Organization for the Assabet River

Assabet River Water Quality Monitoring Program
Final Report - 1999

Issued June 2000

Acknowledgments

OAR wishes to thank our many dedicated volunteers for their work in the field and on our board and advisory committees. We'd especially like to thank our 1999 water quality volunteers: Sue Beede, Jean Collins, Jennifer Chiapella, Red and Betty Couts, Donald Crowley, Steve Fogg, David Gray, Paul Goldman, Erik Hansen, Cindy Hutchison, Tim Lawson, Debbie Listernick, John Meyn, Matt Liebman, Mary Michelman, Michal Mueller, Doug Moffat, Marty Moran, Barbara Offenhartz, Len Rappoli, Amy Rice, Bill Schade, Lee Steppacher, and Jan Wright. For scientific review and editorial help, thanks to Sue Beede, Julia Blatt, Cindy Delpapa, Matt Liebman, Barbara Offenhartz, Nigel Pickering, and Peggy Savage.

We appreciate the support for our water quality sampling program from the towns of Acton, Maynard, Hudson, and Concord. Funding for this program also came from the MA Executive Office of Environmental Affairs, MA Coastal Zone Management, the National Park Service, Compaq Computer Corporation, and Stearns Foundation. In-kind services were provided by Thorstensen's Laboratory Inc. of Westford, and U.S. Environmental Rental Corporation of Waltham.

Author: Suzanne Flint, OAR Water Quality Coordinator

Table of Contents

List of Figures and Tables

Abstract

In 1999 the Organization for the Assabet River monitored water quality in the Assabet River between June and September, continuing to build the database of water quality information which informs OAR's advocacy for the river. Conditions indicative of intense eutrophication of the river were found throughout the river. High nutrient concentrations were measured all along the river, with the highest concentrations found in the upper reaches. Low morning dissolved oxygen (DO) concentrations and large diurnal variations in DO concentrations were measured all along the river, and tended to be associated with the slower moving sections. The effects of eutrophication were most intense in the impoundments. In an afternoon survey of the Ben Smith Impoundment in Maynard both extremely high and very low dissolved oxygen concentrations were measured. Both high (>125% saturation) and low DO concentrations are dangerous for fish and other aquatic organisms. Very low morning DO concentrations and large diurnal variations in DO were also measured in the Powdermill Impoundment. Because nutrient concentrations are so high in the Assabet, control and remediation must be approached on multiple fronts: reduce both point and non-point nutrient inputs to the river, protect baseflow, and assess sediment conditions.

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 Class B water quality standards for warm waters (Table 3). The river suffers primarily from eutrophication caused by excess nutrients entering the river. 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. When the algae and plants decay, they generate strong sewage-like odors and lower dissolved oxygen levels in the river.

The majority of these nutrients come from the seven wastewater treatment plants that discharge treated effluent into the Assabet River. Stormwater runoff and recycling of nutrients trapped in river sediments also contribute to the river's surfeit of nutrients. Dams have altered the river's hydrology, creating large, slow moving sections where nutrient-rich sediments have accumulated over many years. Such sediment accumulations become important long-term, internal sources of pollutants, which keep cycling phosphorus into the water column and are difficult to eliminate. The river's eutrophication problem is exacerbated by low flows, providing insufficient dilution of the wastewater treatment plant effluents.

In 1992, OAR initiated a water quality monitoring program to evaluate the impact of wastewater treatment plant upgrades, completed in the late 1980's, on the river's water quality. Since 1992, OAR has continued to collect baseline water quality data to document the overall condition of the river and assess the impact nutrient additions from a number of sources including: wastewater treatment plant effluent, Nashoba Brook (the largest of the Assabet's tributaries), and nutrient cycling from sediments. The information generated by OAR's water quality program helped to raise awareness throughout the watershed about the Assabet's nutrient problem, to point to the need for stricter phosphorus limits in the waste water treatment plant's NPDES permits, and to make a strong case for a Total Maximum Daily Loading (TMDL) study.

In July 1999, the state of Massachusetts and the US Army Corps of Engineers funded ENSR, a private consulting company, to carry out Phase 1 of the Assabet River TMDL Study. The goal of the Phase 1 study is to better define the river's eutrophication problem and to provide data that can be used to model the river in Phase 2 of the study. From their initial survey in July 1999 (ENSR, 1999), ENSR concluded that nutrient concentrations, both phosphorus and nitrogen species, were at levels indicative of nutrient saturation (i.e. neither nutrient limited plant growth) and that the Assabet is severely eutrophied.

The TMDL study is relevant to OAR's water quality monitoring program in several ways. OAR's water quality program can provide additional data for nutrient modeling, and, after the TMDL recommendations for controlling nutrient loads are implemented, OAR's program will monitor their effect on the river's condition.

The goals of OAR's 1999 water quality monitoring program were:

(1) Continue collecting water quality data to understand long term trends in the Assabet River's condition, to assess whether the river meets Massachusetts Surface Water Quality Standards for Class B waters, and to assess the potential impact of any future 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 ongoing 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 by increasing the number of volunteers participating in the program and expanding public knowledge of the program and its findings.

In support of these goals, a Quality Assurance Program Plan (OAR, 2000) documenting OAR's sampling methods and quality control measures was submitted to the EPA and received approval in April 2000. Water quality data collected under the approved QAPP may be used by EPA and DEP in making regulatory decisions and in modeling for the TMDL phase two study.

Methods

Twenty-nine trained volunteers and two OAR staff members monitored water quality at 24 stations along the main stem and at one station on Nashoba Brook, the largest tributary of the Assabet (Figure 1, Table 1). Sites are designated by rivermiles above the confluence of the Assabet and Sudbury Rivers at Egg Rock in Concord. Samples (bottle samples, YSI measurements, gage readings and observations) were taken one Saturday morning (5:00 am - 9:00 am) each month in June, July, August, and September. In August, sampling was repeated in the afternoon (~ 5:00 p.m. - 9:00 p.m.). Staff gages were read weekly at Cox Street, Damonmill, and the A1 Impoundment. Flow and stage readings from the USGS gage at Maynard were downloaded from the USGS web page twice a week.

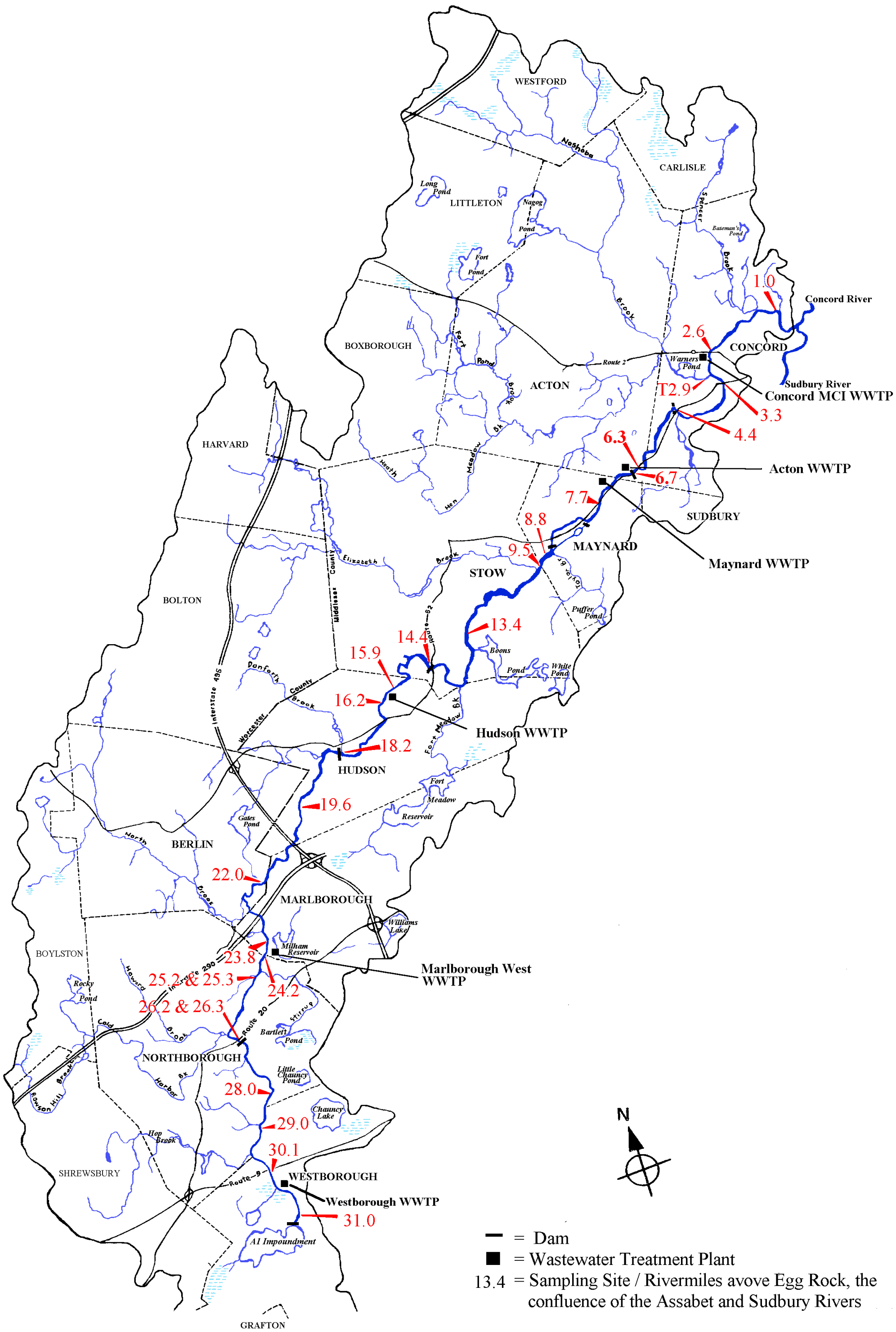
In addition to the baseline monitoring program, two projects were undertaken in 1999. In July, depth profiles of dissolved oxygen were measured at five sites in the Ben Smith impoundment in Maynard (between White Pond Road and the Ben Smith dam) to investigate the dissolved oxygen levels in these impoundments during the growing season. In August, bottle samples and YSI measurements were taken in the morning and again in the evening to assess the diurnal variation in those parameters at all sites.

Table 1: OAR Sampling Sites

OAR Site #	OAR Site Description	Water Quality Data Collected		
		YSI readings*	Bottle Samples**	Stage/ Flow
A1	gage at outflow or in impoundment			X
31.0	by Maynard St. bridge, Westboro	X	X	
Sassacus	off the end of Sassacus Dr.	X		
30.1	by Rte 9 East bridge, Westboro	X	X	
28.0	by School Street bridge, Northboro	X	X	
26.3	above the dam at Rte 20, Northboro	X	X	
25.3	from Allen Street bridge, above dam, Northboro	X	X	
24.2	by Boundary Street bridge, Northb./Marlb.	X	X	
23.8	above dam off Robin Hill Road, Marlboro	X	X	
22.0	by Bridge St. bridge, Berlin	X	X	
19.6	by Chapin Road bridge, Hudson	X	X	
18.2	below Rte 85 bridge, Hudson center	X	X	
16.2	by Cox Street bridge, Hudson	X	X	X
14.4	above Gleasondale dam Rte 62, Stow	X	X	
13.4	by Sudbury Road bridge, Stow	X	X	
9.5	by White Pond Rd. bridge, Stow	X	X	
7.7	by USGS gage, Rte 62, Maynard	X	X	X
6.5a	concrete pad of old weir,, Powdermill dam, Acton	X	X	
6.5b	from Old High St. bridge at dam, Acton	X	X	
6.3	above Rte 62 near Acton Ford, Acton	X	X	
4.7	above old dam @ Damonmill., Concord		X	
4.4	from Rte 62 bridge @ Damonmill, Concord	X		X
3.3	by Rte 62 bridge near Donut Shoppe, Concord	X	X	
2.6	by Rte 2 bridge east of Assabet Ave., Concord	X	X	
T2.9	Nashoba Brook, by Comm. Ave. bridge, Concord	X	X	
1.0	below Dakins Brook, off Lowell Rd., Concord	X	X	

* YSI readings: temperature, DO, pH, conductivity, and oxidation/reduction potential
** Bottle Samples: TSS, BOD5, TP, ortho-P, TKN, nitrates, and ammonia

Figure 1: Assabet River Watershed and Sampling Sites 1999



Samples for nutrients, biochemical oxygen demand, and suspended solids, samples were taken using bottles supplied by the laboratories. Samples were stored on ice. Samples to be analysed by Thorstensen Laboratory were delivered to the laboratory within 4 hours. Total phosphorus samples to be analysed by the Environmental Analysis Laboratory were frozen within 4 hours of sampling and delivered to the lab within 8 weeks (holding time for the frozen samples is up to one year). Temperature, pH, dissolved oxygen, conductivity, and oxidation/reduction potential measurements were taken using multi-function YSI-6920 meters. To ensure that samples were representative of the bulk flow of the river in wadeable free-running sections, bottle samples were taken from the main flow of the river at mid-depth. Where the river was less than ~ 10 ft. wide measurements with the YSI were taken at mid-depth in the main flow of the river; where the river was wider, measurements were taken mid-depth at the left, center, and right of the cross-section and the readings averaged. Where the river was not wadeable (sites 26.3, 25.3, 14.4, and 6.5a & b) bottle samples were taken from the top layer of the water column (less than ~ 1 foot depth), and YSI measurements were taken in the top, middle and bottom layers by sampling from the bridges with a 50-foot cable extension. YSI readings from the several depths are reported as averages when there is no significant difference among the readings. Ten percent field duplicate samples were taken and are reported here as an average of the two measurements. Table 2 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: 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 mS/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.
Biochemical Oxygen Demand (BOD5)	grab	EPA 405.1	>1.0 mg/L	bottle	Thorstensen Laboratory Inc.
Total Phosphorus (Thorstensen)	grab	EPA 365.2	0.01 - 1.0 mg/L	bottle	Thorstensen Laboratory Inc.
Total Phosphorus (Env. Labs)	grab	4500-P E [b]	0.003 - 0.5mg/L	bottle	Environmental Analysis Lab, UMass Amherst
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.

In previous years pH was measured in the lab from bottle samples. In 1999 pH was measured in the field (along with temperature, DO, conductivity and ORP) using the YSI 6920 meters. A study of the two methods was done in June to ensure that the measurements would be comparable. The average difference between measurements was 0.13 pH units, which is well within the acceptable range (0.20 pH units) for duplicate samples. Therefore the methods were deemed comparable and pH measurements taken in previous years may be readily compared with those taken in 1999.

Water quality measurements were compared with the Massachusetts Water Quality Standards for Class B warm waters (Table 3). 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 suggested trophic status boundaries (Table 4) in EPA Draft Nutrient Criteria Technical Guidance Manual: Rivers and Streams (EPA, 1999) and EPA Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs (EPA, 2000).

Table 3: 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 Δ < 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 4: Trophic Classification Boundaries

System	**Parameter**	**Oligotrophic - mesotrophic boundary (mg/L)**	**Mesotrophic - eutrophic boundary (mg/L)**
Rivers and Streams	Total Phosphorus *	0.025	0.075
	Total Nitrogen *	0.70	1.50
Lakes and Impoundments	Total Phosphorus **	0.01	0.02

* adapted from USEPA, 1999.
** adapted from USEPA. 2000.

Results and Discussion

Monthly summary statistics and averages for the upper and lower reaches of the river are presented in Table 5. These statistics were calculated for surface waters and running sections along the length of the river (depth profiles for the Ben Smith and Powdermill Impoundments are discussed below). Site 7.7 (Route 62, Maynard) was selected as the dividing point between the upper and lower reaches because the nutrient concentrations, nitrates in particular, are markedly lower below site 7.7 and because flow is measured at the USGS Maynard gage at this site.

Site 31.0 (Maynard Street, Westborough), the site nearest the headwaters of the Assabet and above the first wastewater treatment plant discharge, is the least impacted. 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). Site T2.9 is on Nashoba Brook, Concord, between Warners Pond and the Assabet River; Nashoba Brook is the Assabet's largest tributary. Individual parameters are discussed below. Full monthly summaries of the water quality data are attached in the Appendix.

DO, Temperature, and pH:
Dissolved oxygen, temperature, pH, conductivity, and oxidation-reduction potential (ORP) measurements were taken in June, July, August, and September between 4am - 8am, when daily dissolved oxygen concentrations are expected to be at their lowest.

Temperatures ranged from 16.7 - 24.9 ° C, meeting the water quality standard of 28.3 ° C for Class B warm waters. However, in August and September the temperature change between sites 31.0 and 30.1 (above and below the Westborough waste water treatment plant) exceeded the water quality standard, a change of > 2.8° C. Warmer temperatures along the river were generally associated with the slower moving sections and impoundments. pH measurements ranged from 6.57 to 7.67 units, which met the Class B standards.

Dissolved oxygen (DO) concentrations are generally at their lowest between 5 am - 8 am after plant and microbial respiration has been removing oxygen from the water column during the night. Low morning concentrations and large diurnal variations in DO indicate eutrophic conditions. Figure 2, morning DO concentrations in July, shows a typical distribution of low DO values along the river. DO concentrations below 5.0 mg/L were found all along the river, especially in the slower-moving sections. During the lowest river flows, in July and August, almost half the stations surveyed failed to meet the water quality standard (5.0 mg/L and 60% saturation) for DO. Five of 22 sites in June, 11 of 21 sites in July, 13 of 25 sites in August, and 1 site (30.1 below the Westborough WWTP) of 24 sites in September failed to meet the water quality standard. Morning DO concentrations in the running river sections and top layers of the impoundments ranged from 3.06 - 8.81 mg/L in June, 3.79 - 10.84 mg/L in July, 1.28 - 8.87 mg/L in August, and 4.87 - 9.11 mg/L in September.

Diurnal Variation:
In August, morning and afternoon samples were taken to assess diurnal variation. Large changes in dissolved oxygen concentrations were measured all along the river. The most significant diurnal variations measured were in dissolved oxygen and pH. Figure 3 shows morning and afternoon values for dissolved oxygen. While 13 of the 25 sites measured failed to meet the water quality standard for DO in the morning, by afternoon DO at all the sites re-tested was above 6.0 mg/L. The diurnal change in DO was relatively large (> 4.0 mg/L) at 9 sites. The largest changes in pH were generally associated with the largest swings in DO and were likely due to photosynthetic activity. Figure 4 plots changes in dissolved oxygen against changes in pH. Diurnal variation in the other parameters measured (temperature, nutrients, and total suspended solids) was less significant.

Table 5: **Statistics and Reach Averages**

Dates	Sample Locations		Statistics and Reach Averages (running river sections and impoundment surface waters)													
			Water Temp (oC)	DO (mg/L)	DO% Sat	pH	TSS (mg/L)	Total Phos (mg/L)	Ortho-Phos (mg/L)	Nitrates (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Avail. Nitrogen (mg/L)	Avail. N:P	Total Nitrogen (mg/L)	TN:TP
June	All	Maximum	24.9	8.81	97.6	7.54	20.0	0.56		5.1	0.12					
June	All	Minimum	18.2	3.06	35.9	6.71	4.0	0.03		0.30	0.03					
June	31.0	Maynard St., Westboro	18.2	8.81	93.1	7.39	17.0	0.03		1.0	0.06					
June	30.1 - 7.7	Rte 9 to Maynard Gage	21.8	5.85	66.4	7.14	9.5	0.28		3.0	0.07					
June	7.7 - 1.0	Maynard Gage to Dakins	23.0	6.17	71.6	7.36	10.2	0.17		0.77	0.06					
June	T2.9	Nashoba Brook	23.4	5.27	73.1	7.17	11.0	0.07		0.30	0.07					
July	All	Maximum	26.6	10.84	133.7	9.05	23.0	0.90	0.71	6.2	0.11	0.95	6.3	99.0	6.98	37.1
July	All	Minimum	21.0	3.79	45.2	6.65	1.0	0.04	0.01	0.10	0.03	0.43	0.19	1.2	0.83	2.7
July	31.0	Maynard St., Westboro	21.0	8.14	89.5	7.31	3.0	0.04	0.01	0.90	0.05	0.55	0.99	99.0	1.49	37.1
July	30.1 - 7.7	Rte 9 to Maynard Gage	24.4	5.65	67.2	7.24	9.2	0.39	0.30	3.9	0.06	0.75	3.9	16.5	4.63	13.8
July	7.7 - 1.0	Maynard Gage to Dakins	24.6	4.96	59.3	7.23	5.5	0.24	0.15	0.50	0.06	0.57	0.57	3.7	1.08	4.6
July	T2.9	Nashoba Brook	26.6	5.30	65.3	7.24	12.0	0.06	<0.01	0.30	0.07	0.80	0.37	37.0	1.11	18.5
August AM	All	Maximum	23.1	8.87	102.3	7.67	66.0	1.04	0.81	7.6	0.25	1.2	7.8	43.0	8.60	12.8
August AM	All	Minimum	16.7	1.28	14.6	6.71	1.0	0.12	0.09	0.25	0.04	0.36	0.31	3.5	0.61	1.8
August AM	31.0	Maynard St., Westboro	16.7	7.51	71.3	7.42	4.0	0.12	<0.01	0.39	0.04	0.58	0.43	43.0	0.97	8.1
August AM	30.1 - 7.7	Rte 9 to Maynard Gage	20.9	5.86	63.6	7.15	5.5	0.54	0.35	4.0	0.08	1.03	4.0	14.7	5.00	9.4
August AM	7.7 - 1.0	Maynard Gage to Dakins	21.3	4.79	53.4	7.13	13.1	0.43	0.19	0.80	0.13	0.69	0.93	5.1	1.49	3.9
August AM	T2.9	Nashoba Brook	22.9	6.02	68.9	7.21	4.7	0.17	<0.01	0.25	0.06	0.36	0.31	31.0	0.61	3.6
August PM	All	Maximum	21.9	11.05	119.4	7.72	8.0	1.2	0.94	7.3	0.30	0.83	7.4	48.6	7.90	42.5
August PM	All	Minimum	19.0	6.03	66.5	6.80	1.0	0.02	<0.01	0.20	0.04	0.38	0.28	3.7	0.59	3.7
August PM	31.0	Maynard St., Westboro					8.0	0.02	<0.01	0.38	0.04	0.47	0.42	42.0	0.85	42.5
August PM	30.1 - 7.7	Rte 9 to Maynard Gage	20.4	8.59	95.3	7.21	3.0	0.53	0.35	3.9	0.09	0.65	4.0	16.1	4.56	9.0
August PM	7.7 - 1.0	Maynard Gage to Dakins	19.8	9.13	99.9	7.45	3.9	0.29	0.17	0.86	0.15	0.52	1.0	6.5	1.38	4.8
August PM	T2.9	Nashoba Brook	21.1	8.88	99.8	7.60	3.0	0.08	<0.01	0.21	0.07	0.38	0.28	28.0	0.58	7.4
Sept.	All	Maximum	19.5	9.11	94.3	7.19	17.0	0.6	0.56	6.3	0.18	1.4	6.4	77.0	7.20	24.8
Sept.	All	Minimum	15.3	4.87	52.5	6.57	2.0	0.05	0.02	0.45	0.05	0.59	0.60	8.0	1.20	7.7
Sept.	31.0	Maynard St., Westboro	15.3	8.65	84.9	7.19	2.0	0.05	<0.01	0.74	<0.03	0.60	0.80	77.0	1.30	24.8
Sept.	30.1 - 7.7	Rte 9 to Maynard Gage	17.6	7.42	77.0	6.82	9.0	0.25	0.20	2.6	0.11	0.84	2.7	14.1	3.40	14.1
Sept.	7.7 - 1.0	Maynard Gage to Dakins	18.2	7.89	83.5	6.75	10.5	0.17	0.13	0.94	0.14	1.0	1.1	8.6	2.00	11.5
Sept.	T2.9	Nashoba Brook	18.1	8.02	84.7	6.57	4.0	0.06	0.02	0.45	0.11	0.78	0.60	28.0	1.20	20.5

Figure 2: **Dissolved Oxygen Concentrations**

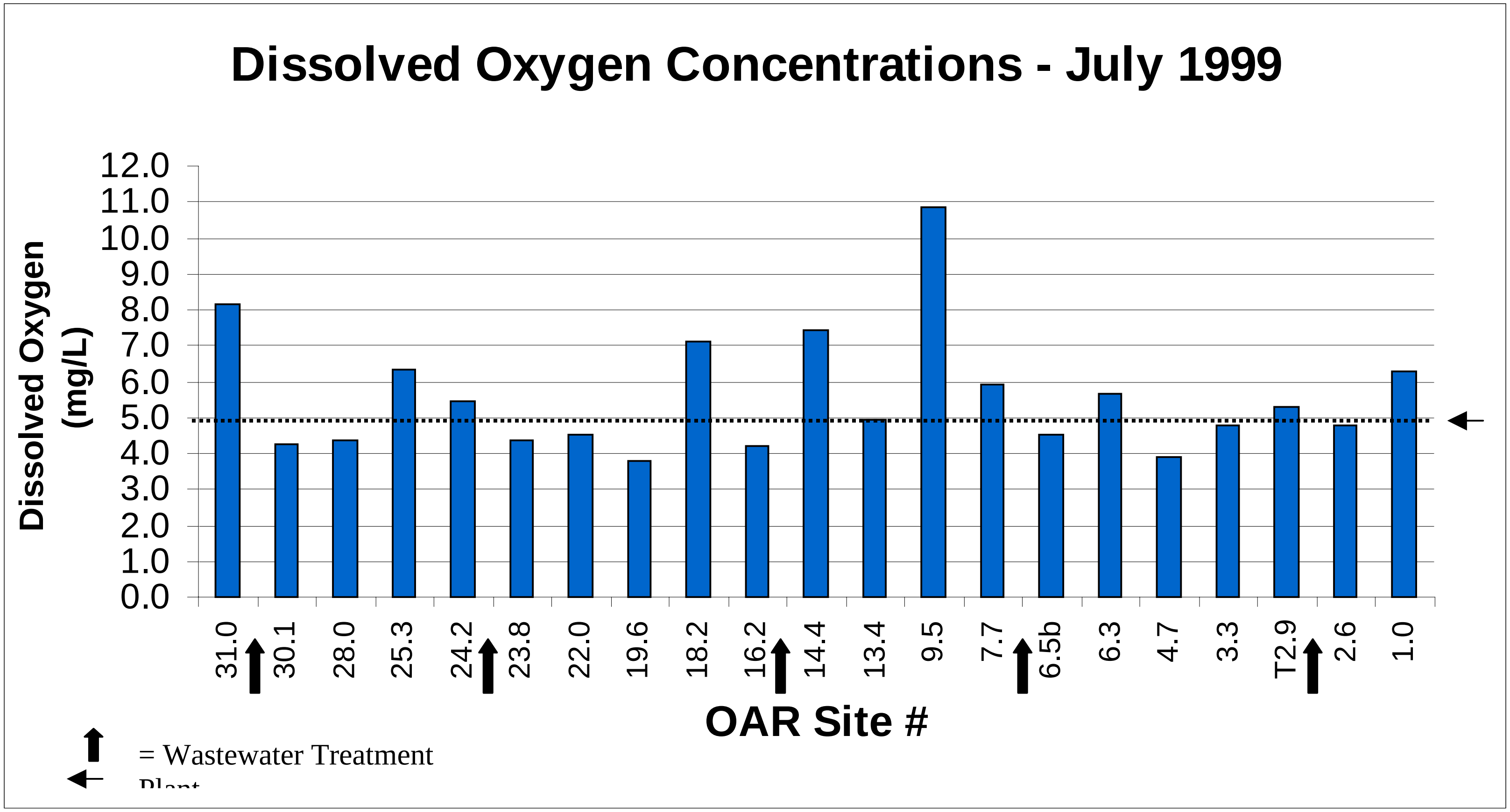


Figure 3: **Dissolved Oxygen Concentrations (AM and PM)**

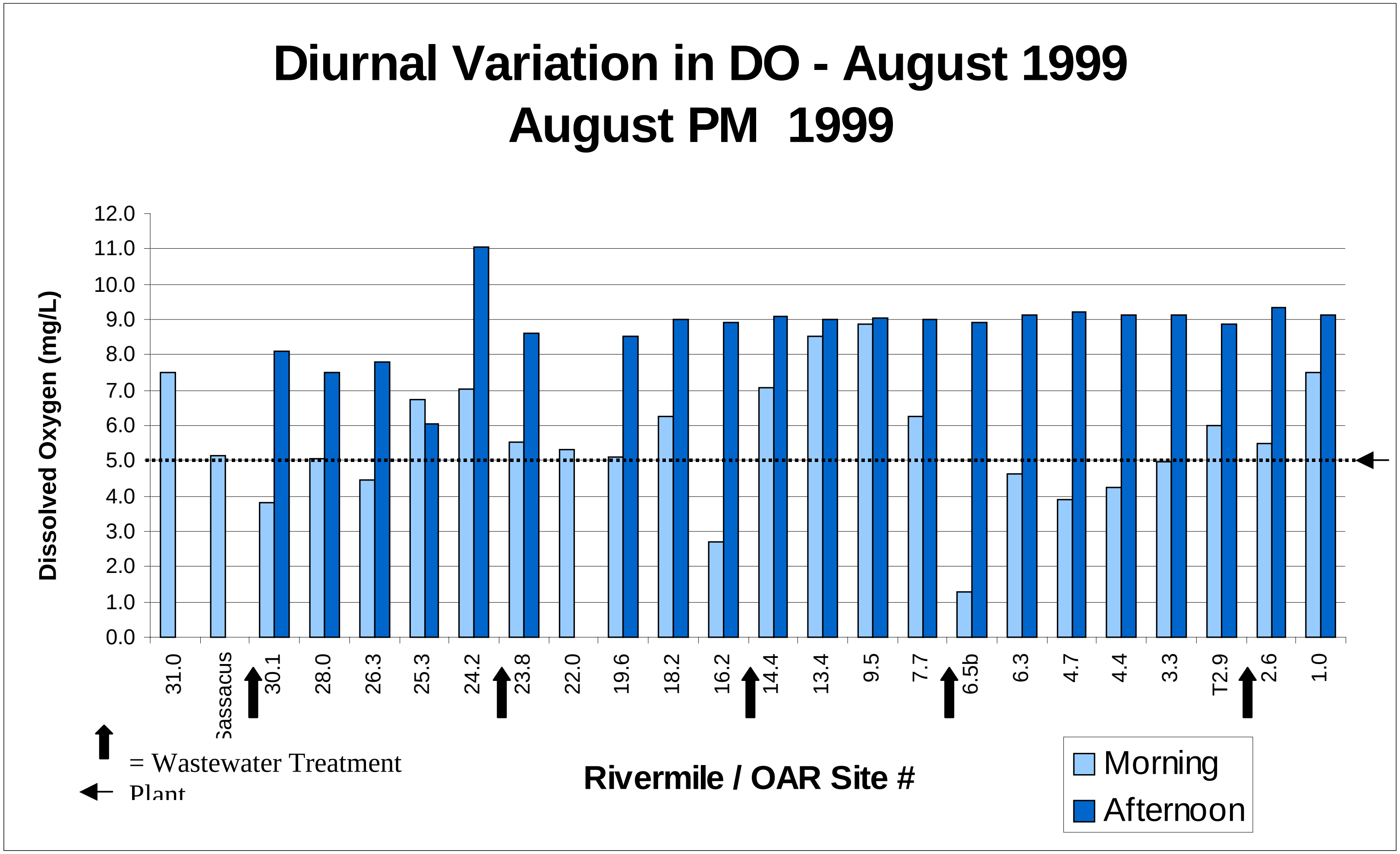
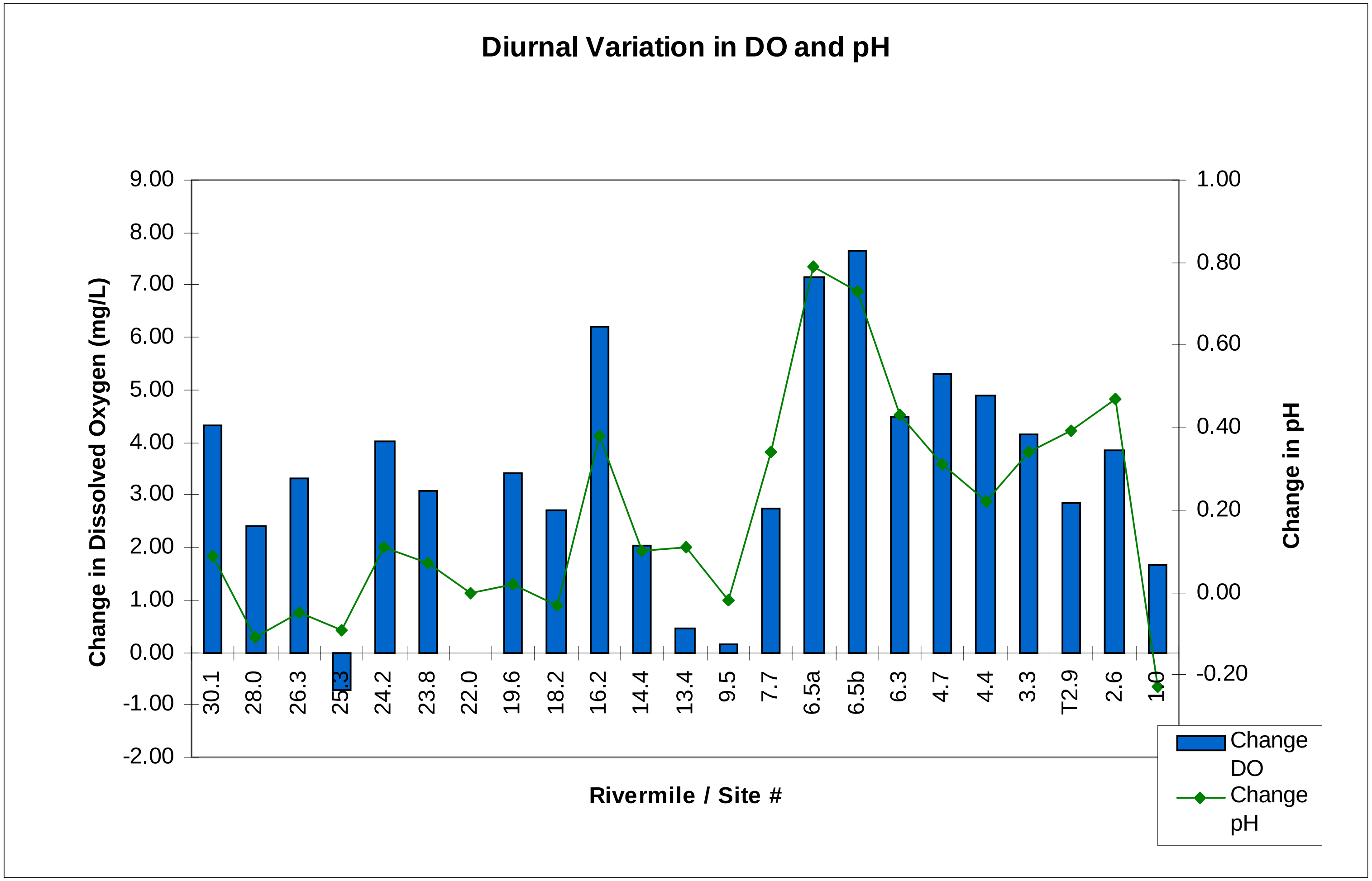


Figure 4: **Diurnal Variation in DO and pH**



Nutrients:
Summary statistics for nutrient and solids concentrations are in Table 5. Figures 5 - 8 of nutrient concentrations in August (morning) show typical distributions of the nutrients along the river. In general, nutrient concentrations were in eutrophic or hypereutrophic ranges 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 generally in the mesotrophic range.

Concentrations of total phosphorus (which represents both the dissolved and particulate phosphorus in the water column) tended to be highest in the upper reaches of the river where dilution of the wastewater treatment plant effluent by baseflow was the least. All sites except 31.0 (Maynard St., Westborough) and T2.9 (Nashoba Brook) exceeded 0.075 mg/L total phosphorus, the phosphorus threshold for eutrophication of rivers, on all dates tested. Concentrations of ortho-phosphorus, which represents the available phosphorus in the water column, ranged from <0.01 - 0.94 mg/L along the river.

Nitrogen species concentrations were also high. Total nitrogen (TN, calculated as the sum of TKN and nitrates concentrations) concentrations were consistently ~3 - 7 times higher in the upper reach of the river than in the lower reach. Sites along the upper reach exceeded 1.5 mg/L, the TN threshold for eutrophication for both rivers and impoundments, on each date tested. In the lower reach the TN concentrations ranged from 1.08 - 2.0 mg/L. Nitrates ranged from 2.6 - 4.0 mg/L in the upper reach and 0.50 - 0.94 mg/L in the lower reach. Ammonia concentrations ranged from 0.06 - 0.11 mg/L in the upper reach and 0.06 - 0.15 mg/L in the lower reach. Available nitrogen (the sum of nitrates and ammonia) represents the fraction of nitrogen readily available for uptake by plants. Available nitrogen ranged from 2.7 - 4.05 mg/L in the upper reach and 0.57 - 1.1 mg/L in the lower reach.

The lower concentrations of nitrogen and phosphorus species in the lower half of the river may be explained by two factors: the larger relative proportion of baseflow to effluent in the lower river, and nutrient uptake by plants. In the lower reach of the river the lowest average nitrates concentration was measured in July, during the height of the aquatic plant growing season, whereas the highest average concentration measured in that reach was in September. This suggests that, during the height of the growing season, nitrates were being taken up by actively growing macrophytes and algae.

Nitrogen:phosphorus ratios have been used as the basis for estimating which nutrients limit algal growth. Low Total N:P ratios (less than about 7:1) can indicate N limitation, while ratios greater than 10:1 can indicate phosphorus limitation. However, low Total N:P ratios are also seen hypereutrophic water bodies and are typically the result of high TP loads from point or nonpoint sources in the watershed rather than a shortage of nitrogen. TN:TP ratios ranged from 42.5 to 1.8. The ratio of available nitrogen:phosphorus ranged from 99.0 to 1.2.

Figure 5: Total Phosphorus

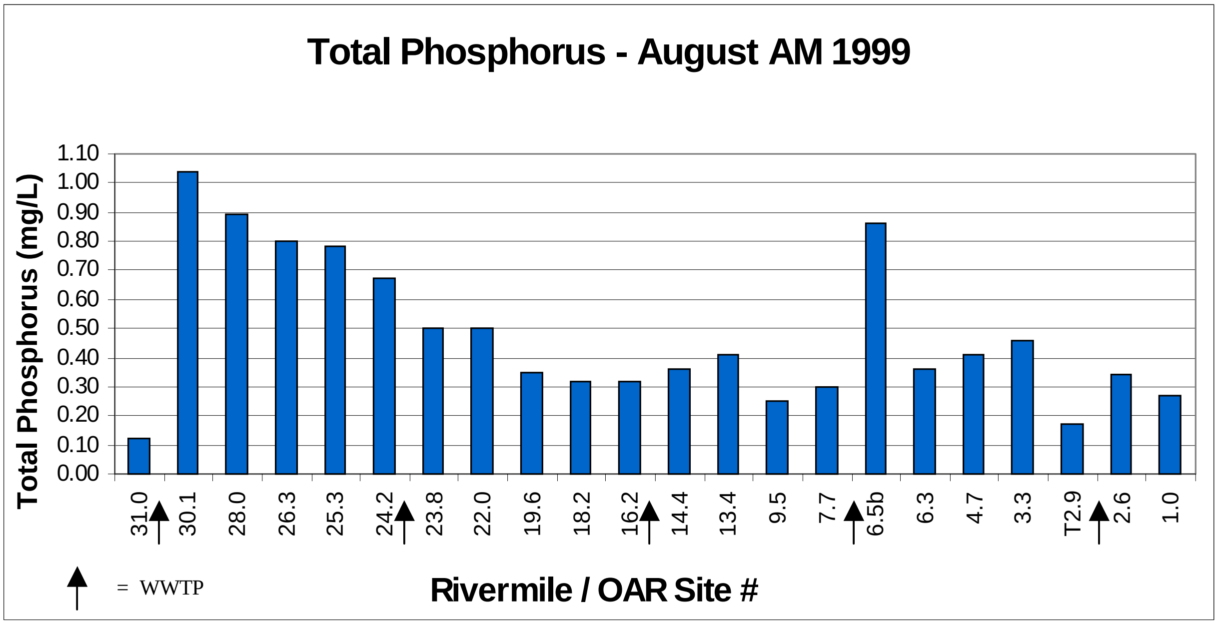


Figure 6: Total Nitrogen

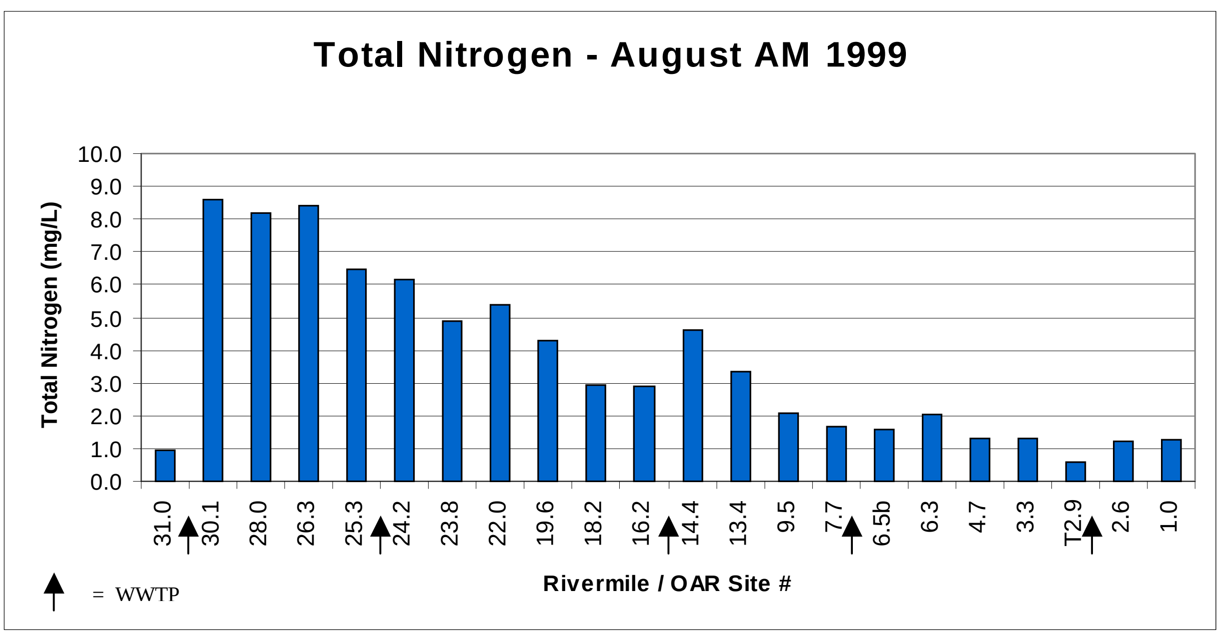


Figure 7: Ortho-Phosphorus

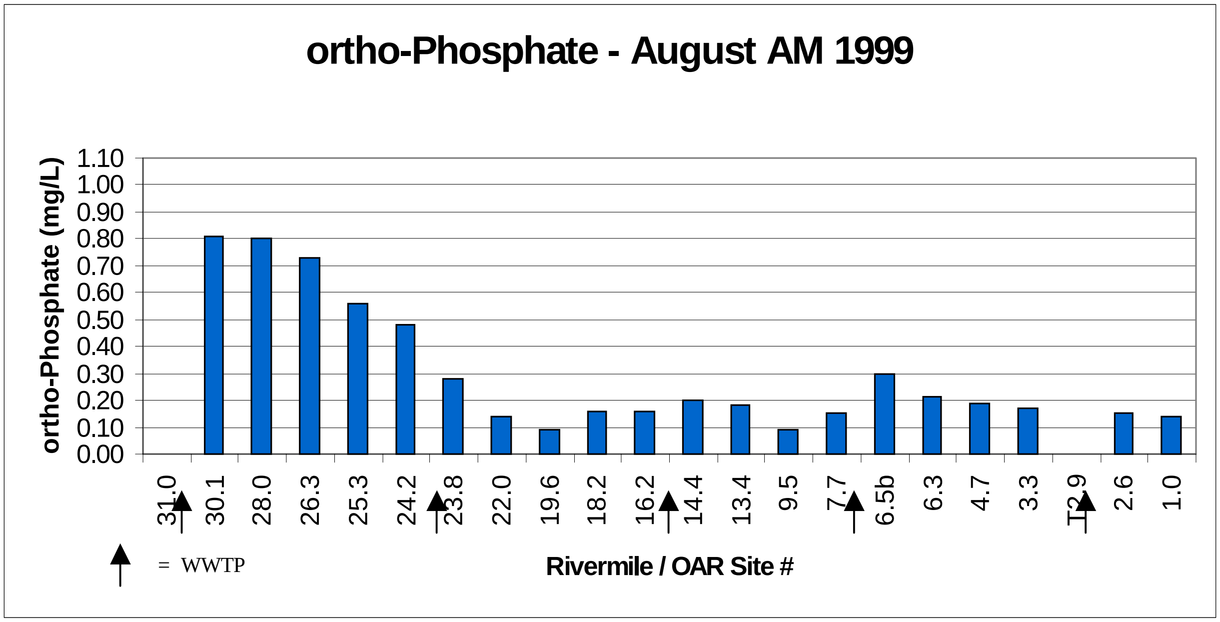
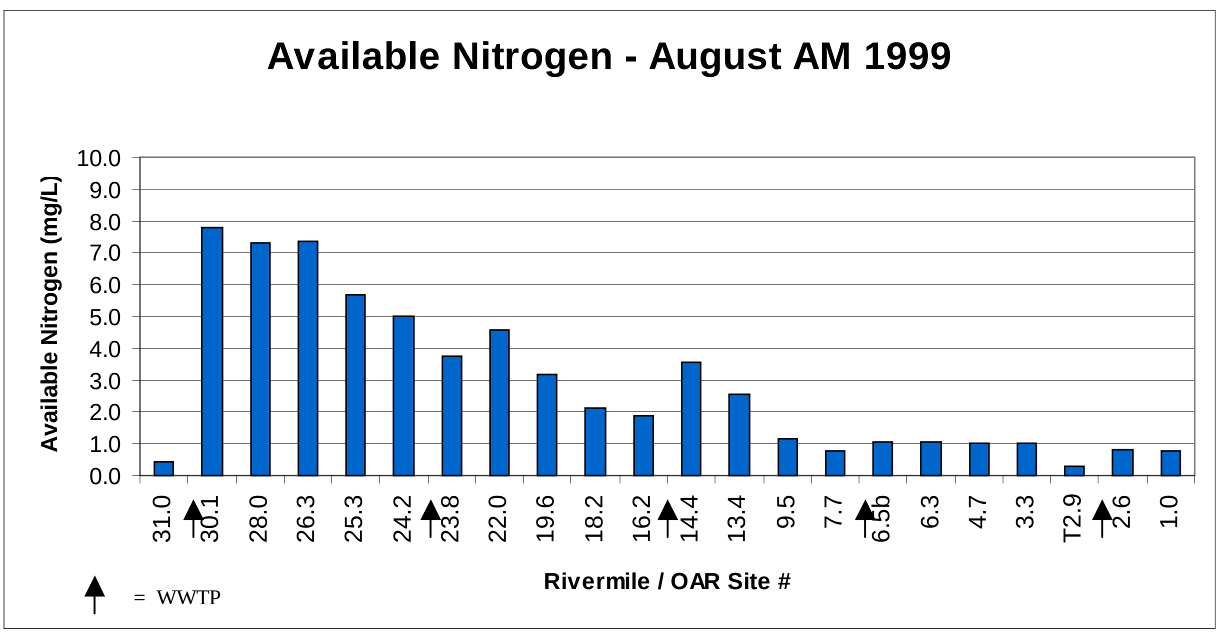


Figure 8: Available Nitrogen



Depth Profiles (DO vs. depth):
To assess conditions in a typical impoundment, dissolved oxygen, temperature, pH, conductivity and ORP measurements were taken at a series of depths in the Ben Smith Impoundment (between White Pond Rd., Stow, and Rte. 117, Maynard). All measurements were taken between 4 - 6 p.m. Figure 9 shows the sampling site locations; Figure 10 shows the dissolved oxygen concentrations at five sites on the impoundment.

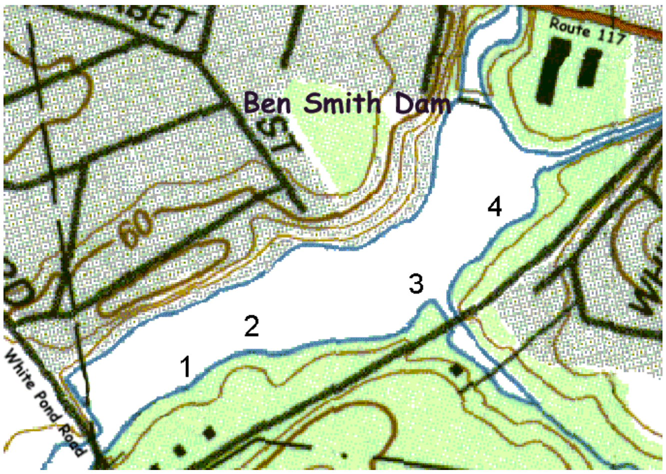


Figure 9: Sampling Sites on the Ben Smith Impoundment

Both extremely high and extremely low dissolved oxygen concentrations, both of which damage fish habitat, were present in the impoundment. The highest DO concentrations were measured at Site 2, over a shallow sand bar with prolific rooted plant growth. DO concentrations at all depths at Site 2 were in excess of 200% saturation (~8.0 mg/L is saturated at 25 °C). Dissolved oxygen concentrations in excess of 125% saturated are considered dangerous to fish. pH's in excess of the water quality standard (pH 8.3) were measured at sites 1, 2, and 3 and were generally associated with high photosynthetic activity/high DO concentrations. The lowest DO concentrations was measured at Site 4, near the Ben Smith dam, under 100% duckweed cover. DO concentrations at Sites 4 were < 5.0 mg/L below about 5 ft depth, and near the bottom DO concentrations were close to 0 mg/L. The duckweed was likely shading out growth of other aquatic plants below the surface, so that dissolve oxygen was not being replenished during the day. Thus, beneath the duckweed cover, the dominant influence on DO concentration was likely microbial uptake. The lower layers of this impoundment were likely anoxic for long periods during the summer.

DO concentrations were also measured each month at Site 6.5b (from the Old High St. bridge) in the Powdermill Impoundment, Maynard, at three depths (bottom, mid-depth, and top). Figure 11 shows dissolved oxygen concentrations in the impoundment. In July and August, morning DO concentrations in the whole water column were below 5.0 mg/L and the bottom layer was below 1.0 mg/L.

Figure 10: Dissolved Oxygen Concentrations - Ben Smith Impoundment

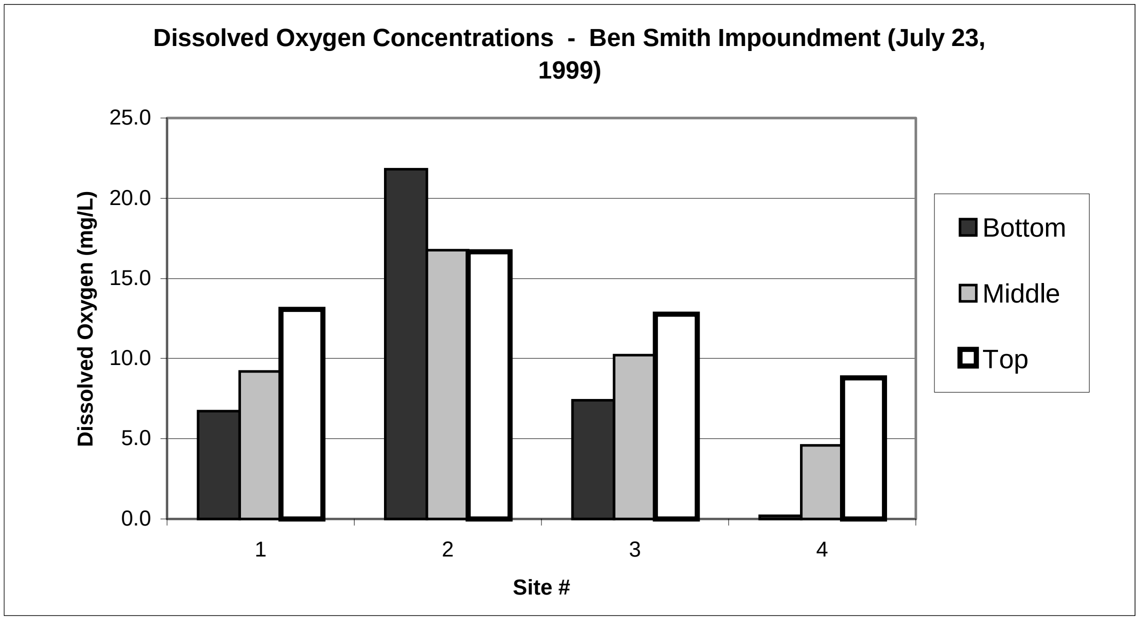
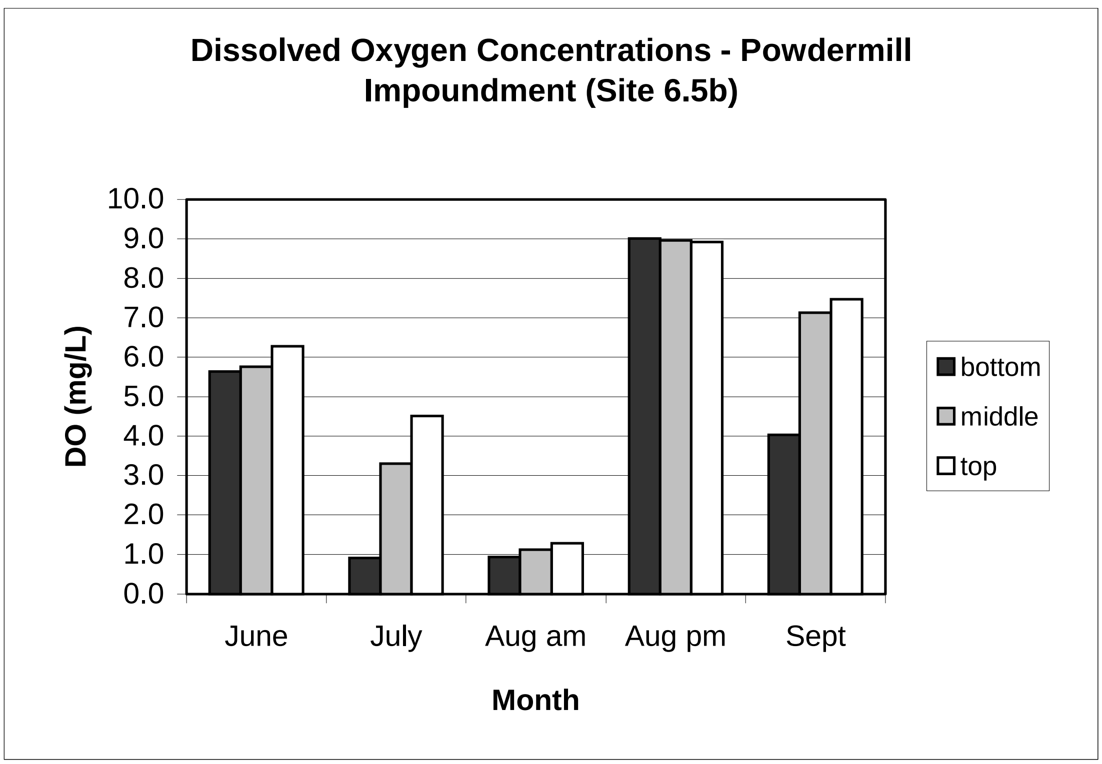


Figure 11: Dissoved Oxygen Concentrations - Powdermill Impoundment



Conclusions

The summer of 1999 probably provided worst case conditions for eutrophication in the river. In June, July and August flows in the river were at record lows according to the USGS gage measurements at Maynard. Low flows meant little dilution for the wastewater treatment plant effluents and thus high concentrations of nutrients. ENSR estimated that in July 80% of the streamflow at the Maynard gage was effluent. High nutrient concentrations, slow moving water, and warm temperatures combined to produce prolific macrophyte growth.

In general the highest nutrient concentrations were seen in the upper reaches of the river where there was little dilution of the wastewater treatment plant effluent, while low dissolved oxygen readings were observed all along the river. Both nitrogen and phosphorus concentrations were lower further down river; this is probably the effect of greater dilution by baseflow in the lower sections and uptake by macrophytes and algae. The greatest macrophyte growth was observed in the slow moving impoundments, with large mats of duckweed accumulating behind the dams. However, even in the lower, free flowing sections of the river (below the Powder Mill impoundment) floating duckweed and low dissolved oxygen levels were observed. Depth profiles of dissolved oxygen levels in the Ben Smith and Powdermill impoundments showed DO concentrations below 5.0mg/L at the bottom of the impoundments in July and August.

Large diurnal variations in dissolved oxygen concentrations were measured at sites all along the river in August. Large diurnal variations in dissolved oxygen are indicative of eutrophication and may be harmful to fish and aquatic organisms.

The data collected in the 2000 season will be used to continue building a baseline water quality record and to support OAR's program goals. The choice of model for the nutrient TMDL project is currently under discussion by DEP and the U.S. Army Corps of Engineers. As soon as a model is chosen, OAR will review the specific requirements of the model and the data being provided by ENSR to identify any data gaps. OAR's water quality program should be then tailored to provide additional information for TMDL nutrient modeling and to continue monitoring the river once management recommendations have been implemented.

Because nutrient concentrations are so high in the Assabet, control and remediation must be approached on multiple fronts: reduce both point and non-point nutrient inputs to the river, protect baseflow, and assess sediment conditions. A fishable, swimmable Assabet River would be a significant asset to the communities in its watershed.

References

American Public Health Association. 1995. Standard Methods for the Examination of Water and Wastewater, 19th Edition. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington D.C., 1995.

Behar, Sharon. 1996. Testing the Waters: Chemical and Physical Vital Signs of a River. Kendall/Hunt Publishing Company.

ENSR. 1999. SuAsCo Watershed Phased TMDL Study: Assabet River Part One - Interim Report, Executive Summary. ENSR Corporation #9000-221-802, November 1999.

GEC. 1994. Final Water Resource Study: Sudbury, Assabet and Concord Rivers. Goldman Environmental Consultants, Inc. April 21, 1994.

MADEP. Surface Water Quality Standards. 314 CMR 4.0 Division of Water Pollution Control. May 1, 1998.

OAR. 2000. Quality Assurance Project Plan for the Volunteer Water Monitoring Program. Organization for the Assabet River. January 2000.

USEPA. 1983. Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati. EPA-600/4-87-017. March 1983.

USEPA. 1999. Draft Nutrient Criteria Technical Guidance Manual: Rivers and Streams. EPA-822-D-99-003. September 1999.

USEPA. 2000. Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs. First Edition. EPA-822-B-00-001. April 2000.

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 stream bed. 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 flow 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. Flow 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.