Organization for the Assabet River

Water Quality Monitoring Program
Final Report - Summer 2001

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Acknowledgments

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Cover photos: Volunteers and the Assabet at Chapin Road, Hudson, by Pru Stuhr.

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Table of Contents

List of Figures and Tables

Abstract

In 2001 the Organization for the Assabet River monitored water quality in the Assabet River between June and October, continuing to build the database of water quality information, which informs OAR's advocacy for the river. Dissolved oxygen (DO) and nutrient concentrations indicative of eutrophication were found throughout the river.

Streamflows dropped relative to mean monthly flows over the summer of 2001. Flows measured at the USGS Maynard gage during the June and July samplings were close to mean monthly flow, but in August, September and October, flows were only about half the monthly means. The low flows in the late summer were reflected in lower dissolved oxygen and higher nutrient concentrations relative to measurements in 2000.

In general, the nutrient concentrations in 2001 were, again, well above the thresholds for eutrophication for both phosphorus and nitrogen species and were higher in the upper reach of the river where wastewater treatment plant effluent is least diluted by natural flow.
In June and July '01, DO concentrations were above the Class B water quality standard (WQS; 5.0 mg/L and 60% saturation) at all sites tested along the free-flowing sections of the river. However, with lower streamflows in the late summer, DO concentrations failed to meet the WQS at nine sites in August, five sites in September, and three sites in October along the free-flowing sections. DO concentrations in the bottom layer of the deepest site (8.8-4) in the Ben Smith Impoundment in Maynard were very low (< 2.0 mg/L DO) from June to September. DO concentrations at the remaining sites in the Ben Smith were above the WQS every month except September.

Water levels in both the Ben Smith and Powdermill Impoundments were drawn down below the crest of their dams in September. During the several weeks that the Ben Smith was drawn down, floating aquatic vegetation accumulated over the entire surface of the impoundment and morning dissolved oxygen concentrations dropped, failing to meet the Class B water quality standard for DO at all sites tested. The Powdermill Impoundment was not completely covered with floating vegetation and DO concentrations failed to meet the water quality standard at only one site on the date sampled.

Introduction

The Massachusetts Department of Environmental Protection (DEP) lists all sections of the Assabet River on the 303(d) List of Waters as failing to meet water quality standards (Class B warm water standards listed in Table 4). The river suffers primarily from eutrophication caused by excess nutrients entering the river. During the growing season, these excess nutrients, phosphorus in particular, fuel nuisance algal and aquatic plant growth which interfere directly with recreational use of the river and cause large daily variations in the concentration of dissolved oxygen in the water, making the river poor habitat for aquatic life. At the end of the growing season, the algae and plants decay, generating strong sewage-like odors and lowering dissolved oxygen levels in the river.

The findings of the Assabet River TMDL Phase One Study confirm that the majority of the nutrients entering the river come from the wastewater treatment plants that discharge treated effluent to the river (ENSR 200; Table 1). In particular, treatment plants are the major source of ortho-phosphorus (the bioavailable form of phosphorus) throughout the year. Non-point sources also contribute nutrients, but, overall, contribute significantly less than the point sources over the growing season. Sediments, which tend to accumulate in the impoundments behind dams, are currently a minor source of nutrients to the river compared with point- and nonpoint-source contributions. The river's eutrophication problem is exacerbated by low flows, providing insufficient dilution of the wastewater treatment plant effluents.

Table 1: Nutrient Loadings from Point Sources

	% Nutrient loading from Point Sources*			
	Total Phosphorus	Ortho-Phosphorus	Total Nitrogen	Nitrate
Dry weather surveys	82-97%	97-98%	70-97%	78-99%
Wet weather surveys	23-91%	88-98%	32-88%	41-99%

* Point sources, the four major WWTP's: Westborough, Marlborough, Hudson, Maynard. Adapted from ENSR 2001.

The 2001 water quality monitoring season was OAR's tenth consecutive summer of collecting data on the mainstem of the Assabet River. To date the information generated by OAR's water quality program has helped to raise awareness of the Assabet's nutrient problem, pointed to the need for stricter phosphorus limits in the wastewater treatment plant's NPDES permits made a strong case for a Total Maximum Daily Loading (TMDL) study, and indicated the need for a groundwater model of the Assabet watershed. Water quality data collected under the approved OAR's Water Quality Monitoring Program QAPP, which was approved by the EPA in 2000, may be used by EPA and DEP in making regulatory decisions and in modeling for the TMDL phase two study.

The goals of OAR's 2001 water quality monitoring program were:

(1) Understand long-term trends in the river's condition, assess whether the river meets Massachusetts Surface Water Quality Standards for Class B waters, and assess the impact of any changes in management of point and non-point pollution sources.

(2) Provide sound scientific information to evaluate and, where appropriate, support or challenge regulatory decisions.
(3) Provide water quality data useful in modeling nutrient loadings in the Assabet River as a part of the Total Maximum Daily Loading study.
(4) Identify problem spots for further investigation by OAR or other appropriate agencies or organizations.
(5) Promote stewardship of the river through volunteer participation in the program and by expanding public knowledge of the program and its findings.

In 2002 OAR will shift 10 of the mainstem sampling sites to tributaries of the Assabet River as a part of the new StreamWatch project (a cooperative project of the Assabet River Consortium, OAR, USGS, Massachusetts Division of Fisheries and Wildlife, and the Massachusetts Audubon Society). Sampling will continue at 12 mainstem sampling sites, including the longest standing sites above and below each major wastewater treatment plant, as a part of OAR's ongoing commitment to monitoring the condition of the mainstem of the Assabet River.

Methods

Sampling methods and sites remained largely the same as they had been in 1999 and 2000 (OAR 2000, OAR 2001). Twenty-three trained volunteers and two OAR staff members monitored water quality at 25 stations along the main stem and at one station on Nashoba Brook, the largest tributary of the Assabet (Figure 1, Table 2). Sites are designated by rivermiles above the confluence of the Assabet and Sudbury Rivers at Egg Rock in Concord. Monitoring (bottle samples*, in-situ* measurements, gage readings and observations) was performed one weekend (5:00 am - 9:00 am) each month in June, July, August, and September. In October*,* only *in-situ* measurements (see Table 2) were taken. Staff gages were read weekly at Cox Street, Hudson, and Damonmill, Concord. Flow and stage readings from the USGS gage at Maynard were downloaded from the USGS web page twice a week.

As in the summer 2000 sampling season, depth profiles of *in-situ* parameters (Table 3) were measured in four impounded sections of the river. Sites 26.3 and 25.3 are in small impoundments behind the Sawmill dam at Route 20, Northborough, and the Woodside dam at Allen Street, Northborough, respectively. Both 26.3 and 25.3 were sampled at single locations on Saturday morning of the sampling weekend. Sites 8.8 and 6.7 are in the larger impoundments behind the Ben Smith dam near Rte 117, Maynard, and the Powdermill dam at Old High Street, Acton, respectively. *In-situ* readings were taken at multiple depths at five sites within the Ben Smith Impoundment (Figure 2) on Sunday morning of the sampling weekend each month; readings at five sites within the Powdermill Impoundment (Figure 3) were taken in September only when the water levels were low. The sites chosen within the impoundments are representative of their various conditions: open water/channel, embayment or backwater, among rooted aquatic plants, under duckweed cover (or where the duckweed is likely to accumulate).

Samples for nutrients and suspended solids, were taken using bottles supplied by the laboratories and were stored in the dark on ice during transport from the field to the lab. Samples to be analyzed by Thorstensen Laboratory were delivered to the laboratory within 4 hours. Temperature, dissolved oxygen, pH, conductivity, and oxidation/reduction potential measurements were taken using multi-

function YSI-6920 or YSI-6820 meters. To ensure that samples were representative of the bulk flow of the river in wadeable free-running sections, bottle samples and YSI readings were taken from the main flow of the river at mid-depth. Where the river was not wadeable (sites 26.3, 25.3, 8.8, 6.7 and 6.5) *in-situ* measurements were taken in the top, middle and bottom layers by sampling from a bridge or canoe using a 50-foot cable extension for the YSI meter. YSI readings from the several depths are reported as averages when there is less than about 10% relative percent difference between readings (the quality contol goals). At ten percent of the sites during each sampling event, duplicate field samples were taken and are reported here as an average of the original sample and the field duplicate. At ten percent of the sites during each sampling event, field blanks of distilled water were taken. Table 3 summarizes the parameters measured, laboratory methods and equipment used. A detailed description of sampling methods and quality control measures is available in the QAPP (OAR, 2000).

Table 2: OAR Sampling Sites - Summer 2000

Reach		OAR Site #	ENSR Site #	OAR Site Description	Water Quality Data Collected		
					YSI readings[a]	Bottle Samples[b]	Stage/Flow
Upper Reach		A1		gage at outflow or in impoundment			X
		31.0	R28	by Maynard St. bridge, Westboro	X	X	
		30.1	R27	by Rte 9 East bridge, Westborough	X	X	
		29.0	R26	Milk Street, Westborough	X	X	
		28.0	R25	by School Street bridge, Northborough	X	X	
		26.3	R24	above the dam at Rte 20, Northborough	X		
		26.2		below the dam at Rte 20, Northborough	X	X	
		25.3	R23	from Allen Street bridge, above dam, Northboro	X		
		25.2	R22	below the Allen Street dam, Northborough	X	X	
		24.2	R21	by Boundary Street bridge, Northb./Marlb.	X	X	
		23.8	R20	above dam off Robin Hill Road, Marlboro	X	X	
		22.0	R19	by Bridge St. bridge, Berlin	X	X	
		19.6	R18	by Chapin Road bridge, Hudson	X	X	
		18.2	R16	below Rte 85 bridge, Hudson center	X	X	
		16.2	R15	by Cox Street bridge, Hudson	X	X	X
		15.9	R14	Below Hudson WWTP	X	X	
		14.4	R12	below Gleasondale dam Rte 62, Stow	X	X	
		13.4	R11	by Sudbury Road bridge, Stow	X	X	
		9.5	R10	by White Pond Rd. bridge, Stow	X	X	
		8.8	R9	Ben Smith Impoundment, Maynard	X		
	Lower Reach	7.7	R7	by USGS gage, Rte 62, Maynard	X	X	X
		6.7	R6	Powdermill Impoundment, Acton/Maynard	X		
		6.5		from Old High St. bridge at dam, Acton	X		
		6.3	R5	above Rte 62 near Acton Ford, Acton	X	X	
		4.4	R4	from Rte 62 bridge @ Damonmill, Concord	X	X	X
		3.3	R3	by Rte 62 bridge near Donut Shoppe, Concord	X	X	
		2.6	R2	by Rte 2 bridge east of Assabet Ave., Concord	X	X	
		T2.9	T2	Nashoba Brook, by Comm. Ave. bridge, Concord	X	X	
		1.0		below Dakins Brook, off Lowell Rd., Concord	X	X	

[a] YSI readings: temperature, DO, pH, conductivity, and oxidation/reduction potential
[b] Bottle Samples: TSS, TP, ortho-P, TKN, nitrates, and ammonia

Figure 1: Assabet River Watershed and Sampling Sites 2001

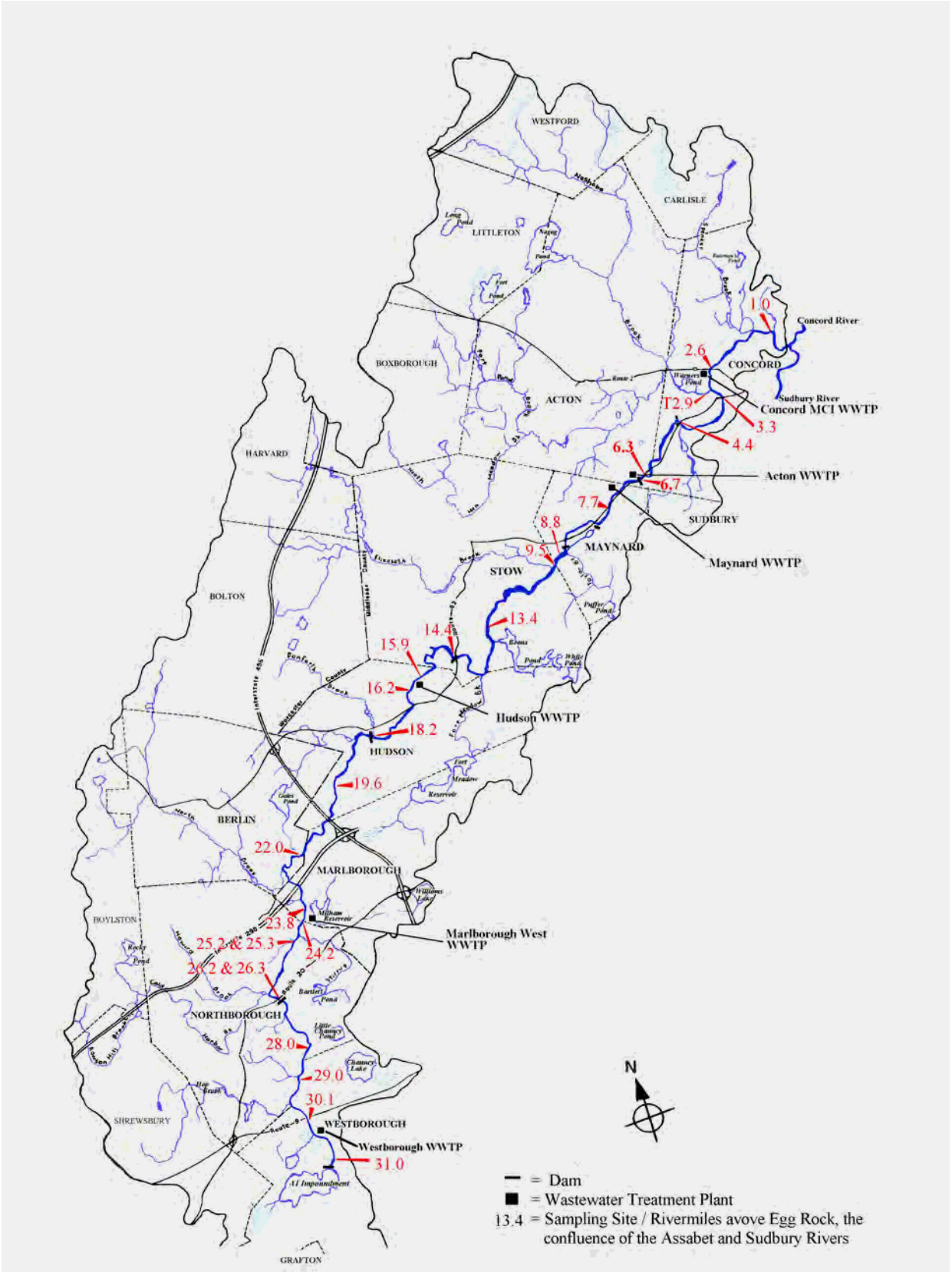


Figure 2: Ben Smith Impoundment Sampling Locations

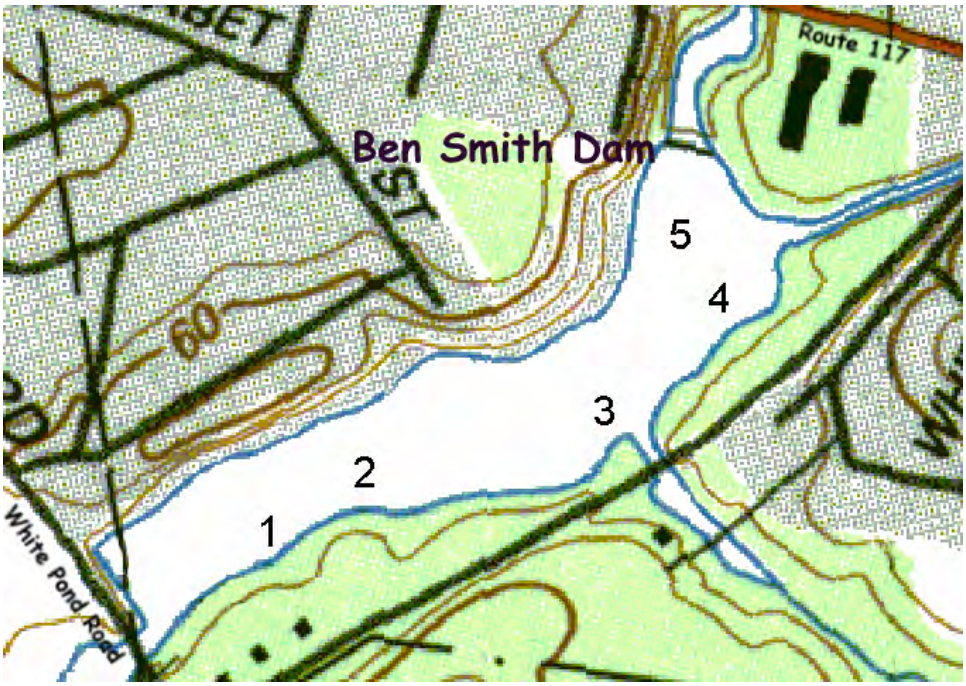


Figure 3: Powdermill Impoundment Sampling Locations

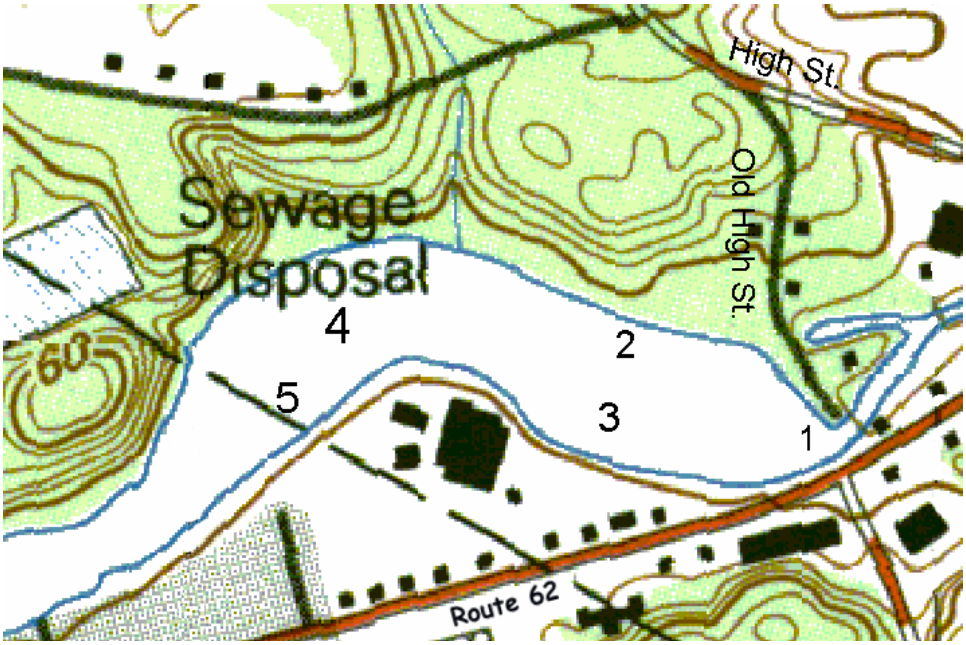


Table 3: Sampling and Analysis Methods

Parameter	Sample Type	Analysis Method #	Measurement Range/Detection Limits	Sampling Equipment	Laboratory
Temperature	*in-situ*	---	-5 - 45° C	YSI 6920	---
pH	*in-situ*	---	0 to 14 units	YSI 6920	---
Dissolved oxygen	*in-situ*	---	0 - 50 mg/L	YSI 6920	---
Conductivity	*in-situ*	---	0 to 100 µS/cm	YSI 6920	---
Oxid./reduction potential	*in-situ*	---	-999 to 999 mV	YSI 6920	---
Total Suspended Solids (TSS)	grab	EPA 160.2[a]	> 1.0 mg/L	bottle	Thorstensen Laboratory Inc.
ortho – Phosphate	grab	EPA 365.2	0.01 - 1.0mg/L	bottle	Thorstensen Laboratory Inc.
Total Kjeldahl Nitrogen	grab	EPA 351.3	0.05 - 100 mg/L	bottle	Thorstensen Laboratory Inc.
Nitrates	grab	EPA 352.1	0.01 - 10 mg/L	bottle	Thorstensen Laboratory Inc.
Ammonia	grab	EPA 350.3	0.03 - 10 mg/L	bottle	Thorstensen Laboratory Inc.

[a] USEPA, 1983.
[b] American Public Health Association, 1995.

Water quality measurements were compared with the Massachusetts Water Quality Standards for Class B warm waters (Table 4). All segments of the Assabet are designated Class B warm waters. For nutrient concentrations (where the Massachusetts Class B standard is narrative) results were compared with the reference conditions for aggregate ecoregion XIV streams (Table 5) in EPA Ambient Water Quality Criteria Recommendations: Rivers and Streams in Ecoregion XIV (EPA, 2000).

Table 4: Massachusetts DEP Class B Water Quality Standards*

Parameter	Standard
Dissolved oxygen	5.0 mg/l and 60% saturation
pH	6.5 – 8.3 for inland waters
Nutrients	"control cultural eutrophication"
Temperature	28.3° C and $\Delta < 2.8°$ C
Solids	Not impair use, cause aesthetically objectionable conditions, impair benthic biota, or degrade the chemical composition of the bottom

* MADEP. 1993. Massachusetts Surface Water Quality Standards - 314 CMR 4.00 1993

Table 5: Reference conditions for aggregate ecoregion XIV streams*

Parameter	Reference condition (25th percentile based on all seasons data for the decade)
Total Phosphorus (mg/L)	0.031
Total Nitrogen (calculated) (mg/L)	0.44
NO2 + NO3 (mg/L)	0.07
TKN (mg/L)	0.37

* adapted from USEPA. 2000.

Note that the EPA recommendations for total phosphorus and total nitrogen water quality standards in river systems changed between the draft and final recommendations. In 2000 our results were compared with the draft recommendations (USEPA 1999); in 2001 we are comparing our results with the final recommendations (USEPA 2000).

Results and Discussion

Monthly summary statistics and averages for the upper and lower reaches of the running sections of the river are presented in Table 6. Statistics for impounded sections of the river are presented in Table 7. Individual parameters are discussed below. Full monthly summaries of the water quality data are attached in the Appendix.

Reaches and Impoundments

For the purposes of data analysis, the river is divided into an upper and a lower reach for the free-flowing sections of the river (those not immediately behind an dam), and impounded sections. Site 7.7 (Route 62, Maynard) was selected as the dividing point between the upper and lower reaches of the river because the nutrient concentrations are markedly lower below site 7.7 and because flow is measured at the USGS Maynard gage at this site. The upper reach of the river is from site 30.1 (Route 9, Westborough) to site 7.7 (Route 62, Maynard). The lower reach of the river is from site 7.7 (Route 62, Maynard) to site 1.0 (near the outlet of Dakins Brook, Concord). Sites 31.0 and T2.9 are reported separately. Site 31.0 (Maynard Street, Westborough), is the site nearest the headwaters of the Assabet and above the first wastewater treatment plant discharge. Site T2.9 is on Nashoba Brook, Concord, between Warners Pond and the Assabet River; Nashoba Brook is the Assabet's largest tributary.

There are impoundments along the Assabet River above the dams at: the A1 Impoundment, Westborough; Route 20, Northborough; Allen Street, Northborough; Route 85, Hudson; Gleasondale, Stow; Route 62/117 (Ben Smith dam), Maynard; Route 62 (Powdermill dam), Acton. *In-situ* measurements were taken in each of the impoundments except the A1, Westborough and Rte 85, Hudson.

Table 6: Reach Statistics

				Reach Statistics and Average (morning measurements on running river sections)														
	Site #s	Reaches	Statistic	Water Temp (°C)	DO (mg/L)	DO % Sat	Cond. (µS/cm)	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Avail. N	Avail. N:P	Total N	Total N:P
9-June-01	all*	all	Maximum	20.81	9.02	95.1	631	7.08	11.5	0.42	0.56	1.8	0.54	5.2	1.96	79.0	5.8	79.0
	all*	all	Minimum	16.68	6.02	64.1	176	6.52	3.5	0.02	<0.01	0.3	0.05	1.0	0.33	3.1	1.6	8.1
	31.0	Maynard St., Westboro	Single Reading	19.15	8.22	89.0	176	6.98	6.0	0.02	0.0	0.3	0.05	1.3	0.33	33.0	1.6	79.0
	30.1 - 7.7 *	Rte 9 to Maynard Gage	Average	18.24	7.47	80.0	471	6.82	6.5	0.21	0.18	1.1	0.18	2.1	1.26	8.0	3.2	19.1
	7.7 - 1.0 *	Maynard Gage to Dakins	Average	19.65	7.72	86.5	339	6.82	7.6	0.13	0.10	0.6	0.18	2.3	0.81	20.2	2.9	23.7
	T2.9	Nashoba Brook	Single Reading	19.92	7.19	85.9	273	6.93	2.5	0.02	0.03	0.4	0.12	1.6	0.49	16.3	2.0	98.5
21-July-01	all*	all	Maximum	23.52	10.04	112.0	848	7.30	5.0	0.85	0.85	4.5	0.13	3.4	4.63	57.0	6.8	125.0
	all*	all	Minimum	17.25	5.89	63.8	300	6.49	<1.0	0.02	0.02	0.84	0.03	0.8	0.88	4.6	1.7	6.9
	31.0	Maynard St., Westboro	Single Reading	17.25	8.98	93.5	300	6.87	2.5	0.02	0.02	1.1	0.04	1.4	1.14	57.0	2.5	125.0
	30.1 - 7.7 *	Rte 9 to Maynard Gage	Average	21.13	7.41	83.6	614	6.99	3.5	0.29	0.27	2.1	0.08	1.5	2.18	12.9	3.7	20.1
	7.7 - 1.0 *	Maynard Gage to Dakins	Average	22.04	7.37	84.5	413	7.12	1.6	0.07	0.07	1.0	0.05	1.2	1.00	14.8	2.2	30.5
	T2.9	Nashoba Brook	Single Reading	21.36	8.21	92.8	324	7.02	1.0	0.01	0.01	0.5	0.05	0.75	0.55	55.0	1.3	125.0
11-August-01	all*	all	Maximum	27.17	8.08	90.2	742	7.62	2.0	0.68	0.57	6.4	0.15	3.2	6.55	83.0	9.0	160.0
	all*	all	Minimum	20.72	3.49	41.8	308	6.68	<1.0	0.01	0.01	0.8	0.06	0.8	0.83	9.5	1.6	11.8
	31.0	Maynard St., Westboro	Single Reading	20.72	8.08	90.2	308	7.62	<1.0	0.01	0.01	0.8	<0.03	0.8	0.83	83.0	1.6	160.0
	30.1 - 7.7 *	Rte 9 to Maynard Gage	Average	24.81	4.91	59.4	686	7.04	1.3	0.29	0.24	3.0	0.10	2.0	3.08	15.9	4.9	21.5
	7.7 - 1.0 *	Maynard Gage to Dakins	Average	25.86	5.69	69.7	593	7.19	1.0	0.10	0.07	1.3	0.08	1.3	1.33	18.8	2.5	27.6
	T2.9	Nashoba Brook	Single Reading	25.53	5.24	64.1	544	7.17	1.0	0.02	0.02	0.7	0.07	0.8	0.77	38.5	1.5	75.0
15-September-01	all*	all	Maximum	19.25	10.07	91.3	783	7.31	5.0	0.9	0.63	12.5	0.3	4.4	12.64	100.0	13.5	200.5
	all*	all	Minimum	10.96	4.92	52.1	240	6.51	<1.0	0.01	<0.01	<0.01	0.04	0.32	0.06	11.0	1.3	15.0
	31.0	Maynard St., Westboro	Single Reading	10.96	10.07	91.3	240	7.03	<1.0	0.04	0.01	1.0	0.04	0.3	1.00	100.0	1.3	32.0
	30.1 - 7.7 *	Rte 9 to Maynard Gage	Average	16.69	6.69	68.9	709	6.99	2.3	0.31	0.25	5.9	0.11	1.3	6.01	38.6	7.3	32.3
	7.7 - 1.0 *	Maynard Gage to Dakins	Average	15.61	7.17	72.2	534	7.13	2.8	0.07	0.05	1.6	0.12	2.0	1.45	42.0	3.3	78.9
	T2.9	Nashoba Brook	Single Reading	18.40	6.93	73.9	394	7.10	<1.0	0.05	0.03	1.6	0.04	1.4	1.64	54.7	3.0	60.0
13-October-01	all*	all	Maximum	17.97	11.09	110.2	702	7.43										
	all*	all	Minimum	12.62	5.20	53.4	219	6.60										
	31.0	Maynard St., Westboro	Single Reading	12.62	7.54	71.0	219	7.22										
	30.1 - 7.7 *	Rte 9 to Maynard Gage	Average	14.91	7.66	75.8	594	7.06										
	7.7 - 1.0 *	Maynard Gage to Dakins	Average	14.52	7.87	77.4	499	7.25										
	T2.9	Nashoba Brook	Single Reading	14.95	9.74	96.6	346	7.54										

* excluding Impoundments (26.3, 25.3, 6.5b) and tributary, Nashoba Brook (T2.9)

Table 7: Impoundment Statistics

	Impoundment Statistics and Averages (all depths averaged)								
	Impoundments		Statistic	Time	Water Temp (°C)	DO (mg/L)	DO % Sat	Cond. (µS/cm)	pH
June	all	all	Maximum	6/10/01 9:08 AM	22.08	7.91	89.3	583	6.87
	all	all	Minimum	6/9/01 6:05 AM	17.34	0.24	2.5	305	6.5
	26.3	Sawmill, Route 20, Northborough	Average	6/9/01 7:36 AM	17.55	5.94	62.2	583	6.63
	25.3	Allen St, Northborough	Average	6/9/01 7:10 AM	17.85	8.46	83.4	521	6.77
	8.8	Ben Smith, Maynard	Average	6/10/01 8:42 AM	21.30	6.22	70.7	393	6.75
	6.5b	Powdermill, Acton	Average	6/9/01 6:05 AM	19.85	7.15	78.8	342	6.74
July	all	all	Maximum	7/21/02 10:10 AM	23.92	9.34	110.7	770	7.26
	all	all	Minimum	7/22/01 7:58 AM	19.11	0.34	3.7	256	6.77
	26.3	Sawmill, Route 20, Northborough	Average	7/21/02 9:50 AM	20.41	5.91	65.8	770	6.81
	25.3	Allen St, Northborough	Average	7/21/02 10:07 AM	20.15	8.53	94.2	616	7.08
	8.8	Ben Smith, Maynard	Average	7/22/01 8:23 AM	23.31	6.75	79.7	429	6.98
	6.5b	Powdermill, Acton	Average	7/21/02 5:37 AM	23.27	7.76	91.1	446	7.18
August	all	all	Maximum	8/12/01 8:07 AM	27.53	6.99	88.4	709	7.30
	all	all	Minimum	8/11/01 5:34 AM	18.63	0.11	1.2	418	6.72
	26.3	Sawmill, Route 20, Northborough	Average	8/11/01 7:13 AM	23.73	4.17	49.4	666	6.99
	25.3	Allen St, Northborough	Average	8/11/01 6:55 AM	25.09	5.57	67.6	709	7.13
	8.8	Ben Smith, Maynard	Average	8/12/01 7:40 AM	25.41	3.78	46.6	610	6.83
	6.5b	Powdermill, Acton	Average	8/11/01 5:38 AM	26.81	4.86	61.6	614	7.21
September	all	all	Maximum	9/16/01 8:57 AM	19.96	8.74	91.7	730	7.33
	all	all	Minimum	9/15/01 5:57 AM	14.40	1.18	12.4	525	6.65
	26.3	Sawmill, Route 20, Northborough	Average	9/15/01 7:22 AM	15.18	6.04	60.2	639	6.86
	25.3	Allen St, Northborough	Average	9/15/01 7:08 AM	16.13	7.70	78.4	730	6.99
	8.8	Ben Smith, Maynard	Average	9/16/01 8:09 AM	18.21	4.67	49.7	583	6.88
	6.7	Powdermill, Acton	Average	9/16/01 8:27 AM	16.73	7.02	72.8	597	7.21
	6.5b	Powdermill, Acton	Average	9/15/01 5:59 AM	18.63	6.30	66.7	557	7.02
October	all	all	Maximum	10/13/01 10:01 AM	15.86	10.84	109.1	670	7.43
	all	all	Minimum	10/13/01 6:38 AM	13.27	6.63	63.5	487	6.96
	26.3	Sawmill, Route 20, Northborough	Average	10/13/01 7:59 AM	15.68	5.97	60.2	640	6.84
	25.3	Allen St, Northborough	Average	10/13/01 7:37 AM	15.47	7.44	74.7	663	7.00
	8.8	Ben Smith, Maynard	Average	10/13/01 9:45 AM	14.28	9.45	92.5	540	7.28
	6.5b	Powdermill, Acton	Average	10/13/01 6:38 AM	14.80	8.87	87.9	501	7.17

Flow

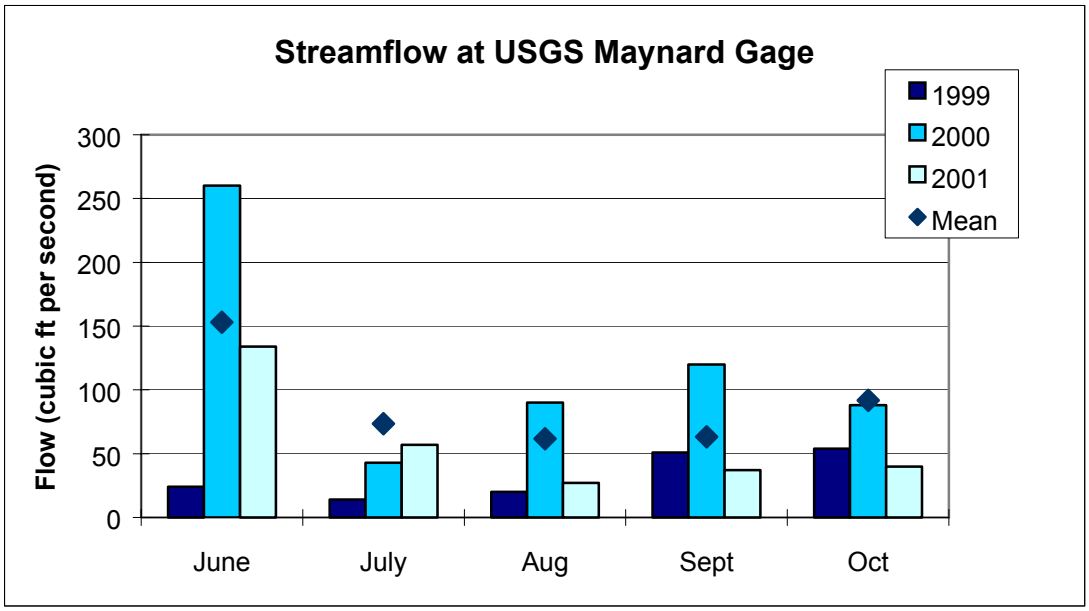
Streamflows, as measured at the UGSG gage in Maynard, dropped from close to the monthly mean in June to well below the monthly means in August, September, and October 2001. (Table 8 and Figure 4) Since the amount of baseflow, reflected in the streamflows, is a significant factor affecting the variation in water column concentrations of nutrients over the summer, we would expect to see the higher nutrient concentrations in August and September 2001 compared with the corresponding measurements in 2000.

Table 8: Streamflows on sampling dates (1999 - 2001)

	Flow at USGS Maynard Gage (cfs)			
Month	1999	2000	2001	Mean Monthly [a]
June	24	260	134	153
July	14	43	57	73.4
August	20	90	27	61.7
September	51	120	37	63.3
October	54	88	40	91.7

[a] based on 57 years of record at the USGS gage in Maynard

Figure 4: Streamflow on sampling dates (1999 - 2001)



Temperature and pH

Dissolved oxygen, temperature, pH, conductivity, and oxidation-reduction potential (ORP) measurements were taken in June, July, August, September, and October between 4am - 8am, when daily dissolved oxygen concentrations are expected to be at their lowest. Water temperatures in free-flowing sections ranged from 10.9 - 27.7 ° C, meeting the water quality standard of 28.3 ° C for Class B warm waters. However, in July, September, and October the temperature change between sites 31.0 and 30.1 (above and below the Westborough waste water treatment plant) exceeded the water quality standard for change in temperature (> 2.8° C). pH measurements in free-flowing sections ranged from 6.47 to 7.62 units, which met the Class B standards. In the impoundments, water temperatures were generally warmer (from 13.7 - 27.5 ° C) than in free-flowing sections and pHs ranged from 6.50 - 7.43, meeting the water quality standards for temperature and pH.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations are lowest between 5 am - 8 am after plant and microbial respiration has been removing oxygen from the water column overnight. Low morning concentrations and large diurnal variations in DO indicate eutrophic conditions. Morning DO concentrations in the free-flowing sections ranged from 6.02 - 9.02 mg/L in June, 5.89 - 10.04 mg/L in July, 3.48 - 8.08 mg/L in August, 4.92 - 10.07 mg/L in September, and 5.20 - 11.09 mg/L in October. DO concentrations failed to meet water quality standards (5.0 mg/L DO and 60% saturation) at nine sites in August and at five sites in September.

Figures 5 – 7 show the distribution of morning DO concentrations in free-flowing sections of the river in July, August and September compared with corresponding measurements in 1999 and 2000. In August 2001, when streamflows had dropped below the monthly mean, DO concentrations were similar to those observed in August 1999 and much lower than in August 2000. By the end of the growing season in September, although streamflows were lower in 2001 than in 1999 or 2000, DO concentrations were similar for all three years.

Morning DO concentrations in the impoundments (sites 26.3, 25.3, 8.8, and 6.5b) ranged from 0.24 - 7.91 mg/L in June, 0.34 - 9.34 mg/L in July, 0.34 - 9.34 mg/L in August, 1.18 - 8.74 mg/L in September, and 6.63 - 10.84 mg/L in October. Site 8.8-4, the deepest site sampled in the Ben Smith Impoundment, showed stratification of DO over depth from June to September (Figure 12). The bottom measurements at 8.8-4 yielded the lowest DO readings of all the impoundment sites although it had little submerged plant growth over the summer and little floating plant cover until September.

Figure 5: Dissolved Oxygen Concentrations in Free-Flowing Sections (July 99, 00, & 01)

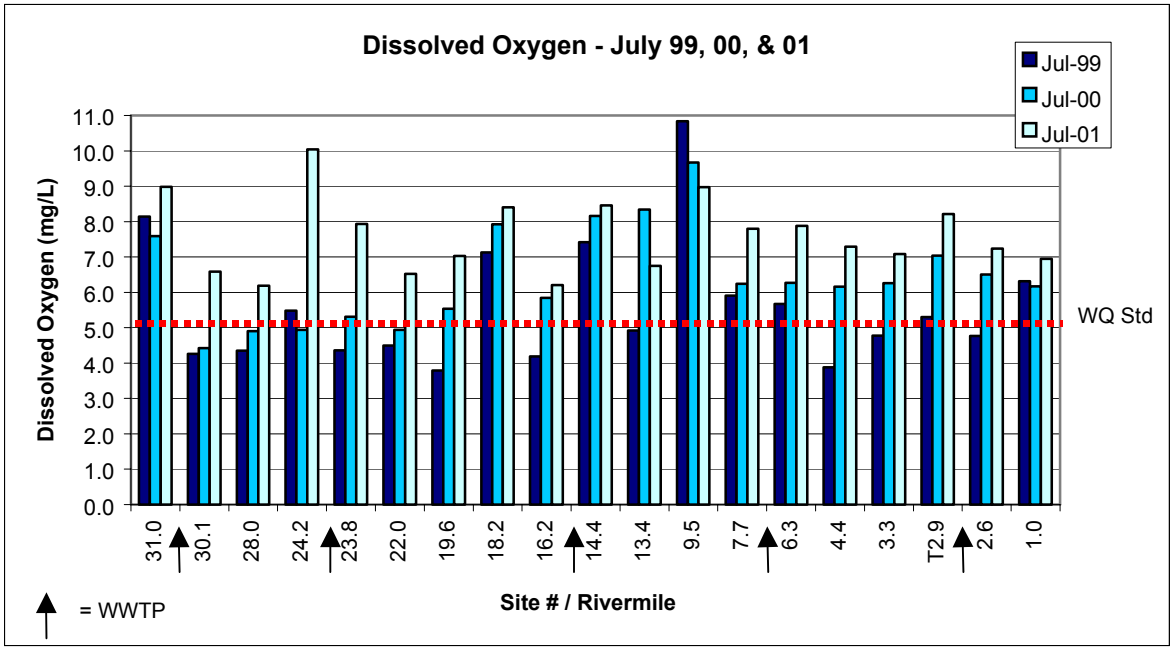


Figure 6: Dissolved Oxygen Concentrations (Aug 99, 00, & 01)

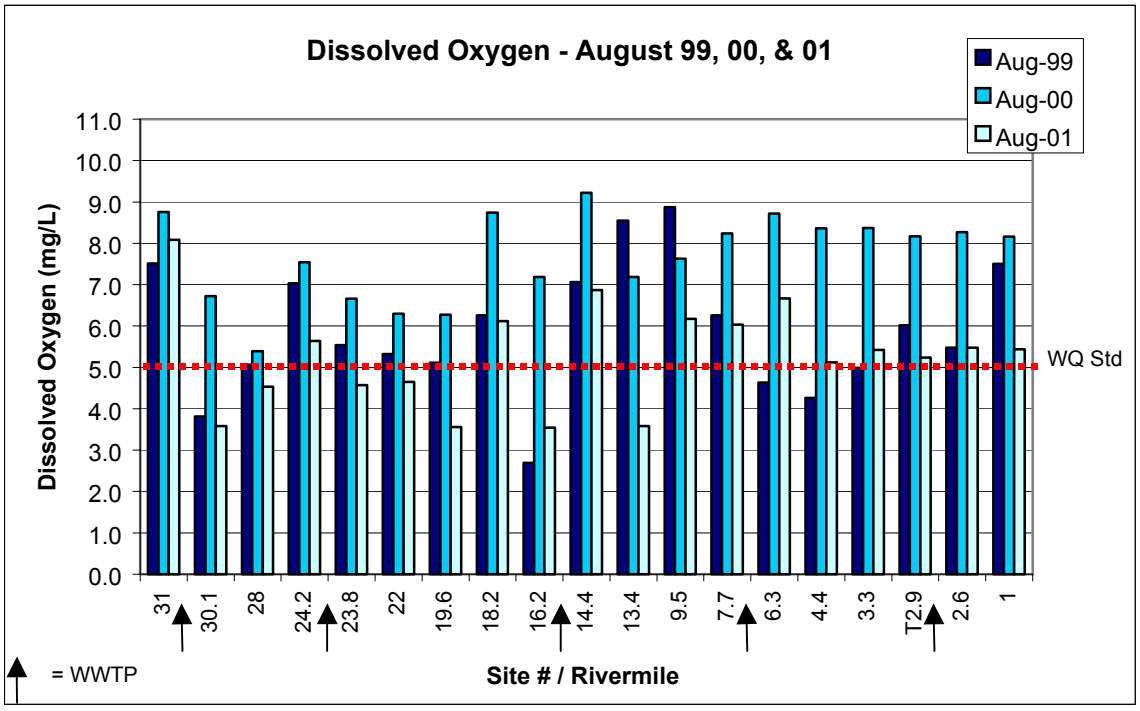
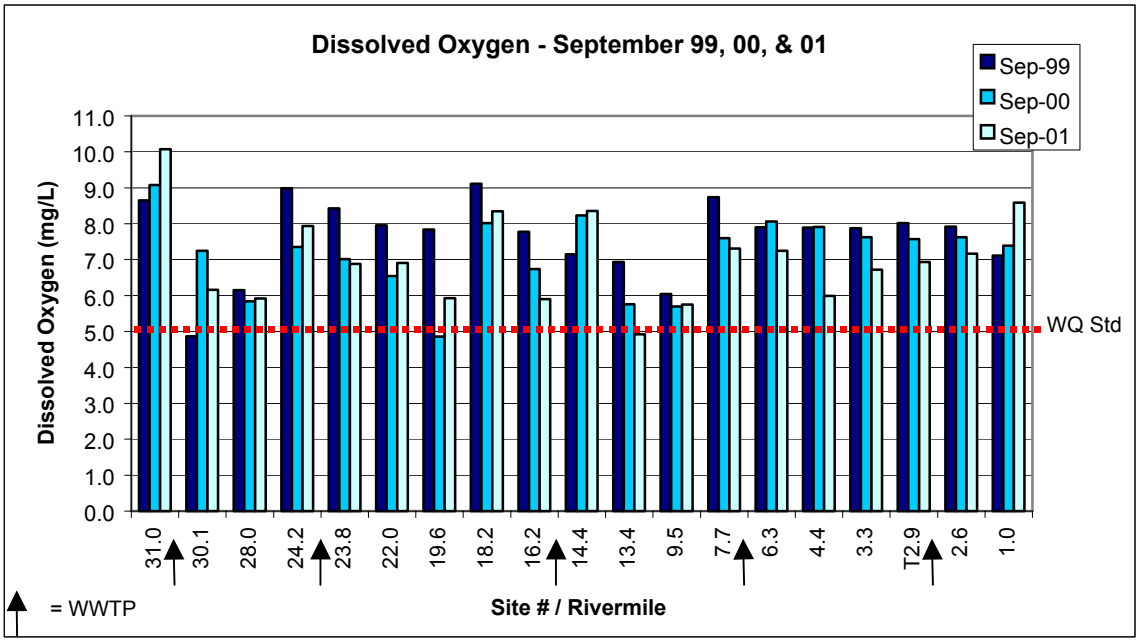


Figure 7: Dissolved Oxygen Concentrations (Sept 99, 00, & 01)



Conditions in the Ben Smith & Powdermill Impoundments – September 2001

Water levels in both the Ben Smith and Powdermill Impoundments fell below the crest of their dams in September. During the period that water levels in the Ben Smith were below the crest of the dam, floating aquatic vegetation accumulated over the entire surface of the impoundment and morning dissolved oxygen concentrations dropped, failing to meet the WQS at all but one of the Ben Smith Impoundment sites tested. The Powdermill Impoundment was not completely covered with floating vegetation and DO concentrations failed to meet WQSs at only one site.

Observations:

Roger Gay, a resident of Stow living on the Ben Smith Impoundment, between about September 2nd and September 14th observed that water levels in the Ben Smith Impoundment were below the crest of the Ben Smith dam (Figure 10). Gates to the millpond at Clock Tower Place (the old mill in Maynard center; Figures 8 and 9) had been left open, diverting flow from the impoundment and river to the millpond and drawing water levels in the impoundment down. The flow in Maynard's canal and Mill ponds has separate inflow and outflow controls so that both the level of the Mill ponds and the water level behind the Ben Smith Dam can be controlled separately. On September 6th, after local residents complainted to the mill owner, the millpond gates were closed, but it took another 8 days for water levels to return to the level of the dam crest (pers.com. Mr. Gay). Between September 2nd and September 14th, 2001, duckweed and other floating vegetation trapped behind the dam accumulated on the surface of the impoundment (Figures 10 and 11).

Water Quality Testing:

Water quality was tested in both the Ben Smith Impoundment and downstream in the Powdermill Impoundment (Figures 2,3, and 8) on September 16th as a part of the OAR's regular water quality monitoring program. On September 16th, the surface of the Ben Smith Impoundment was still completely covered with duckweed up to the White Pond Road Bridge (Figure 11). Dissolved oxygen concentrations in the impoundment failed to meet water quality standards (5.0 mg/L and 60% saturation) at all sites and all depths sampled except one (Table 9, Figure 12). In contrast, in June, July, and October, dissolved oxygen concentrations in the impoundment were above WQSs at all the Ben Smith sites sampled except the bottom depth at Site 4 (Figure 13). In August, dissolved oxygen concentrations were below WQSs at two of the five sites tested. Dissolved oxygen measurments immediately above (Site 9.5) and below (Site 7.7) the impoundment met the WQSs in September (Figure 14, Appendix A). Water quality data for both the Ben Smith and Powdermill Impoundments for September is presented in Table 9.

Figure 8: Assabet River and Mill Pond, Maynard MA

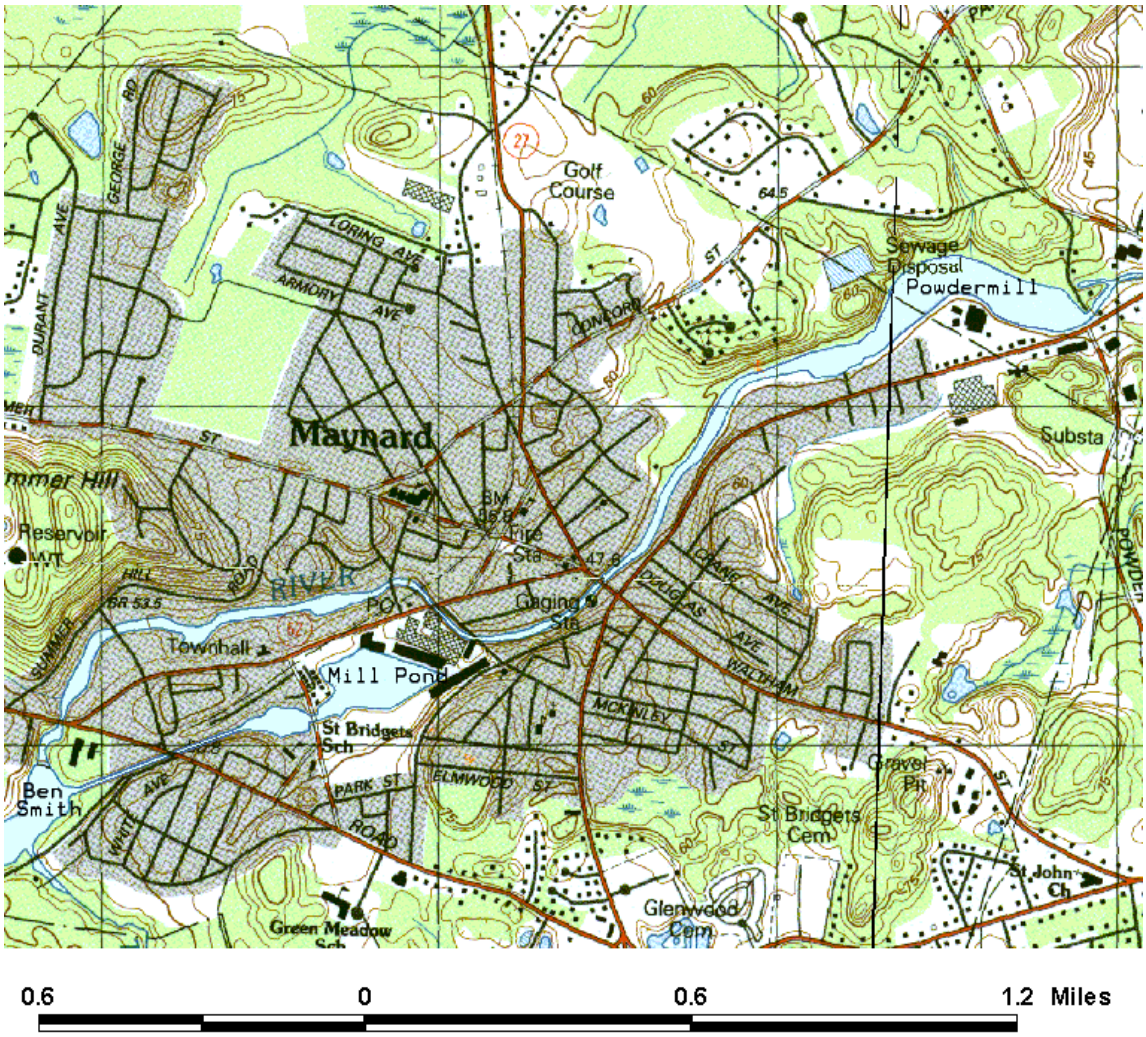


Table 9: Data Summary for the Ben Smith and Powdermill Impoundments, Sept 2001

Assabet River Data Summary - September 2001									
Impoundment			*In-situ* Readings						
Site ID #	Site Name	Town	Date / Time	Water Temp (°C)	DO (mg/L)	DO % Sat	Cond. (µS/cm)	pH	Measure./ Total Depth (ft)
8.8-1	Ben Smith - Site 1 bottom	Maynard	9/16 7:47 AM	18.25	5.61	59.7	601	6.89	6.0/6.8
	middle		9/16 7:49 AM	18.27	5.51	58.6	601	6.89	3.0/6.8
	top		9/16 7:50 AM	18.27	5.52	58.8	601	6.89	1.0/6.8
8.8-2	Ben Smith - Site 2 bottom	Maynard	9/16 7:56 AM	17.79	5.02	52.9	588	6.94	2.5/3.2
	middle		9/16 7:57 AM	18.20	5.54	58.8	600	6.94	2.0/3.2
	top		9/16 7:58 AM	18.24	5.70	60.6	600	6.95	1.0/3.2
8.8-3	Ben Smith - Site 3 bottom	Maynard	9/16 8:07 AM	18.13	4.03	42.7	578	6.97	6.0/6.5
	middle		9/16 8:09 AM	18.30	4.56	48.5	578	6.94	3.0/6.5
	top		9/16 8:11 AM	18.30	4.68	49.8	577	6.93	1.0/6.5
8.8-4	Ben Smith - Site 4 bottom	Maynard	9/16 8:18 AM	17.77	1.18	12.4	525	6.65	12.0/12.5
	middle		9/16 8:20 AM	18.33	4.94	52.7	579	6.79	6.0/12.5
	top		9/16 8:22 AM	18.33	5.13	54.6	579	6.84	1.0/12.5
8.8-5	Ben Smith - Site 5 bottom	Maynard	9/16 8:28 AM	18.32	4.08	43.5	578	6.80	3.0/3.8
	middle		9/16 8:30 AM	18.35	4.29	45.7	577	6.88	2.0/3.8
	top		9/16 8:32 AM	18.35	4.30	45.8	577	6.87	1.0/3.8
6.7-1	Powdermill - Site 1 bottom	Acton	9/16 7:50 AM	17.40	6.64	69.4	596	7.09	8.0/8.2
	middle		9/16 7:54 AM	17.55	8.61	89.6	596	7.26	4.0/8.2
	top		9/16 8:57 AM	17.52	8.74	91.7	596	7.31	1.0/8.2
6.7-2	Powdermill - Site 2 bottom	Acton	9/16 8:05 AM	17.44	8.10	84.5	608	7.30	6.0/6.9
	middle		9/16 8:07 AM	17.48	8.22	85.9	608	7.31	3.5/6.9
	top		9/16 8:08 AM	17.50	8.18	86.7	609	7.32	1.0/6.9
6.7-3	Powdermill - Site 3 middle	Acton	9/16 8:16 AM	17.30	8.41	88.0	605	7.33	0.6/1.8
6.7-4	Powdermill - Site 4 bottom	Acton	9/16 8:32 AM	14.40	4.39	43.0	584	7.13	2.0/2.3
	top		9/16 8:34 AM	14.75	5.09	50.2	584	7.11	1.0/2.3
6.7-5	Powdermill - Site 5 bottom	Acton	9/16 8:48 AM	16.42	6.12	63.4	594	7.14	5.0/5.4
	middle		9/16 8:49 AM	16.47	5.90	60.6	594	7.10	2.8/5.4
	top		9/16 8:50 AM	16.48	5.85	60.1	595	7.09	1.0/5.4
Impoundment Averages (all depths averaged)									
	Impoundments		Date / Time	Water Temp (°C)	DO (mg/L)	DO % Sat	Cond. (µS/cm)	pH	
all	all	Maximum	9/16 8:57 AM	19.96	8.74	91.7	730	7.33	
all	all	Minimm	9/15 5:57 AM	14.40	1.18	12.4	525	6.65	
26.3	Route 20	Average	9/15 7:22 AM	15.18	6.04	60.2	639	6.86	
25.3	Allen St	Average	9/15 7:08 AM	16.13	7.70	78.4	730	6.99	
8.8	Ben Smith	Average	9/16 8:09 AM	18.21	4.67	49.7	583	6.88	
6.7	Powdermill	Average	9/16 8:27 AM	16.73	7.02	72.8	597	7.21	
6.5b	Powdermill	Average	9/15 5:59 AM	18.63	6.30	66.7	557	7.02	

Figure 9: Mill Pond outlet below Clock Tower Place, Sept 4 - 12, 2001

Left: outlet on 9.4.01 Right: outlet on 9.12.01

Figure 10: Ben Smith Impoundment, Sept 4 - 12, 2001

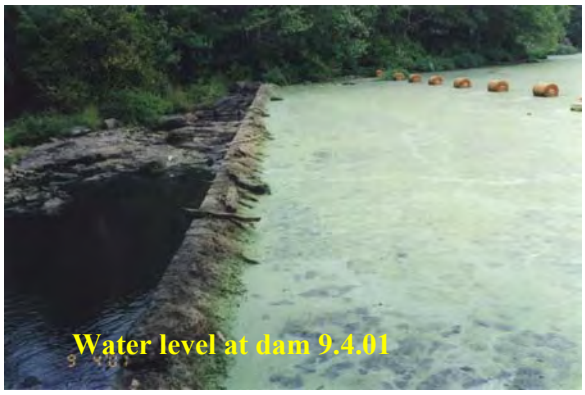


Figure 11: Ben Smith Impoundment, Sept 16, 2001

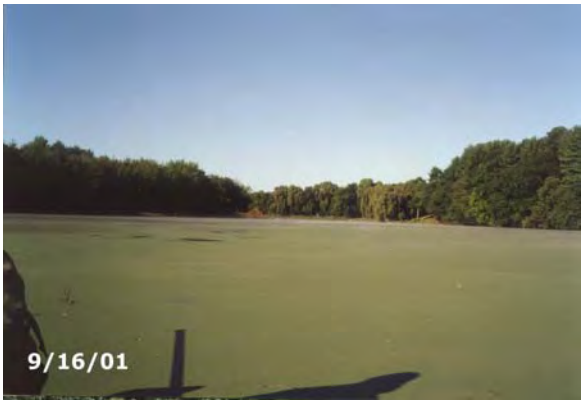


Figure 12: Morning DO Concentrations in the Ben Smith Impoundment, Sept 16, 2001

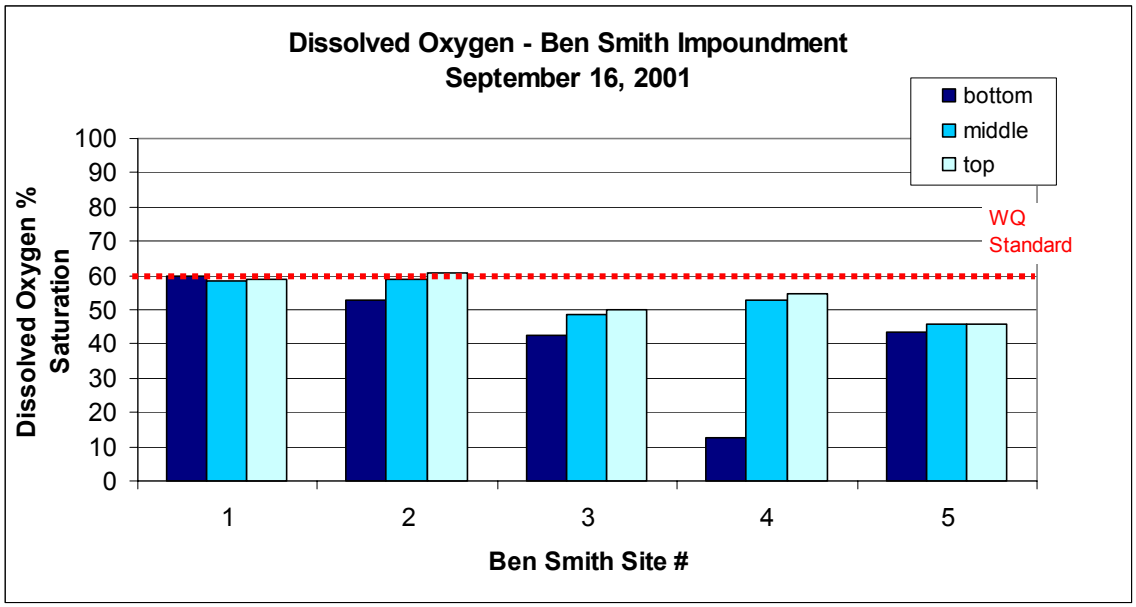
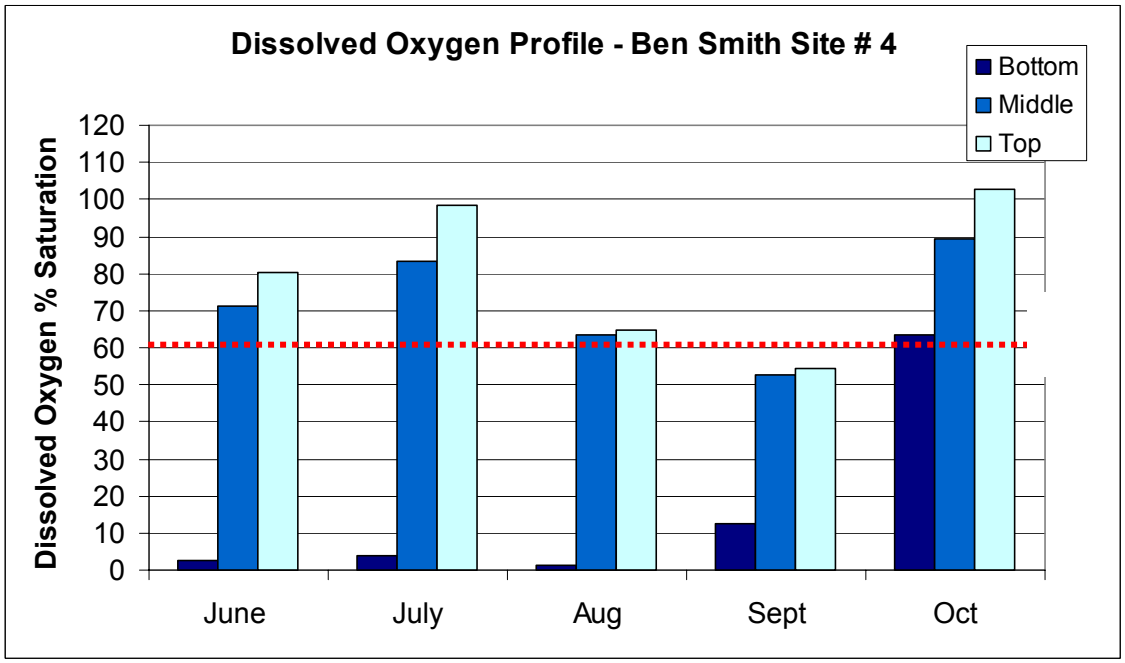


Figure 13: Morning DO Concentrations at Ben Smith Site #4 – Summer 2001



By September 12th water levels in the Powdermill Impoundment, on the Acton/Maynard line downstream of the Ben Smith, had dropped dramatically (Figure 14). Like the Ben Smith, the Powdermill dam has a second outlet below the level of the main dam (supplying flow to a licensed hydroelectric plant). Although by September 16th water levels in the Powdermill Impoundment had dropped below the lip of the dam, the

impoundment was not completely covered with floating vegetation and DO concentrations were not as low as in the Ben Smith Impoundment (Appendix). Dissolved oxygen concentrations failed to meet water quality standards at one of the five sites tested. (Figure 8 shows a map of Maynard center, the impoundments, mainstem river, and millpond.)

Figure 14: Powdermill Impoundment next to Rte 62, Acton, September 12, 2001.

Left: exposed banks

Right: exposed lip of dam

Nutrients

Summary statistics for nutrient and solids concentrations are in Table 6. Figures 15 - 18 show typical distributions of nutrient concentrations along the river in July and August 2001 compared with the corresponding measurements in 1999 and 2000. In general, the nutrient concentrations in 2001 were again well above the thresholds for eutrophication for both phosphorus and nitrogen species and were higher in the upper reach of the river than in the lower reach.

Nutrient concentrations at site 31.0 (Maynard St., Westborough) and T.2.9 on Nashoba Brook were below the threshold for eutrophication for total phosphorus (0.031 mg/L) in June, July and August and slightly above the threshold in September when flows were lowest. Total nitrogen concentrations at these two sites were above the EPA-recommended threshold (0.44 mg/L) on all dates tested.

Concentrations of total phosphorus (which represents both the dissolved and particulate phosphorus in the water column) ranged from 0.01 - 0.90 mg/L. Total phosphorus (TP) concentrations tended to be highest in the upper reaches of the river where dilution of the wastewater treatment plant effluent by baseflow was the least (Figures 15 & 16). All sites except 31.0 and T2.9 exceeded 0.031 mg/L total phosphorus on all dates tested. Concentrations of ortho-phosphorus (which represents the available phosphorus in the water column) ranged from <0.01 - 0.86 mg/L along the river and comprised most of the total phosphorus concentrations in the river.

Nitrogen species concentrations were also high. Total nitrogen (TN, calculated as the sum of TKN and nitrates concentrations) concentrations tended to be higher in the upper

reach of the river than in the lower reach. TN concentrations exceeded 0.44 mg/L, the recommended TN threshold, on each date tested at all sites. Available nitrogen (the sum of nitrates and ammonia) represents the fraction of nitrogen readily available for uptake by plants. Available nitrogen ranged from 0.06 - 12.64 mg/L along the river. Nitrate concentrations ranged from <0.01 - 12.5 mg/L and ammonia concentrations ranged from 0.03 - 0.54 mg/L along the river.

Figure 15: Total Phosphorus - July

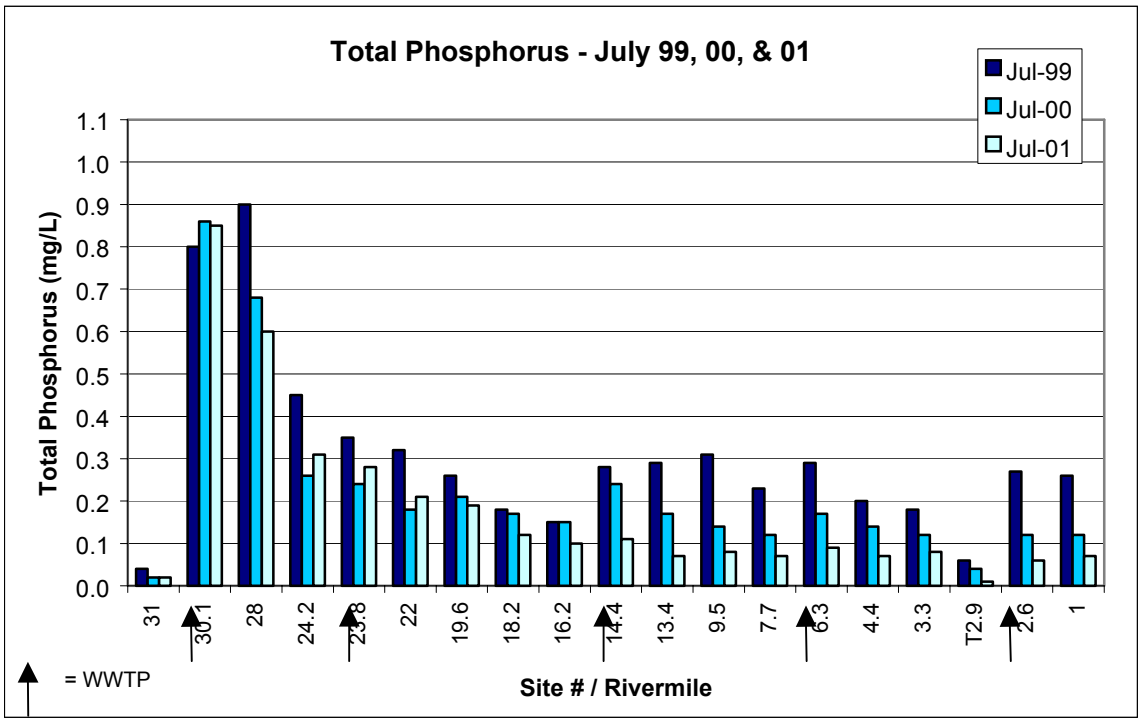


Figure 16: Total Phosphorus - August

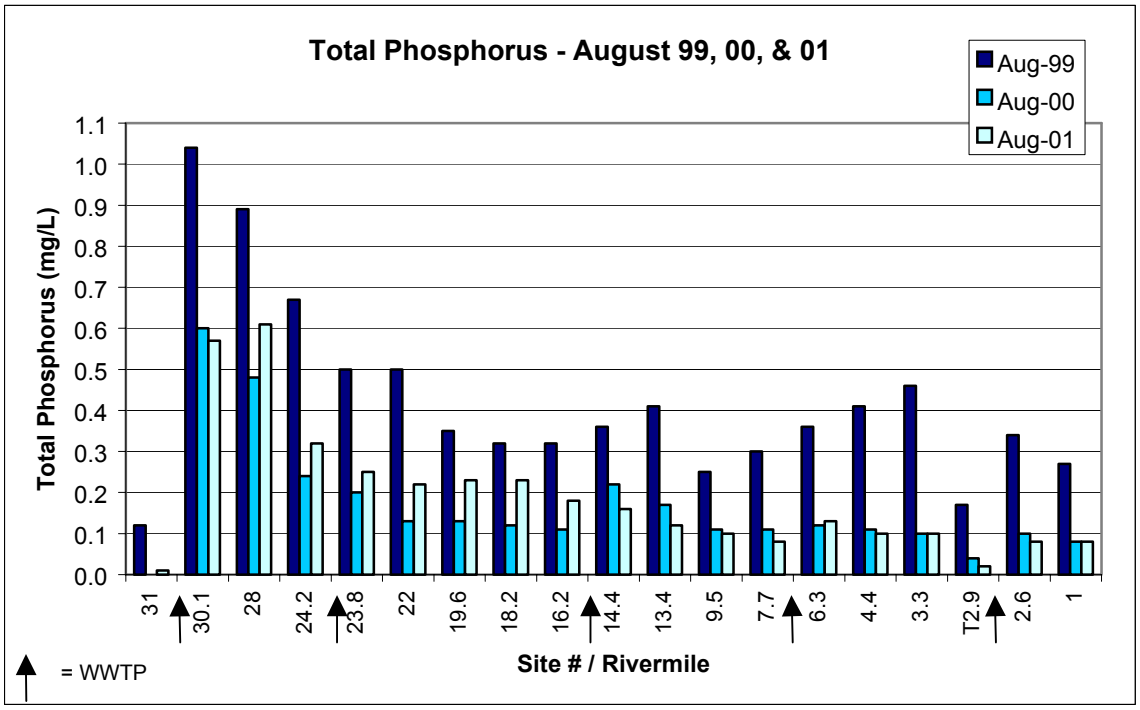


Figure 17: Total Nitrogen - July

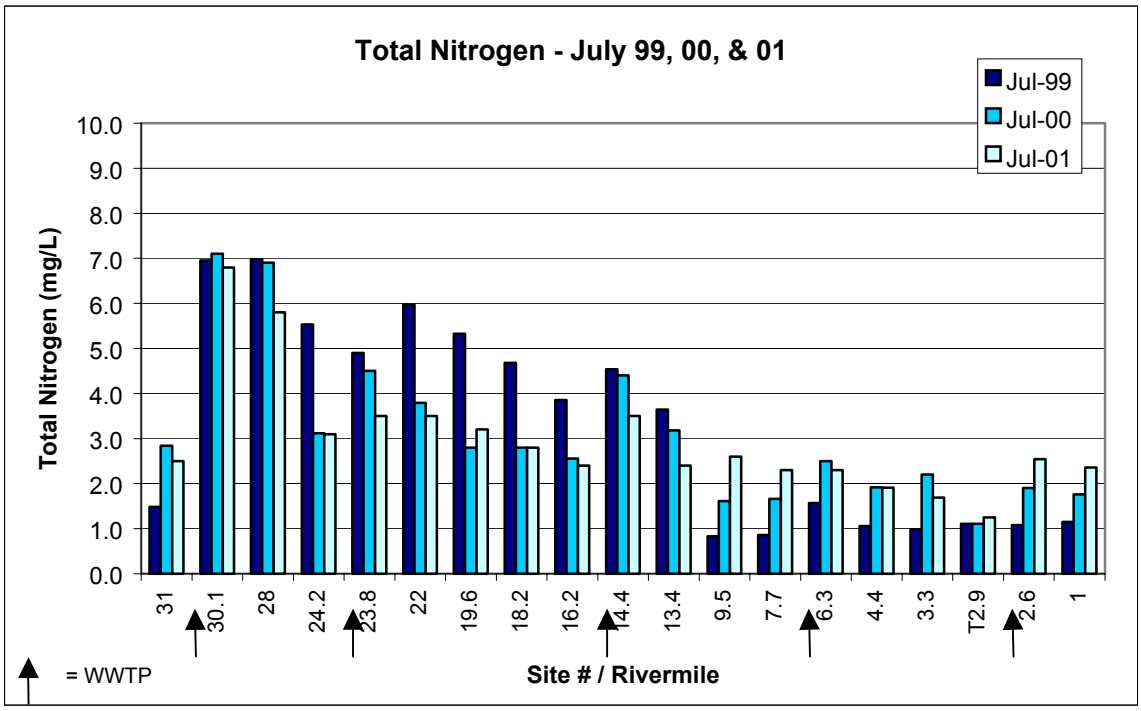
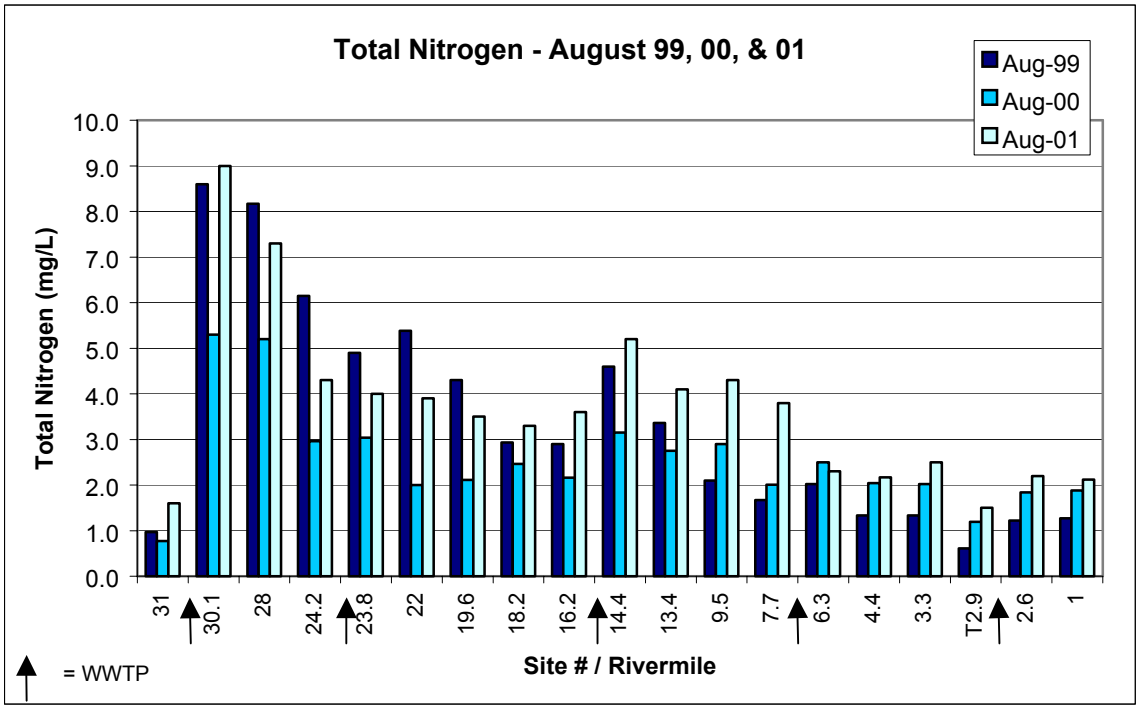


Figure 18: Total Nitrogen - August



Conclusions

Streamflows dropped relative to mean monthly flows over the summer of 2001. Flows measured at the USGS Maynard gage during the June and July samplings were close to mean monthly flow, but in August, September and October, flows were only about half the monthly means. The low flows in the late summer were reflected in lower dissolved oxygen and higher nutrient concentrations relative to measurements in 2000.

In general, the nutrient concentrations in 2001 were, again, well above the thresholds for eutrophication for both phosphorus and nitrogen species and were higher in the upper reach of the river where dilution of the wastewater treatment plant effluent by natural flow is the least. The lower nutrient concentrations in the lower half of the river may be explained by several factors: the larger proportion of natural flow to effluent in the river, nutrient uptake by plants during the growing season, and deposition of bound nutrients to the sediments in slow moving river sections.

Low morning dissolved oxygen (DO) concentrations and large diurnal changes in DO concentration are indicative of eutrophication and may be harmful to fish and other aquatic organisms. In June and July '01, DO concentrations were above the Class B water quality standard (WQS; 5.0 mg/L and 60% saturation) at all sites tested along the free-flowing sections of the river. However, with lower streamflows in the late summer, DO concentrations failed to meet the WQS at nine sites in August, five sites in September, and three sites in October along the free-flowing sections. DO concentrations in the bottom layer of the deepest site (8.8-4) in the Ben Smith Impoundment in Maynard were very low (< 2.0 mg/L DO) from June to September. DO concentrations at the remaining sites in the Ben Smith were above the WQS each month except August and September; DO concentrations failed to meet WQSs at three sites in August and at all five sites in September. In August DO concentrations also failed to meet WQS at sites in two other impoundments (Rte 20, Northborough and Powdermill, Acton).

Water levels in both the Ben Smith and Powdermill Impoundments were drawn down below the crest of their dams in September. During the several weeks that the Ben Smith was drawn down, floating aquatic vegetation accumulated over the entire surface of the impoundment and morning dissolved oxygen concentrations dropped, failing to meet the WQS at all sites tested in September. The Powdermill Impoundment was not completely covered with floating vegetation and DO concentrations failed to meet WQSs at only one site. The drawdown and water quality violations in the Ben Smith and Powdermill Impoundments suggest the need for minimum flow releases over the Ben Smith dam.. This could be an issue again in the summer of 2002 following the winter drought conditions.

Because nutrient concentrations are so high in the Assabet, control and remediation must be approached on multiple fronts: significantly reduce point-source nutrient inputs to the river, assess and protect baseflow, and assess the viability of dam removal. Through science, outreach, and advocacy OAR continues to be committed to the goal of a fishable, swimmable Assabet River.

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Glossary of Terms

Ammonia (NH3): a form of nitrogen available to uptake by plants and microorganisms. Sources include the breakdown of organic nitrogen in sediments and untreated sewage. Other sources of ammonia include: fertilizer, home cleaning products and food processing. While ammonia can be readily utilized by plants, high concentrations of ammonia are directly toxic to aquatic life. A secondary effect of increased ammonia occurs when bacteria oxidize the NH_3 to NO_3, a process called nitrification, consuming four atoms of oxygen for every atom of nitrogen converted. This process can dramatically lower dissolved oxygen in the water.

Baseflow: the flow of water from aquifers into the streambed. In natural systems in New England baseflow makes up most of the river flow during the summer.

Biochemical oxygen demand (BOD): oxygen required to break down organic matter and to oxidize reduced chemicals (in water or sewage). BOD provides a direct measure of the decomposition or oxidation processes in the water column. The more difficult-to-perform **sediment oxygen demand (SOD)** test measures the decomposition processes in the sediments.

Conductivity: the ability of the water to conduct a charge, which increases with increasing concentrations of charged ions in the water. Conductivity is a rough indicator of pollutants, such as untreated waste, entering the stream.

Dissolved Oxygen: the presence of oxygen gas molecules (O2) in the water. The concentration of dissolved oxygen (DO) in the water column provides a direct indication of the water's ability to support aquatic life like fish and macroinvertebrates. Aquatic plants and bacteria in the sediments remove dissolved oxygen from the water when they respire (plants respire mainly at night). Therefore, the lowest dissolved oxygen concentrations of the day occur in the early in the morning. During the day plants add oxygen to the water column through photosynthesis. Both extreme (low or high) DO concentrations and large changes in DO concentrations over the day (diurnal variation) are damaging to the habitat.

Eutrophic: abundant in nutrients and having high rates of productivity frequently resulting in oxygen depletion below the surface layer.

Mesotrophic: having a nutrient loading resulting in moderate productivity.

Nitrogen: a major nutrient supporting plant growth. Nitrogen is measured in its various forms as **nitrate (NO_3)**, **ammonia (NH_3)**, and **total Kjeldahl nitrogen (TKN**). **Total nitrogen** is calculated as the sum of TKN and nitrates. **Available nitrogen**, calculated as the sum of nitrate and ammonia, gives a measure of the nitrogen readily available for absorption by plants. Once absorbed, nitrogen is incorporated into proteins, amino acids, nucleic acids, and other molecules. Although most aquatic plant growth in rivers is

limited by the availability of phosphorus, increased nitrogen availability can also lead to algal blooms.

Oligotrophic: having a small supply of nutrients, low production of organic matter, low rates of decomposition, and high dissolved oxygen in the lower layers of the water column.

Phosphorus: Plants need nutrients to grow; in particular they need a balance of phosphorus (P) and nitrogen (N). Phosphorus is measured as **total phosphorus** (TP) and **ortho-phosphate** (ortho-P; soluble inorganic phosphate, the form required by plants). In most fresh waters, the concentration of phosphorus available to plants is low enough that the plants cannot grow at their maximum rate. But in water bodies, like the Assabet, where human activities add phosphorus to the environment, the added phosphorus allows much greater growth of aquatic plants.

Oxidation/reduction potential provides a measure of the condition of the suspended solids: to what extent the organic material in them has been degraded by microorganisms.

pH: the negative log of the hydrogen ion concentration in water, a measure of the acidity of water. pH is measured on a scale from 1 to 14, with 1 being very acidic, 7 being neutral, and 14 being very basic. Extreme pHs, in either direction, can be toxic to fish and other aquatic life. pH plays role in the behavior of other pollutants such as heavy metals in the environment. High or low pH levels can be the result of acid rain/snow, chemicals entering the waterways, or algal blooms.

Total suspended solids (TSS): the amount of silt, clay, organic material and algae in the water. Sources include erosion and the solids in effluent. Once in the water column, suspended solids are transported downstream and settle gradually, along with decaying plant matter, to form thick organic-rich sediments in the slower sections of the river.

Stage and streamflow measure the amount of water in the river. Stage is the height of the water above the riverbed, and is read at staff gages at several points along the river. Streamflow measures the volume of water passing a given point in the river. Flow is measured by the USGS at their gage in Maynard and reported on the USGS web page.

Temperature affects the ecosystem in a number of ways: many organisms, especially cool water fish, are sensitive to high temperatures; the solubility of oxygen is lower in warmer water, decreasing the supply of dissolved oxygen; algae, weeds, and pathogenic microorganisms can all grow faster in warmer water.