under P-Flux Analysis and have been give alternative IDs (MRK#). SMAST field crews collected cores only from the three upstream impoundments due to high flows in the river during the summer of 2009. The maps in Appendix A show the SMAST cores labeled with the MRK designation.

5.2 Data Summary and Observations

5.2.1 Sediment Nutrient Flux

The p-flux rates for the sites sampled and analyzed by SMAST in September 2009 are shown in Figure 5-2. The different bars represent the aerobic and anaerobic phases of phosphorus uptake/release, with error brackets showing one standard deviation for the data. Positive values indicate p-flux from the sediment to the overlying water; negative values indicate uptake of phosphorus from the water by the sediment. Phosphate (inorganic phosphorus) flux is shown in the top graph and total dissolved phosphorus flux is shown in the bottom. The following are observations from the p-flux analysis of cores taken in Ayers Island, Franklin Falls, and Eastman Falls impoundments:

- Water column oxygen concentrations at the sediment coring locations were at or near air saturation values.

- Water column nutrients showed N:P ratios (nitrate+nitrite+ammonium:phosphate) higher than typical freshwater N:P ratios.

- Aerobic nutrient fluxes showed an overall decreasing trend from the upstream to downstream impoundments.

- Total dissolved phosphorus flux release was observed at four locations: two within the Ayers Island impoundment and two within the Franklin Falls impoundment.

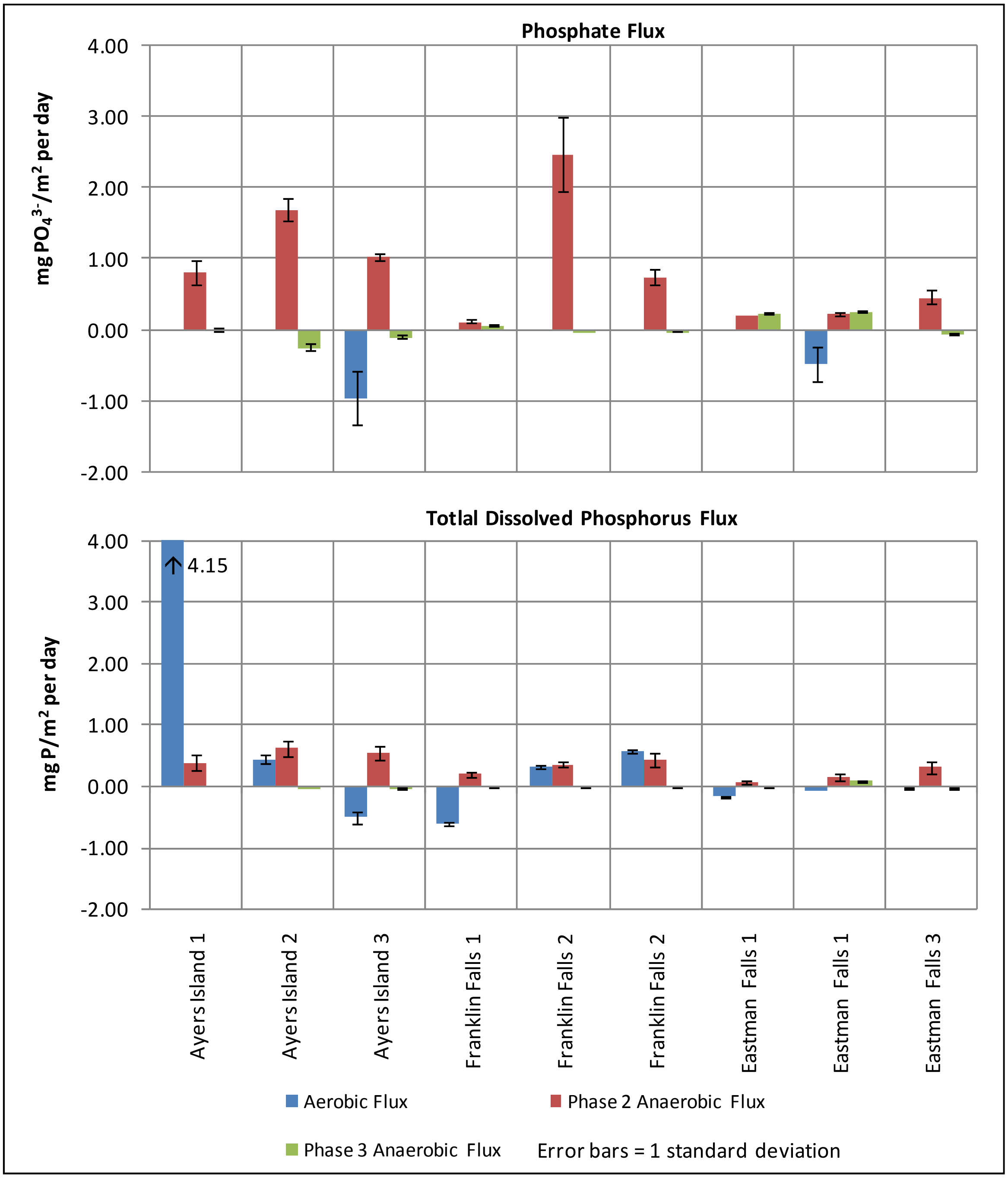
The highest rate of release from the sediments was observed in the furthest station upstream of Ayers Island Dam, 4.15 mg P/m^2 per day.

- Anaerobic phosphate flux release was observed at all locations, though at low levels (<0.5 mg PO_4^{3-}/m^2 per day) in Eastman Falls impoundment and the most upstream location within Franklin Falls impoundment.

- Compared to other rivers in the region where p-flux has been discovered as a significant load of phosphorus to the riverine system (e.g. Assabet River in Massachusetts), the rates found in the Pemigewasset impoundments were low.

- There was no clear trend in p-flux approaching a dam, with rates generally uniform and low.

Figure 5-2: Sediment Phosphorus Flux Rates



Phase 1: Micro-aerobic and anaerobic microbial regeneration processes modified by changing sediment redox conditions and competitive inhibition by other available respiration pathways

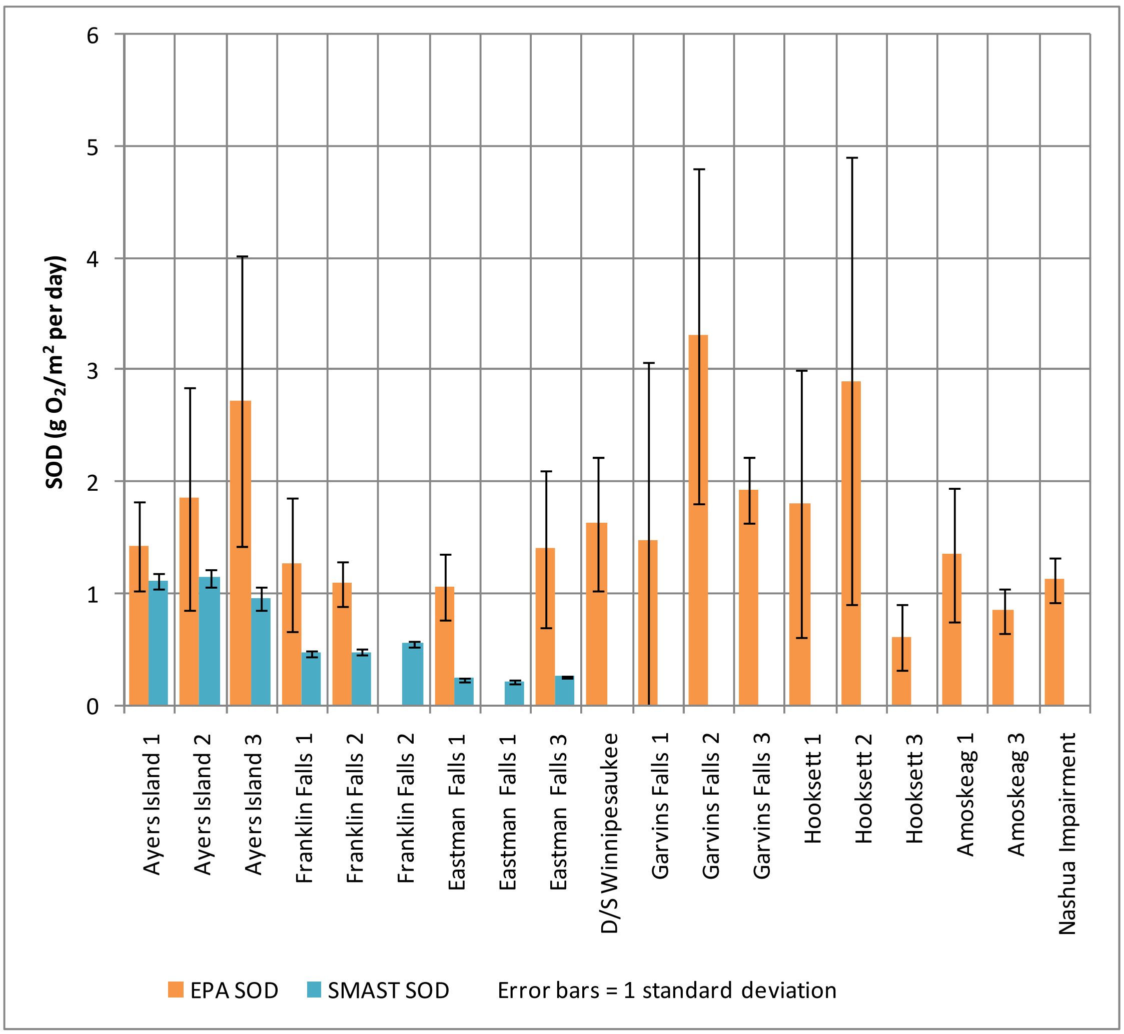
Phase 2: Anaerobic microbial regeneration of organic phosphorus and chemical release of inorganically bound phosphate

Phase 3: Anaerobic microbial regeneration of remaining labile organic matter in the sediment after release of chemically bound phosphorus has ceased

5.2.2 Sediment Oxygen Demand

SOD rates were included in the nutrient flux analysis by SMAST for the cores in the upstream three impoundments. According to the SMAST core results for the upstream three impoundments, SOD levels followed a decreasing trend from the upstream impoundment to the downstream. It is unclear whether this was due to sediment accumulation in upstream impoundments or different river conditions within the impoundments. The EPA cores loosely followed this trend for the upstream three impoundments, but showed higher SOD levels in the downstream impoundments (that were not sampled by SMAST). Figure 5-3 shows the results of SOD measurements made by EPA in all six impoundments and two riverine stations, and by SMAST in the upstream three impoundments.

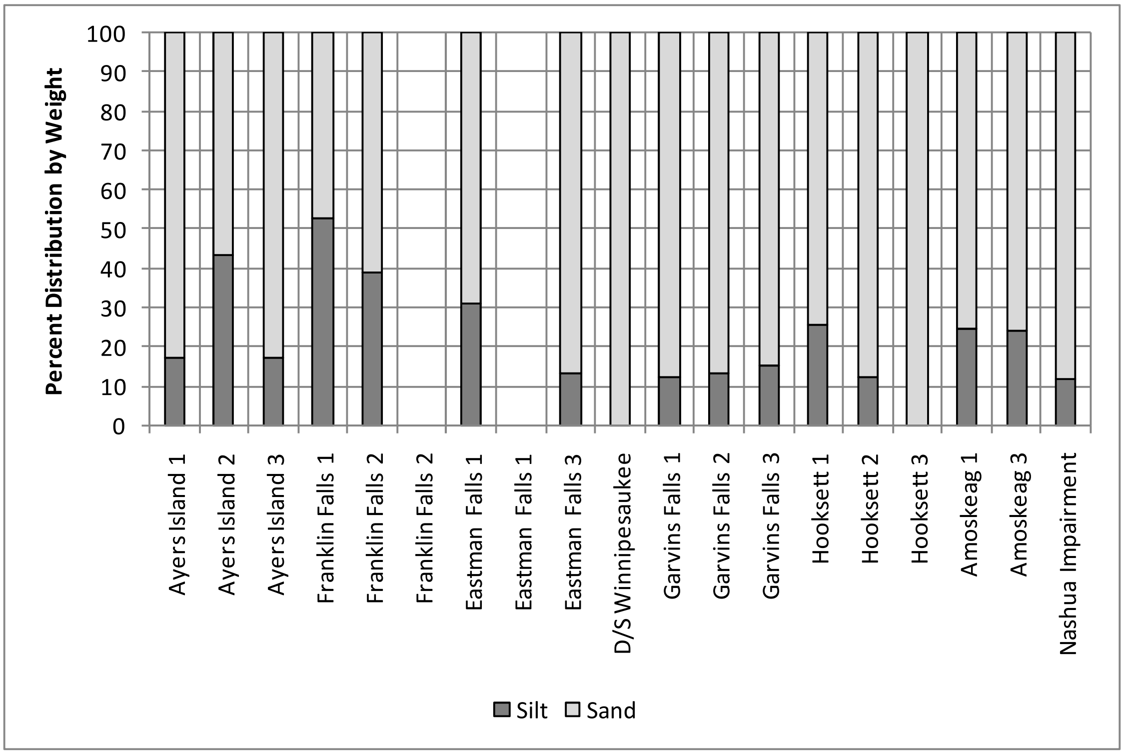
Figure 5-3: Sediment Oxygen Demand Rates



5.2.3 Grain Size Distribution

Figure 5-4 shows the grain size distribution by weight of sediments collected from the six impoundments and two riverine stations. In general the grain size distribution indicates a very sandy environment. The highest percentage of silt and clay was observed in the Franklin Falls impoundment (53%).

Figure 5-4: Grain Size Distribution by Weight



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