Organization for the Assabet River

StreamWatch and Water Quality Monitoring Program
Final Report – May to September 2006

June 2007

Acknowledgments

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Abstract

OAR collected water quality, streamflow, and aquatic plant biomass on the Assabet and Concord Rivers and on tributary streams in the watershed between May and September 2006. Conditions over the summer of 2006 were wetter than normal with particularly high rainfall in May and June. The Department of Conservation and Recreation reported monthly rainfall for the Central Region of Massachusetts was 132% of normal over the summer; precipitation in the Northeast Region over the same period of time was 174% of normal. Streamflows measured by the USGS gages on the Assabet River in Maynard and the Concord River in Lowell were above normal for most of May and June and near normal for the remainder of the summer. Weekly streamflows were recorded at eight tributary monitoring sites and near the headwaters of the Assabet River. Streamflows at these sites tended to be at their lowest in mid-August and again in mid- to late September.

Dissovled oxygen (DO) concentrations generally met acceptable levels 2006, ranging from 3.91 mg/L to 10.27 mg/L in the mainstem with the average about 7.45 mg/L. DO in the mainstem failed to meet water quality standards at one site and one date tested. In the tributaries the range of DO concentrations was 3.37 - 10.34 mg/L, failing to meet water quality standards on six occasions. The lowest readings were likely influenced by upstream beaver impoundments.

As in previous years, nutrient concentrations along the Assabet River mainstem below the first wastewater discharge (Westborough WWTP) were well above Ecoregion reference conditions (25^{th} percentile of the summertime data) for total phosphorus, total nitrogen, and nitrates. Nutrient concentrations at the three Concord River mainstem sites were generally lower than upstream concentration, but still exceeded Ecoregion reference conditions for total phosphorus, total nitrogen, and nitrates. In nutrient concentrations in the mainstem rivers (below the first WWTP input) tended to decrease from upstream to downstream. Nutrient concentration in the tributaries were generally lower than mainstem concentrations.

The aquatic plant biomass (as wet weight) per impoundment was assessed on four impoundments of the Assabet River and one impoundment of the Concord. Total biomass per impoundment calculated in 2006 was from 51% to 83% less than reported in 1999 as part of the Assabet River Nutrient TMDL. Much of the variability may be attributable to differences in climate, as indicated by rainfall and streamflows. Summer streamflows in 1999 were about 30% of normal. In comparison, summer streamflows were near normal in 2000 (88%) and 2005 (97%), but considerable higher than normal in 2006 (147%). The differences in total biomass calculated per impoundment among the years suggest that annual variation in biomass is relatively high, and that a long-term baseline of measurements will be needed to be able to detect future changes in biomass attributable to changes in watershed management. Comparison of the first two year of monitoring suggests that aquatic plant biomass tends to vary inversely with summer streamflows and rainfall.

Stream Health Readings were calculated at eight tributary sites and one site near the Assabet River headwaters (above the first wastewater discharge). The stream health was rated “excellent” or “good” for more than half of the weeks assessed at all of the sites tested. Lowest stream health readings tended to be in mid-August when streamflows were the lowest. Flow measurements in Cold Harbor Brook were disrupted again this summer by a beaver dam in the culvert just downstream of the gage by mid-August.

Introduction

The combined Assabet and Concord River watershed is about 236 square miles in eastern Massachusetts and is within EPA's Ecoregion XIV subregion 59, the Eastern Coastal Plain. The Massachusetts Department of Environmental Protection (MA DEP, 2004b) lists all sections of the Assabet and Concord Rivers, from the Assabet River Reservoir (A1 Impoundment) in Westborough to the confluence with the Merrimack River in Lowell, as Category 5 Waters, "Waters Requiring a TMDL." Two of the tributaries in the basin, Elizabeth Brook and River Meadow Brook, are also listed as Category 5 Waters (MA DEP, 2004b). Spencer Brook, from the outlet of Angiers Pond to its confluence with the Assabet River, is listed as Category 4c Waters, "Impairment not caused by a pollutant." Other tributaries are listed as either Category 2 ("Attaining some uses; other uses not assessed") or Category 3 ("No Uses Assessed"). A nutrient TMDL for the Assabet River, completed in 2004 (MA DEP, 2004a) concluded that the Assabet River is severly eutrophied and that reductions in nutrient loads from both point and non-point sources will be required to restore the Assabet River to Class B conditions.

The mainstem rivers, particularly the Assabet, suffer primarily from cultural eutrophication caused by excess nutrients entering the river. During the growing season these excess nutrients, phosphorus in particular, fuel nuisance algal and macrophytic plant growth which interferes with recreational use of the rivers and causes large daily variations in the concentration of dissolved oxygen in the water, making poor habitat for aquatic life. When the algae and plants decay (whenever they are exposed on the river banks and/or at the end of the growing season) they generate strong sewage-like odors and can dramatically lower the dissolved oxygen levels in the rivers.

The findings of the Assabet River Total Maximum Daily Loading Study (ENSR 2001, MA DEP 2004) confirms that the majority of the nutrients entering the Assabet come from the wastewater treatment plants that discharge treated effluent to the river. In particular, treatment plants are the major source of ortho-phosphorus (the bioavailable form of phosphorus) throughout the year. While non-point sources contribute nutrients, they contribute significantly less than 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 other sources. Ways to reduce sediment contributions to the nutrient load are currently being assessed in a study overseen by the U.S. Army Corps of Engineers.

Flow, particularly baseflow, is critical to supporting fish and other aquatic life in the mainstem river and tributaries and is essential to diluting the effluent discharged to the river. For the nutrient load reductions proposed in the state's TMDL to be effective in restoring water quality in the mainstem, the existing baseflow in the river and its tributaries must be preserved and, if possible, augmented. The water resources of the area are under the strain of an increasing demand for water supply and centralized wastewater treatment, which results in the net loss of water from many sub-basins and reduced baseflow in the mainstem and tributaries.

Because of these problems, the Organization for the Assabet River (OAR) conducts a water quality, streamflow, and biomass monitoring program aimed at understanding water quality and quantity in the mainstem and large tributaries of the Assabet and Concord. The summer of 2006 was OAR's fifteenth consecutive summer collecting data at 12 mainstem Assabet River sites, including the longest standing sites above and below each major wastewater treatment plant, its fifth year collecting data at tributary sites, and its third year collecting data at three mainstem Concord River sites, and its second year assessing aquatic plant biomass in the large impoundments of the Assabet River. Water quality data collected under OAR's Water Quality Monitoring Program Quality Assurance Program Plan (OAR 2000a), and the Quality Assurance Program Plan for the StreamWatch Project (OAR 2003a) may be used by EPA and DEP in making regulatory decisions. The goals of OAR's monitoring program remain: to understand long-term trends in the condition of the river and its tributaries, provide sound scientific information to evaluate regulatory decisions that affect the river, and to promote stewardship of the river through volunteer participation in the project.

The data collected also support the goals of the StreamWatch project: to characterize fish habitat conditions in the main tributary sub-basins of the Assabet River and make timely, accurate streamflow and water quality data available. Weekly streamflow and habitat availability data were collected at nine tributary sites (Assabet headwaters, Hop Brook, Cold Harbor Brook, North Brook, Fort Meadow Brook, Elizabeth Brook, Danforth Brook, Nashoba Brook, and River Meadow Brook) to calculate "Stream Health Index" readings for those streams as part of the StreamWatch project. (The Stream Health index is described at www.assabetriver.org/streamwatch/howindex.html.) This report covers the water quality and streamflow data and aquatic plant biomass data collected in the major impoundments of the river. Water quality reports and data for 1999 – 2005 (OAR 2000b, OAR 2001, OAR 2002, OAR 2003b, OAR 2004, OAR 2005, OAR 2006b) and 2005 biomass sampling project (OAR 2006a) are available on OAR's website (www.assabetriver.org/wq/).

Water Quality Sampling Methods

Twenty eight (28) trained volunteers and OAR staff monitored water quality at 12 sites along the mainstem Assabet, three sites along the mainstem Concord River, and ten sites on the major tributaries to those rivers (Table 1, Figure 1). Each site is assigned a three letter prefix for the waterbody name plus a three number designation indicating rivermiles above its confluence with the next stream. For example, the Cold Harbor Brook site at Cherry Street in Northborough, 3.0 miles upstream of the confluence of the brook with the Assabet River, is designated "CLD-030." Water quality monitoring (bottle samples, *in-situ* measurements, and observations) was conducted one weekend (5:00 am - 9:00 am) each month in May (headwater and tributary sites only in May), June, July, August, and September. Staff gage readings and habitat availability estimates at the tributary stream sites were made once a week and reported to the OAR office. Streamflow was calculated from the stage readings using stage/discharge rating curves developed in cooperation with USGS.

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 four hours of collection. *In-situ* readings of temperature, dissolved oxygen, pH, and conductivity were taken using multi-function YSI 6000-series 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 possible. At ten percent of the sites during each sampling event, duplicate field samples and field blanks of distilled water were taken. Table 2, below, summarizes

Table 1: OAR Sampling Sites – Summer 2006

Section	New Site #	Site Description (SARIS # in Basin 82)	Data Collected			
			In-situ	Bottle Samples	Staff gage	Plant Biomass
Head-water	ABT-311	Assabet at Maynard Street, Westboro (46775)	X	X	X	
Upper Assabet Mainstem	ABT-301	Assabet by Rte 9 East bridge, Westborough (46775)	X	X		
	ABT-280	Assabet by School St. bridge, Northborough (46775)	X	X		
	ABT-242	Assabet by Boundary Rd. bridge, Northborough (46775)	X	X		
	ABT-238	Assabet upstream of dam off Robin Hill Rd., Marlborough (46775)	X	X		
	ABT-162	Assabet by Cox Street bridge, Hudson (46775)	X	X	X	
	ABT-144	Assabet downstream of Gleasondale dam, Rte 62, Stow (46775)	X	X		
Lower Assabet Mainstem	ABT-077	Assabet by USGS gage, Rte 27/62, Maynard (46775)	X	X		
	ABT-063	Assabet by Rte 62 bridge nr. Acton Ford, Acton (46775)	X	X		
	ABT-033	Assabet by Rte 62 bridge nr. pump station, W. Concord (46775)	X	X		
	ABT-026	Assabet by Rte 2 bridge, Concord (46775)	X	X		
	ABT-010	Assabet nr. Lowell Road, Concord (46775)	X	X		
Concord Mainstem	CND-161	Concord at Lowell Road bridge, Concord (46500)	X	X		
	CND-093	Concord at Rte 4 bridge, Billerica (46500)	X	X		
	CND-009	Concord at Rogers Street bridge, Lowell (46500)	X	X		
Tributaries	HOP-011	Hop Brook, nr. Otis Street, Northboro (47600)	X	X	X	
	CLD-030	Cold Harbor Brook, Cherry Street bridge, Northborough (47550)	X	X	X	
	NTH-009	North Brook, Whitney Ave. bridge, Berlin (47375)	X	X	X	
	DAN-013	Danforth Brook, nr. Rte 85 bridge, Hudson (47275)	X	X	X	
	FTM-012	Fort Meadow Brook, Shay Road bridge, Hudson (47200)	X	X	X	
	ELZ-004	Elizabeth Br. (aka Assabet Br.), nr. White Pond Rd., Stow (47125)	X	X	X	
	NSH-002	Nashoba Brook, Commonwealth Ave. bridge, W. Concord (unnamed; outlet Warners Pond)	X	X	X	
	SPN-003	Spencer Brook, Barrett's Mill Rd bridge, Concord (unnamed; outlet Angiers Pond)	X	X	X	
	RVM-038	River Meadow Brook by Rte 129, Chelmsford (46525)	X	X	X	
	RVM-005	River Meadow Brook by Thorndike Street, Lowell (46525)	X	X		
Impoundments	n/a	Ben Smith Impoundment, above Rte 62/117, Maynard (46775)				X
	n/a	Gleasondale Impoundment, above Rte 62, Stow (46775)				X
	n/a	Hudson Impoudment, above Rte 85, Hudson (46775)				X
	n/a	Allen Street Impoundment, above Allen Street, Northborough (46775)				X
	n/a	Billerica Impoundment, above Faulkner Street, Billerica (46500)				X

[a] *In-situ*: temperature, DO, pH, and conductivity
[b] Bottle Samples: TSS, TP, ortho-P, TKN, nitrates, and ammonia

Figure 1: Sudbury, Assabet, and Concord River Watershed and 2006 Sampling Sites

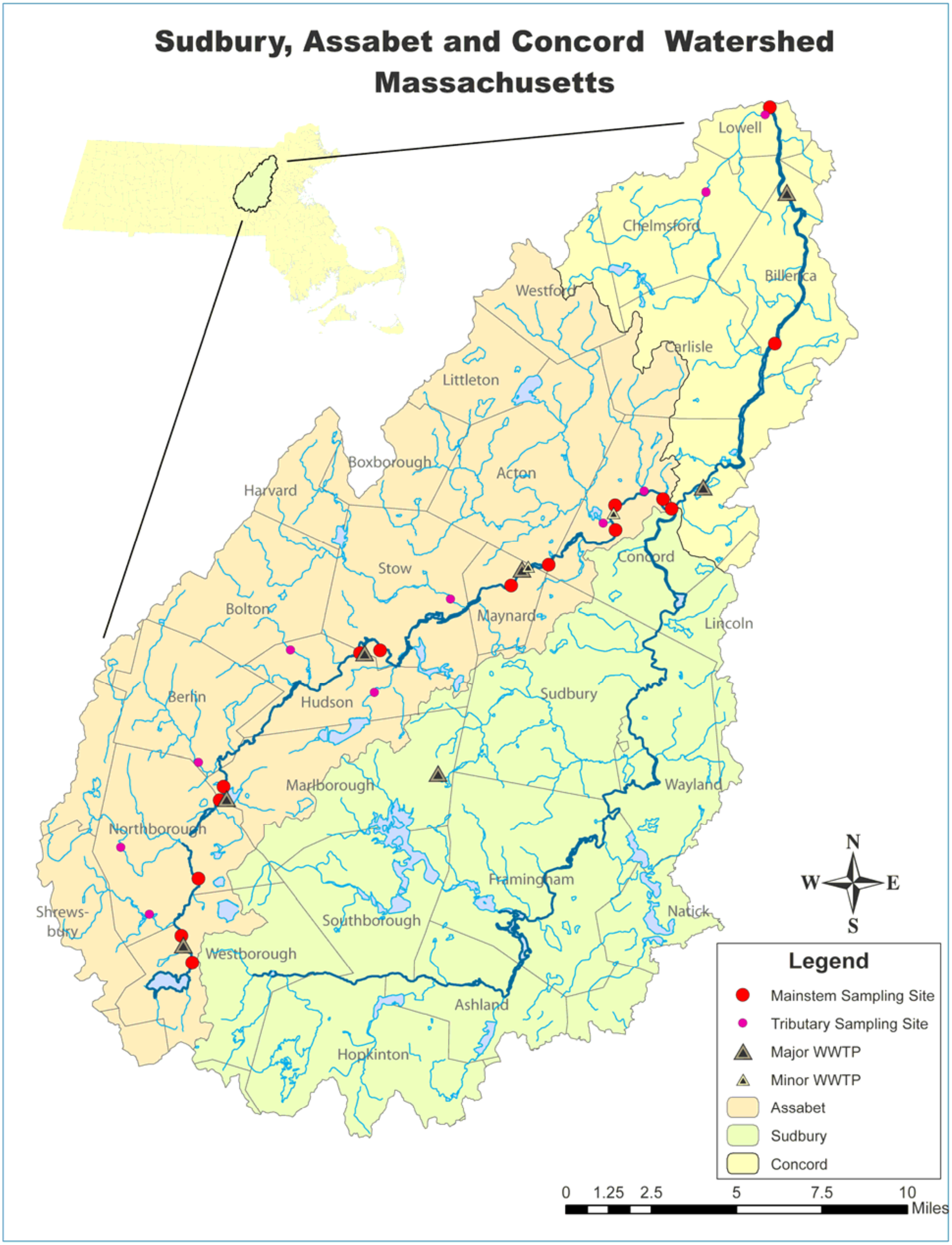


Figure 2: Assabet River Profile - Elevation vs. Rivermile

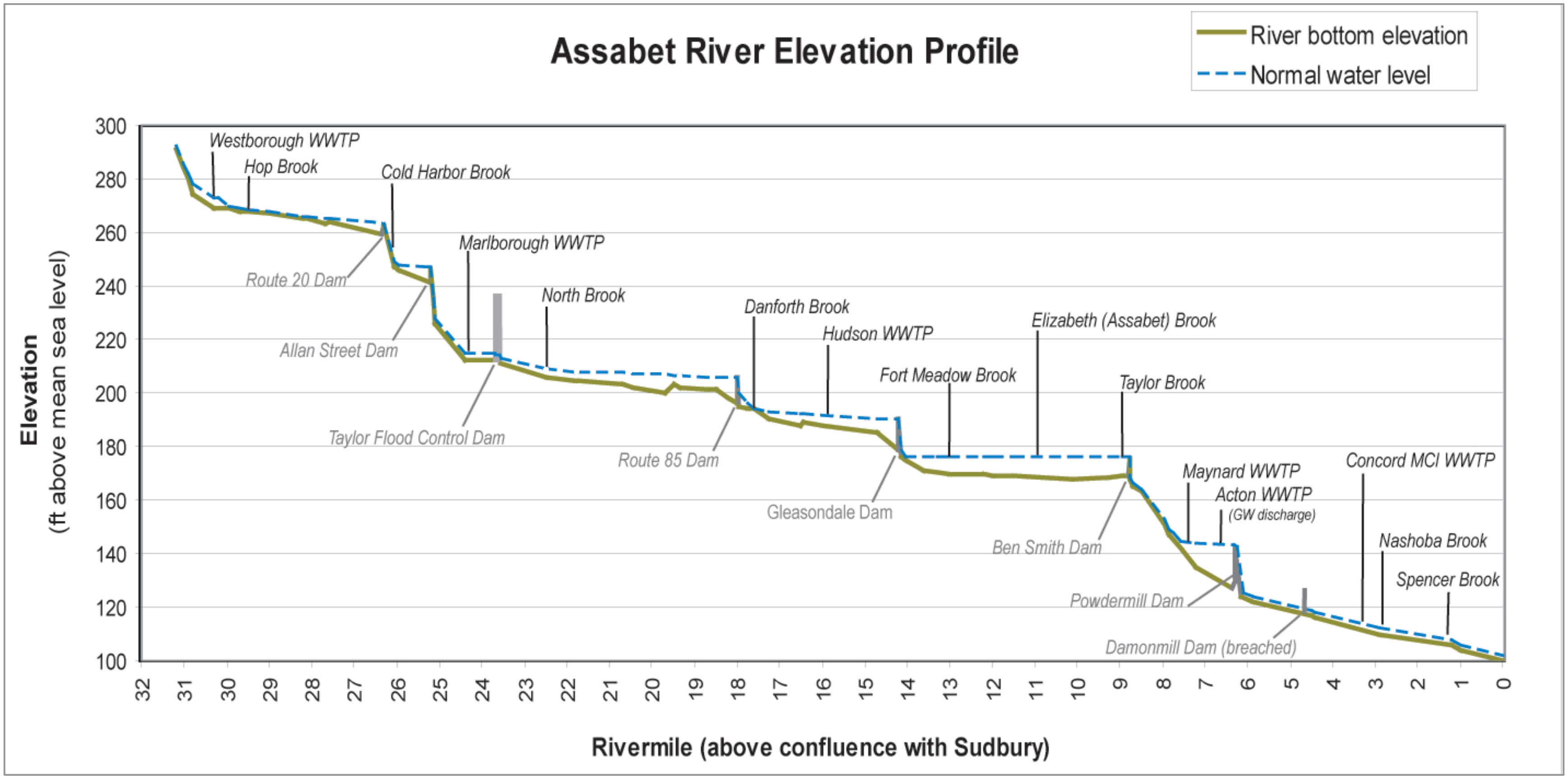


Table 2: Sampling and Analysis Methods

Parameter	Sample Type	Analysis Method #	Equipment Range/ Detection Limits	Sampling Equipment	Laboratory
Temperature	*in-situ*	---	-5 - 45° C	YSI 6000-series	---
pH	*in-situ*	---	0 to 14 units	YSI 6000-series	---
Dissolved oxygen	*in-situ*	---	0 - 50 mg/L	YSI 6000-series	---
Conductivity	*in-situ*	---	0 to 1000 μS/cm	YSI 6000-series	---
Total Suspended Solids	bottle	EPA 160.2[a]	1.0 mg/L	bottle	Thorstensen Laboratory
Total phosphorus	bottle	EPA 365.2	0.01 mg/L	bottle	Thorstensen Laboratory
ortho-Phosphate	bottle	EPA 365.2	0.01 mg/L	bottle	Thorstensen Laboratory
Total Kjeldahl Nitrogen	bottle	EPA 351.3	0.05 mg/L	bottle	Thorstensen Laboratory
Nitrates	bottle	EPA 300.0	0.01mg/L	bottle	Thorstensen Laboratory
Ammonia	bottle	EPA 350.3	0.03 mg/L	bottle	Thorstensen Laboratory

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

the parameters measured, laboratory methods and equipment used. Detailed descriptions of sampling methods and quality control measures are available in the Water Quality Monitoring Program QAPP (OAR, 2000a) and the QAPP for the StreamWatch Project (OAR, 2003a).

Water quality measurements were compared with the Massachusetts Water Quality Standards for Class B waters (MA DEP, 1997) and the guidance for determining use support (MA DEP, 2004b) (Table 3). All segments of the Assabet and Concord are designated Class B warm waters; all of the tributary streams assessed in this project are designated Class B waters. For nutrient concentrations (where the Massachusetts standard is narrative) results were compared with the EPA “Gold Book” total phosphorus criteria of 0.05 mg/L TP (US EPA, 1986) (Table 3) and with summertime data for Ecoregion XIV subregion 59 streams (US EPA, 2000) (Table 4).

Table 3: Water Quality Standards and Guidance for Use Support

Parameter	Standard
Dissolved oxygen[a]	5.0 mg/l and 60% saturation in warm water fisheries 6.0 mg/l and 75% saturation in cold water fisheries
pH	6.5 – 9.0 for freshwater aquatic life [b] 6.5 – 8.3 inland waters (upper limit is a swimming standard) [a]
Nutrients[a]	“control cultural eutrophication”
Total phosphorus[b]	0.050 mg/L total phosphorus
Temperature[a]	28.3° C and Δ < 2.8° C for warm water fisheries 20.0° C and Δ < 1.7° C for cold water fisheries
Suspended Solids [c]	Aquatic life: 25 mg/L maximum, Δ 10 mg/L due to a discharge
Aesthetics Biocommunity [c]	Primary or secondary contact recreational use: no nuisance organisms that render the water aesthetically objectionable or unusable, BPJ; Cover of macrophytes <50% within any portion of the lake area at maximum extent of growth.

[a] MA DEP. 1997.
[b] US EPA. 1986.
[c] MA DEP. 2004b.

Table 4: Reference Conditions for Aggregate Ecoregion XIV Subregion 59 Streams

Parameter	Reference condition (25th percentile based on summer data for Ecoregion XIV subregion 59)[a]
Total Phosphorus (mg/L)	0.025
Total Nitrogen (mg/L)	0.44
NO2 + NO3 (mg/L)	0.34
TKN (mg/L)	0.30

[a] USEPA. 2000.

River Reaches and Tributaries

All the sites tested were in relatively free-flowing sections of the river and tributaries. For the purposes of data analysis, the sites are divided into sections: (1) the upper and lower reaches of the Assabet mainstem, (2) the Concord River mainstem, and (3) the Assabet headwater and all tributary sites (Table 1). The upper reach of the Assabet goes from ABT-301 (Route 9, Westborough) to ABT-144 (Gleasondale, Stow). The lower reach of the Assabet goes from ABT-077 (Route 62, Maynard) to ABT-010 (near Lowell Road, Concord); the Concord mainstem includes three sites from CND-161 (below the confluence of the Assabet and Sudbury) to CND-009 (at Rogers Street in Lowell). Because the headwaters site ABT-311 (Maynard Street, Westborough) is upstream of the first wastewater treatment plant discharge, it is reported separately from the other Assabet River mainstem sites. Sites HOP-011 (Hop Brook), CLD-030 (Cold Harbor Brook), NTH-009 (North Brook), DAN-013 (Danforth Brook), FTM-012 (Fort Meadow), ELZ-004 (Elizabeth Brook), SPN-003 (Spencer Brook), and NSH-002 (Nashoba Brook) are all on tributaries to the Assabet River. RVM-038 (River Meadow Brook at Chelmsford) and RVM-005 (River Meadow Brook at Lowell) are on the largest tributary to the Concord River. Table 5 lists tributary and mainstem basin characteristics calculated using USGS's StreamStats program.

Table 5: StreamStats Drainage Basin Statistics

	Statistics at Mouth of Tributary[a]				
Tributary Streams	Latitude/Longitude at Mouth of Tributary	Drainage Area (sq.mi.)	Stratified Drift Area (sq.mi.)	% area stratified drift	Slope [b] (%)
Cold Harbor Brook, Northborough	42.3238/-71.6413	6.86	1.97	28.72	5.01
Danforth/ Mill Brook, Hudson	42.3897/-71.5666	7.17	2.06	28.73	3.58
Elizabeth Brook, Stow	42.4217/-71.4776	19.09	6.93	36.30	3.73
Fort Meadow Brook, Hudson	42.3975/-71.5169	6.25	1.76	28.16	3.77
Hop Brook, Northborough/Shrewsbury	42.2887/-71.6449	7.87	2.09	26.56	3.57
Nashoba Brook, Concord	42.4592/-71.3942	48.05	19.05	39.65	2.29
North Brook, Berlin	42.3576/-71.6188	16.89	4.12	24.39	4.38
River Meadow Brook, Lowell	42.6318/-71.3087	26.32	16.18	61.47	1.91
Spencer Brook, Concord	42.4714/-71.3731	7.16	2.16	30.17	2.09
Mainstem Sites	Statistics at Mainstem Sites[a]				
mouth Concord River, Lowell	42.6351/-71.3015	400.0	197.97	49.49	2.63
mouth Assabet River, Concord	42.4652/-71.3596	177.81	73.00	41.06	3.01
Assabet at Maynard St., Westboro	42.2741/-71.6322	6.79	1.64	24.15	3.61

[a] Calculated using USGS's StreamStats program (http://ststdmamrl.er.usgs.gov/streamstats/)
[b] Slope is the mean basin slope calculated from the slope of each grid cell in the designated subbasin.

Aquatic Plant Biomass Sampling Methods
The biomass assessment was based on visual examination from a boat of the major river impoundments to assess the nature and extent of aquatic plant biomass in five impoundments (Table 1): Faulkner Mill in Billerica, Ben Smith in Maynard, Rte 85 in Hudson, Gleasondale in Stow, and Allen Street in Northborough. In each impoundment, a series of transects perpendicular to the perceived stream channel were established and observations were made at multiple points along each of the transects. Transects and observation points were spaced appropriately to the size and plant coverage of the impoundment to adequately map the distribution of aquatic plants in the entire impoundment. All assessments were conducted between August 11th and September 1st, 2006.

At each transect point water depth was measured. Observations of biomass were made viewing an area covering a ~ 10 ft diameter circle. A viewing tube, held over the side of the boat, was used to help estimate biovolume and a plant rake was used where samples were needed for confirmatory identification. Aquatic plants at each point were identified using a field guide (Kelly, 1999) and the dominant plants (floating and submerged) were noted. Plant cover was rated into classes on a scale of 0 – 5 (0 = no plants to 5 = 100% cover). Plant biovolume was rated into classes on a scale of 0 – 5 (0 = no plants to 5 = water column completely filled with plants). The presence of algal mats on the bottom or in association with plants (visible periphytic growths) was noted. Transect locations and observation points were recorded on a topographic map in the field; data was recorded directly into a field notebook.

At a subset of the sampling locations, a 0.5-m^2 sample was harvested, drained, and transported to shore for weighing. The mean of the wet weights for each biovolume field rating was used to calculate the factor to convert the field ratings of biovolume to biomass (wet weight in g/m2). The field data was entered as ArcGIS shapefiles and interpolated to raster files to calculate the total biomass for each impoundment. In general, areas of emergent vegetation were not included in the analysis.

Total biomass per impoundment was compared with total biomass calculated as part of the Assabet River TMDL study in 1999 and 2000 (ENSR, 2001). For this comparison, the biomass for the Ben Smith impoundment reported in 1999 and 2000 was recalculated to compare similar assessment areas.

Results and Discussion
Reach (see Table 1 for reaches) and tributary statistics are summarized for the summer in Table 7, below. Full monthly summaries of the water quality data are attached in the Appendix I. Individual parameters are discussed below.

Precipitation and Streamflow
Precipitation and the consequent stormwater runoff affect water quality. Because increased stormwater runoff is correlated with increased concentrations of total suspended solids, total phosphorus, and nitrate/nitrites, it is worth noting precipitation before and during the sampling. For the purposes of this project a “dry weather” sampling is that which is preceded by at least 48 hours with less than 0.1" of precipitation. In 2006, the May, June and September samplings were preceded by rain; the July and August samples were taken in “dry weather” (Figure 3).

Figure 3: Rainfall Data (May to Sept 2006) National Weather Service, Worcester

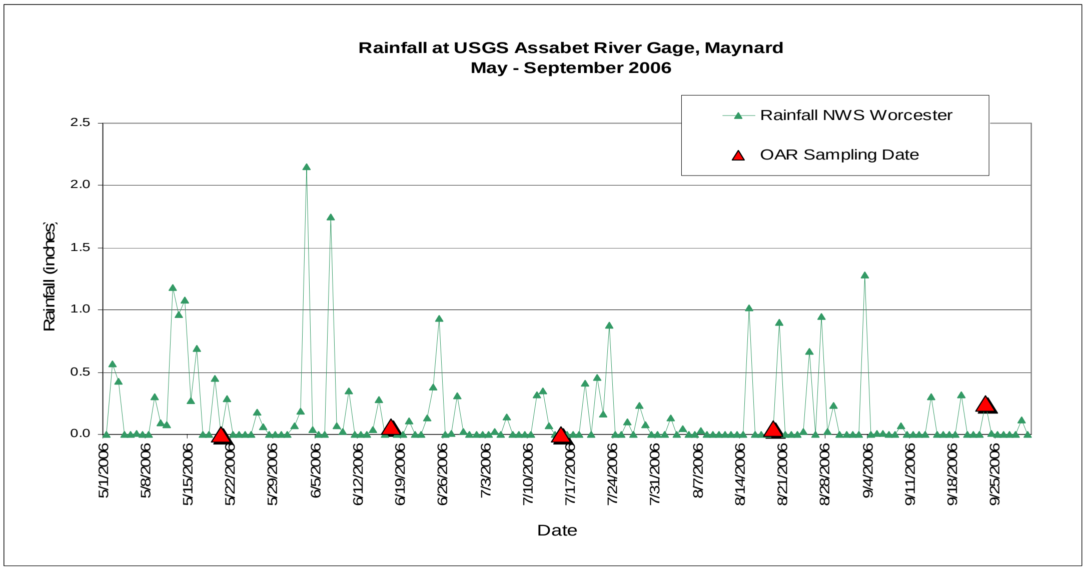


Table 6 shows composite monthly rainfall for the Central Region of Massachusetts as reported by the Department of Conservation and Recreation; as of September, precipitation over the previous 6 months had been 132% of normal. Precipitation in the Northeast Region over the same period of time was 174% of normal. Rainfall was particularly high in May and June in 2006.

Table 6: Composite Rainfall Data (May to Sept 2006)

2006 Rainfall Data from DCR Rainfall Program – Central Region *					
Month	Rainfall (inches)	Normal (inches)	Departure from normal (inches)	Percent of normal for the month (%)	Percent of normal for previous 6 months (%)
May	7.32	3.88	3.44	198	112
June	9.95	3.85	6.04	254	136
July	3.97	3.77	0.20	105	120
August	4.90	3.92	0.98	125	124
Sept	2.23	3.95	-1.72	56	132

* Accessed June 2007, http://www.mass.gov/dcr/waterSupply/rainfall/

Table 7: Mainstem Reach and Tributary WQ Statistics

				Mainstem Reach and Tributary Statistics (morning readings between 5:30 – 8:30 am)											
Date	Reach	Sites	Statistic*	Water Temp (°C)	DO % Sat.	DO (mg/L)	Cond. (µS/cm)	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Total N
20-May-06	Headwater & Tribs (10 sites)	ABT-311 & Tribs	Minimum	11.35	78.9	8.00	74	6.03	1	<0.006	<0.006	0.03	<0.03	<0.1	0.1
		ABT-311 & Tribs	Maximum	14.76	98.8	10.34	362	6.74	4	0.024	0.007	0.38	0.05	0.58	1.0
		ABT-311 & Tribs	Median	13.40	89.0	9.29	187	6.40	1.9	0.006	<0.006	0.21	<0.03	0.20	0.4
17-June-06	Assabet and Concord Mainstem (14 sites)	ABT-301 - CND-009	Minimum	18.23	60.7	5.38	176	6.45	1	0.029	0.011	0.04	0.03	<0.05	0.19
		ABT-301 - CND-009	Maximum	21.33	96.9	9.13	360	7.32	23	0.196	0.169	2.30	0.80	0.38	2.53
		ABT-301 - CND-009	Median	20.01	83.1	7.56	300	6.87	5	0.083	0.061	0.75	0.13	0.23	0.98
	Upper Assabet Mainstem (6 sites)	ABT-301 - ABT-144	Median	18.92	85.6	7.94	315	7.06	3	0.125	0.095	1.24	0.20	0.25	1.50
	Lower Assabet Mainstem (5 sites)	ABT-077 - ABT-010	Median	20.62	87.7	7.88	292	6.68	5	0.056	0.045	0.46	0.08	0.26	0.74
	Concord River Mainstem (3 sites)	CND-161 - CND-009	Median	21.15	70.5	6.26	283	6.79	9	0.042	0.022	0.24	0.05	0.14	0.37
	Assabet Head & Tributaries (11 sites)	ABT-311 & Tribs	Minimum	16.37	67.6	6.32	102	6.35	1	0.012	<0.006	0.05	0.06	0.18	0.27
		ABT-311 & Tribs	Maximum	21.87	96.9	9.13	506	7.37	10	0.047	0.024	4.80	0.12	0.39	4.98
		ABT-311 & Tribs	Median	18.84	85.4	7.94	277	6.99	4	0.029	0.010	0.65	0.08	0.29	0.94
15-July-06	Assabet and Concord Mainstem (14 sites)	ABT-301 - CND-009	Minimum	20.34	47.20	3.91	233	6.75	1	0.029	0.027	0.14	0.03	<0.05	0.28
		ABT-301 - CND-009	Maximum	24.82	91.90	7.96	683	7.19	10	0.288	0.193	3.70	0.26	0.88	3.89
		ABT-301 - CND-009	Median	23.19	79.09	6.76	442	7.00	5	0.123	0.068	1.50	0.09	0.28	1.78
	Upper Assabet Mainstem (6 sites)	ABT-301 - ABT-144	Median	21.88	79.52	6.97	509	7.01	2	0.188	0.108	2.30	0.05	0.17	2.46
	Lower Assabet Mainstem (5 sites)	ABT-077 - ABT-010	Median	24.01	86.60	7.28	411	7.01	6	0.079	0.041	1.19	0.05	0.16	1.35
	Concord River Mainstem (3 sites)	CND-161 - CND-009	Median	24.43	65.73	5.49	357	6.98	7	0.068	0.034	0.42	0.21	0.70	1.12
	Assabet Head & Tributaries (11 sites)	ABT-311 & Tribs	Minimum	20.86	58.70	5.19	115	6.72	1	0.023	<0.006	0.08	0.03	0.11	0.21
		ABT-311 & Tribs	Maximum	25.07	95.80	8.55	552	7.24	11	0.131	0.055	0.41	0.14	0.46	0.76
		ABT-311 & Tribs	Median	22.35	80.58	6.99	302	6.98	3	0.064	0.024	0.23	0.05	0.21	0.44

* calculated as ½ detection level where samples are BDL

Table 7: Mainstem Reach and Tributary Statistics - Continued

	Sites	Reach	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)	Total N
19-August-06	Assabet and Concord Mainstem (14 sites)	ABT-301 - CND-009	Minimum	19.85	58.8	5.15	430	6.71	1	0.025	0.014	0.25	<0.03	<0.05	0.46
		ABT-301 - CND-009	Maximum	24.39	123.0	10.27	1037	7.90	100	0.610	0.488	7.10	0.08	0.59	7.59
		ABT-301 - CND-009	Median	22.04	82.2	7.15	676	7.29	13	0.150	0.113	2.80	0.05	0.39	3.19
	Upper Assabet Mainstem (6 sites)	ABT-301 - ABT-144	Median	21.06	71.9	6.39	873	7.16	2	0.286	0.230	5.03	0.07	0.47	5.50
	Lower Assabet Mainstem (5 sites)	ABT-077 - ABT-010	Median	22.12	80.3	6.99	568	7.23	22	0.055	0.028	1.50	0.05	0.38	1.87
	Concord River Mainstem (3 sites)	CND-161 - CND-009	Median	23.87	105.7	8.91	463	7.63	21	0.038	0.022	0.51	0.04	0.25	0.75
	Assabet Head & Tributaries (11 sites)	ABT-311 & Tribs	Minimum	18.36	48.5	4.49	141	6.87	1	<1	0.020	0.011	0.12	<0.03	0.12
		ABT-311 & Tribs	Maximum	22.61	96.2	8.71	1019	7.91	100	42	0.097	0.076	1.0	0.23	1.40
		ABT-311 & Tribs	Median	20.03	76.4	6.95	405	7.41	13	7	0.041	0.025	0.34	0.06	0.53
23-Sept-06	Assabet and Concord Mainstem (14 sites)	ABT-301 - CND-009	Minimum	15.84	73.2	7.20	372	6.87	<1	0.037	0.017	0.10	0.02	0.03	0.03
		ABT-301 - CND-009	Maximum	19.18	109.1	10.07	622	7.61	21	0.270	0.139	3.90	0.05	0.42	4.02
		ABT-301 - CND-009	Median	17.71	87.8	8.33	495	7.19	4	0.097	0.057	2.07	0.03	0.29	2.15
	Upper Assabet Mainstem (6 sites)	ABT-301 - ABT-144	Median	17.09	83.6	8.04	526	7.17	1	0.149	0.094	3.18	0.03	0.33	3.01
	Lower Assabet Mainstem (5 sites)	ABT-077 - ABT-010	Median	17.70	85.5	8.12	520	7.09	3	0.060	0.035	1.70	0.02	0.28	2.03
	Concord River Mainstem (3 sites)	CND-161 - CND-009	Median	18.95	99.9	9.25	392	7.40	13	0.055	0.022	0.48	0.04	0.26	0.65
	Assabet Head & Tributaries (11 sites)	ABT-311 & Tribs	Minimum	13.76	30.2	3.37	138	6.92	<1	0.017	<0.006	0.05	<0.03	<0.05	0.05
		ABT-311 & Tribs	Maximum	18.99	93.0	9.51	596	7.47	9	0.101	0.045	0.45	0.18	0.75	1.10
		ABT-311 & Tribs	Median	15.70	78.1	7.75	310	7.26	3	0.059	0.024	0.20	0.05	0.25	0.45

* calculated as ½ detection level where samples are BDL

Streamflow has a direct impact on the concentration of nutrients and suspended solids in the water column and the availability of aquatic habitat and an indirect impact on water temperature, dissolved oxygen concentration, pH, and conductivity. Note that streamflows measured at the Assabet River gage in Maynard include effluent discharges from three of the four municipal wastewater treatment plants on the river. Figure 4 shows the median of the daily streamflows (May to September for each year) for the Assabet River gage compared with the median for the period of record. Figures 5 and 6 show 2006 streamflows at the Assabet River gage in Maynard and Concord River gage in Lowell compared with the mean of the daily mean streamflows for the summer.

Weekly streamflows were recorded at eight tributary monitoring sites and near the Assabet River headwaters (above the first wastewater discharge). Streamflows at these sites tended to be at their lowest in mid-August and again in mid- to late September (Figures 16 - 24).

Figure 4: Median of the Daily Mean Streamflows (June 1 - Sept 30): Assabet River

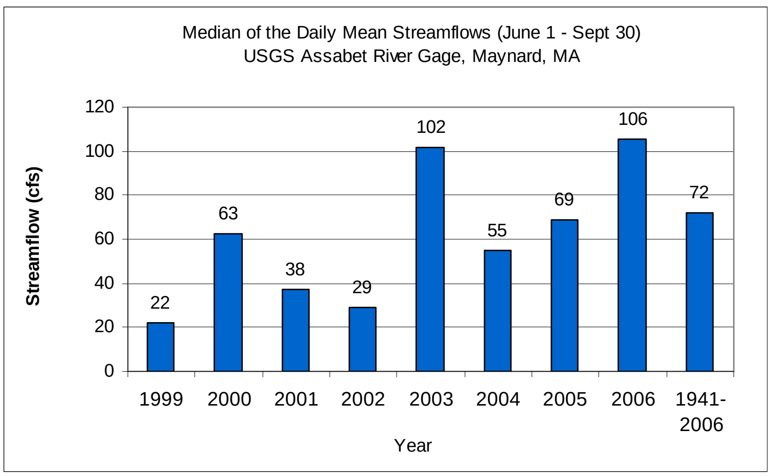


Figure 5: Mean Daily Streamflows at USGS gage, Assabet River

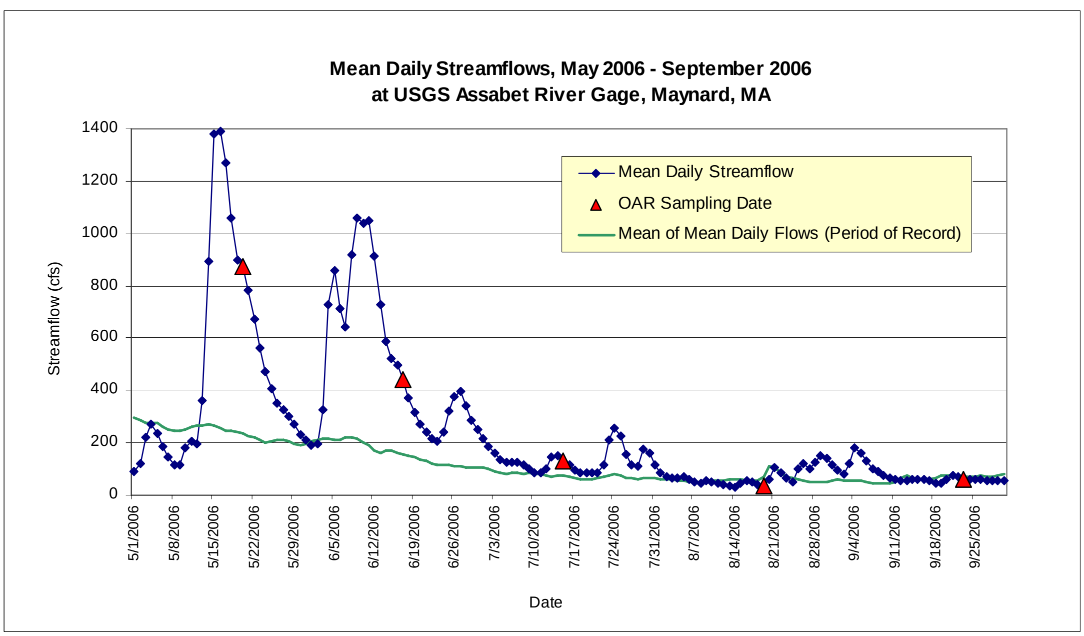
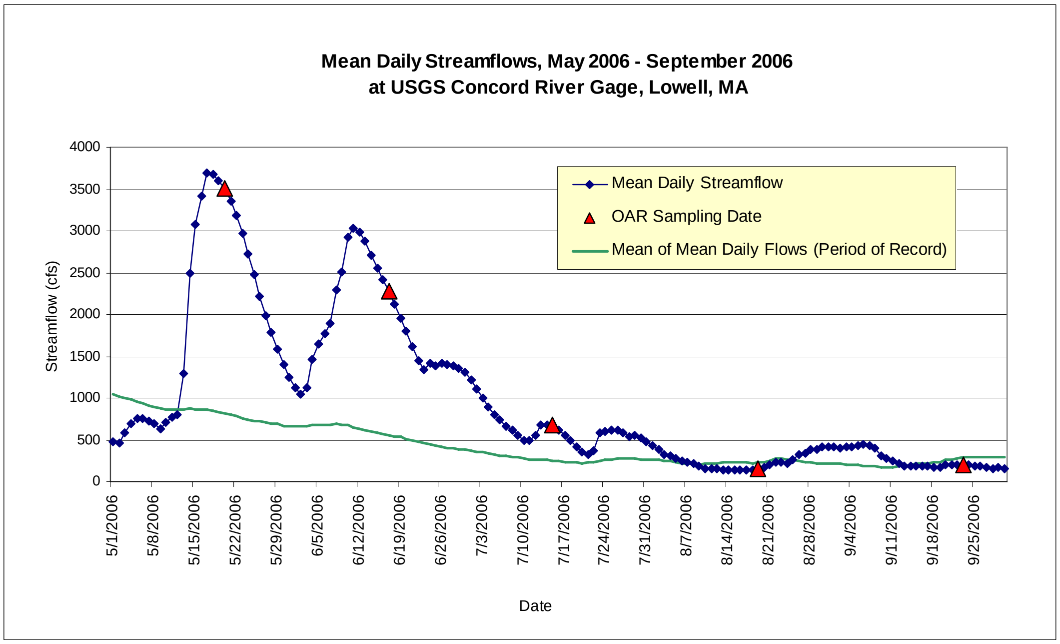


Figure 6: Mean Daily Streamflows at USGS gage, Concord River



Water Temperature, pH, and Conductivity

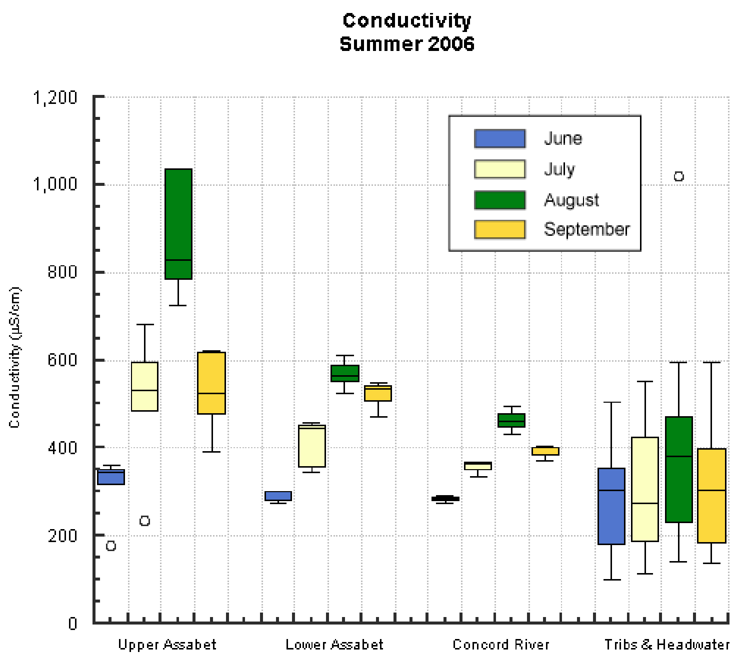
In-situ readings (including dissolved oxygen, water temperature, pH, and conductivity) were taken in May (tributaries and Assabet headwaters only), June, July, August, and September, between about 5:30 am and 9:00 am, when dissolved oxygen concentrations are expected to be at their lowest for the day. Summary statistics for all in-situ readings are in Table 7, above.

Water temperatures at both mainstem and tributary sites met Class B warm water fisheries standards on all dates tested. The range of mainstem temperatures was 15.84 - 24.82 ° C, with the lowest reading in September and the highest reading in July. The range of temperatures in the tributaries was 11.35 - 25.07 ° C, with the lowest reading in September and the highest reading in July.

pH readings in the mainstem varied from 6.45 to 7.90, with one reading failing to meet standards (CND-161 in June). Tributary pH readings ranged from 6.03 to 7.91, with seven of the nine tributary stream readings failing to meet standards in May, and two failing to meet standards in June.

Conductivity is an indirect indicator of pollutants such as effluent, non-point source runoff (especially road salts) and erosion. The range of conductivity readings was 176 - 1037 µS/cm in the mainstem and 74 – 1019 µS/cm in the tributaries. In general the mainstem conductivity readings were higher in the upper Assabet than in other sections (Figure 7) and higher in August than in other months.

Figure 7: Conductivity readings (June to Sept 2006)



Dissolved Oxygen

Dissolved oxygen (DO) concentrations are generally lowest between 5am and 8am after plant and microbial respiration has removed oxygen from the water column overnight. Low minimum DO concentrations and large diurnal variations in DO indicate eutrophic conditions. Summary statistics for DO readings are in Table 7, above. DO readings were all taken between 5:30 am and 9:00 am.

DO concentrations generally met water quality standards in 2006, ranging from 3.91 mg/L to 10.27 mg/L in the mainstem with the average about 7.45 mg/L (Figures 8 and 9). DO in the mainstem failed to meet water quality standards at one site and one date tested (CND-161 in July). In the tributaries the range of DO concentrations was 3.37 - 10.34 mg/L, failing to meet water quality standards at: Cold Harbor Brook (CLD-030) in July; Cold Harbor, Elizabeth (ELZ-004), and Hop (HOP-011) Brooks in August, and Cold Harbor and Elizabeth Brooks in September (Figures 10 and 11). The low readings at the Cold Harbor and Elizabeth Brooks are likely influenced by upstream beaver impoundments. Dissolved oxygen levels in beaver impoundments, and for several hundred meters downstream, have been shown to be lower than in unimpacted streams. This is likely the effect of increased dissolved organic carbon and microbial activity in the impoundment combined with increased residence time in the impoundment.

Figure 8: Histograms of Mainstem DO Measurements (May to Sept 2006)

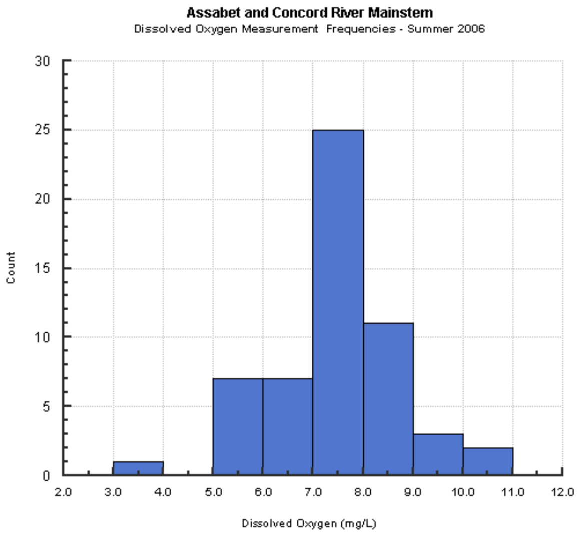
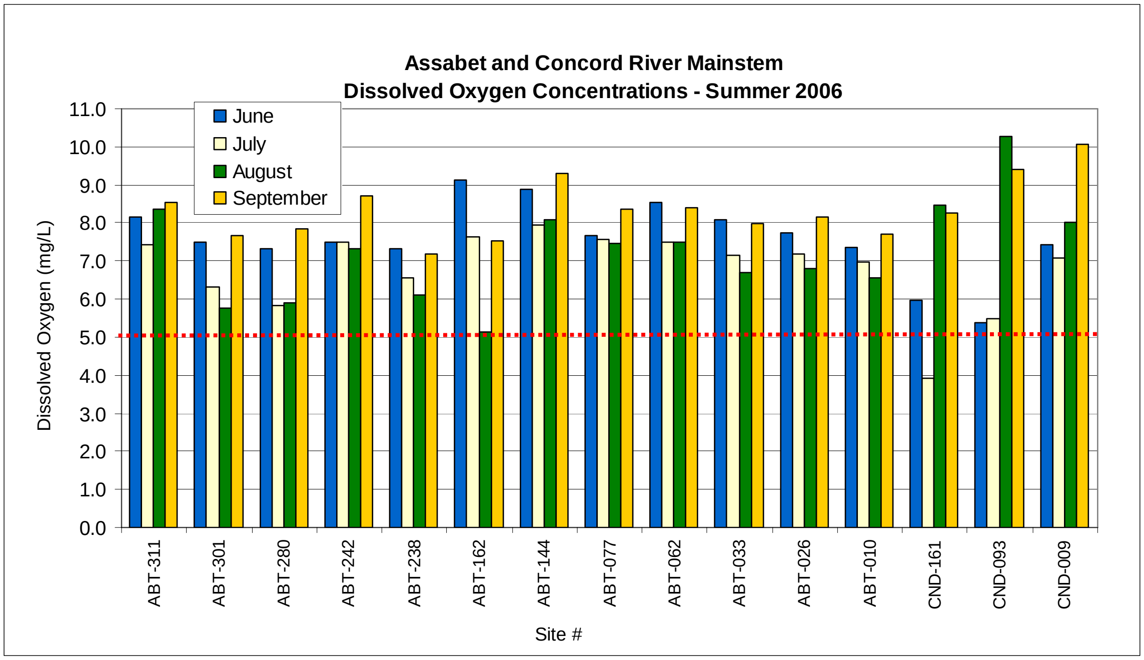


Figure 9: Mainstem Dissolved Oxygen Concentrations (May to Sept 2006)



Water Quality Standard (red line)

Figure 10: Histograms of Headwater & Tributary DO Measurements (May to Sept 2006)

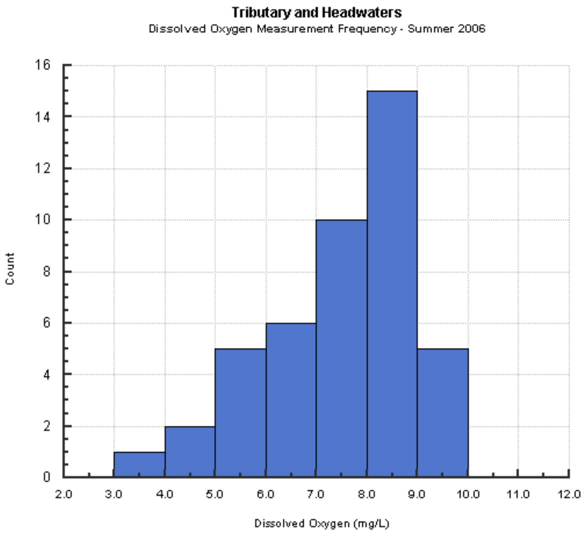
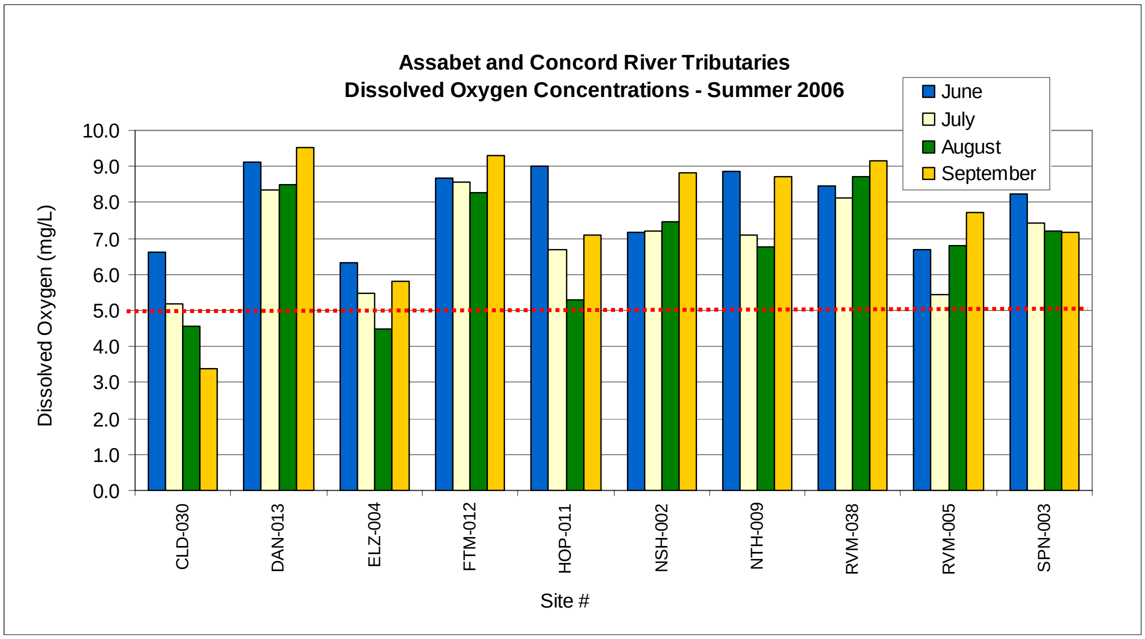


Figure 11: Tributary Dissolved Oxygen Concentrations (May to Sept 2006)



Water Quality Standard (red line)

Nutrients and Suspended Solids

Summary statistics for nutrient concentrations are in Table 7, above. Monthly median nutrient concentrations were calculated for the upper and lower Assabet mainstem and Concord mainstem reaches (see Table 1 for reach definitions) and for the combined Assabet headwaters and tributary sites.

As in previous years, nutrient concentrations along the Assabet River mainstem below the first wastewater discharge (Westborough WWTP) were well above Ecoregion reference conditions (25^{th} percentile of the summertime data) for total phosphorus, total nitrogen, and nitrates. Nutrient concentrations at the three Concord River mainstem sites were generally lower than upstream concentration, but still exceeded Ecoregion reference conditions for total phosphorus, total nitrogen, and nitrates. In general nutrient concentrations in the mainstem rivers (below the first WWTP input) decrease from upstream to downstream. Nutrient concentration in the tributaries were generally lower than mainstem concentrations.

Total phosphorus concentrations at the Assabet and Concord mainstem sites (Figure 12) ranged from 0.025 mg/L to 0.610 mg/L, exceeding the Ecoregion reference condition (0.025 mg/L) in 55 of 56 measurements and exceeding the EPA "Gold Book" standard (0.050 mg/L) in 45 of 56 measurments. Ortho-phosphorus concentrations in the mainstem rivers (Figure 13) ranged from 0.011 mg/L to 0.488 mg/L, exceeding 0.025 mg/L in 33 of 54 measurements and exceeding 0.050 mg/L in 13 of 54 measurements. Mainstem total nitrogen concentrations ranged from 0.03 mg/L to 7.59 mg/L, exceeding the reference condition (0.44 mg/L) in 51 of 56 measurements. Nitrate concentrations ranged from 0.04 mg/L to 7.1 mg/L, exceeding the reference condition (0.34 mg/L for nitrate and nitrite combined) in 50 of 56 measurements. Ammonia (ammonia as N) concentrations ranged from 0.03 mg/L to 0.80 mg/L. Total suspended solids ranged from 1 mg/L to 100 mg/L.

In the headwater and tributary stream sites, total phosphorus and ortho-phosphorus concentrations were generally lower than in the mainstem sites each month (Figures 12 and 13). Total phosphorus concentrations ranged from 0.012 mg/L to 0.131 mg/L, exceeding Ecoregion reference conditions (0.025 mg/L) in 33 of 54 measurements and exceeding EPA "Gold Book" standards (0.050 mg/L) in 17 of 54 measurements. Ortho-phosphorus concentrations ranged from <0.006 mg/L to 0.076 mg/L, exceeding 0.025 mg/L in 13 of 54 measurements and exceeding 0.050 mg/L in 2 of 54 measurements. Total nitrogen concentrations ranged from 0.05 mg/L to 4.98 mg/L, exceeding the Ecoregion reference condition (0.44 mg/L) in 27 of 54 measurements (Figure 14). Nitrate concentrations ranged from 0.03 mg/L to 4.8 mg/L, exceeding 0.34 mg/L in 11 of 54 measurements (Figure 15). Ammonia (as N) concentrations ranged from <0.03 mg/L to 0.23 mg/L (Figure 16). Total suspended sediment concentrations ranged from <1 mg/L to 42 mg/L, with the highest reading from Hop Brook in August when streamflows were low and the sample likely picked up sediment from the bottom.

Figure 12: Total Phosphorus Concentrations (Summer 2006)

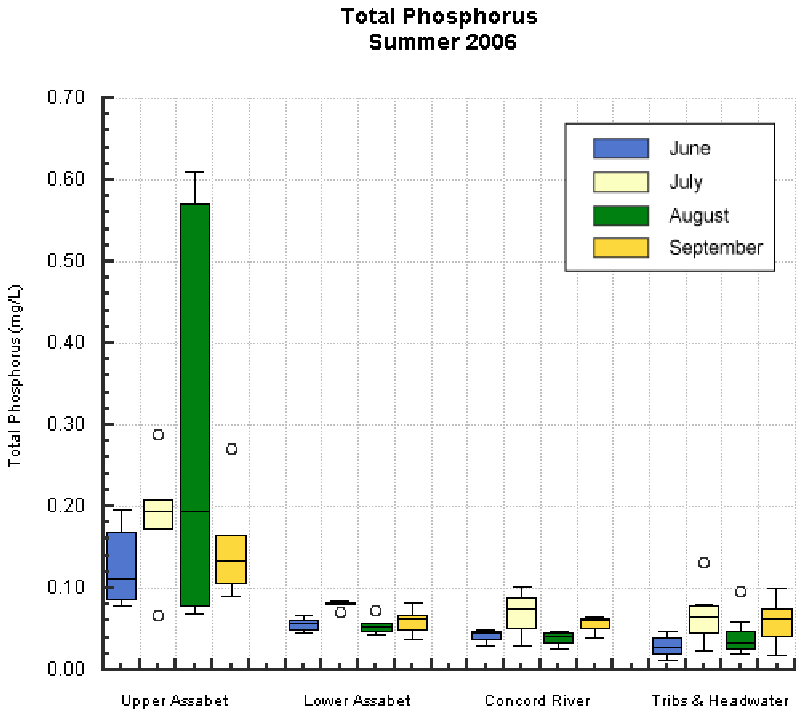


Figure 13: Ortho-Phosphorus Concentrations (Summer 2006)

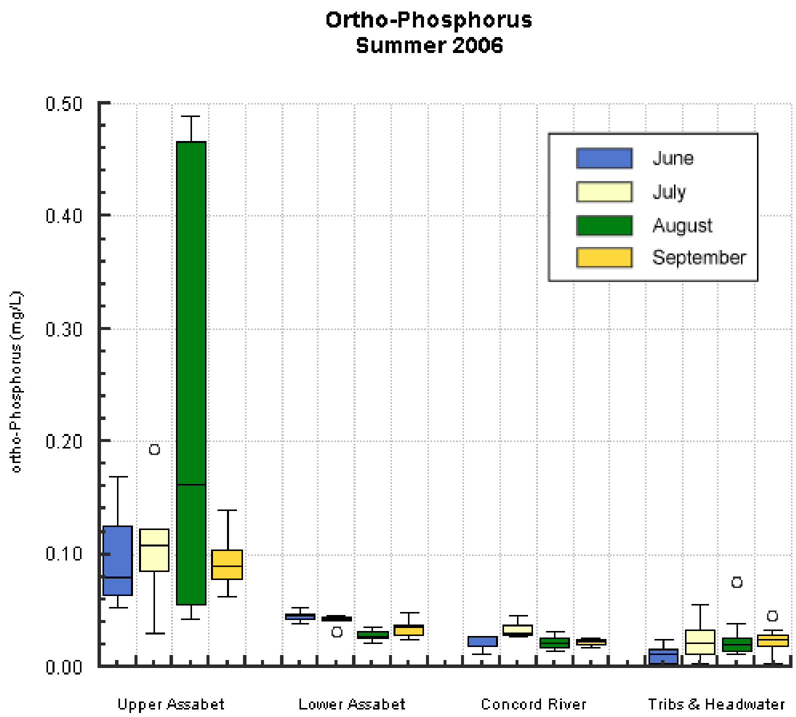


Figure 14: Total Nitrogen Concentrations (2006)

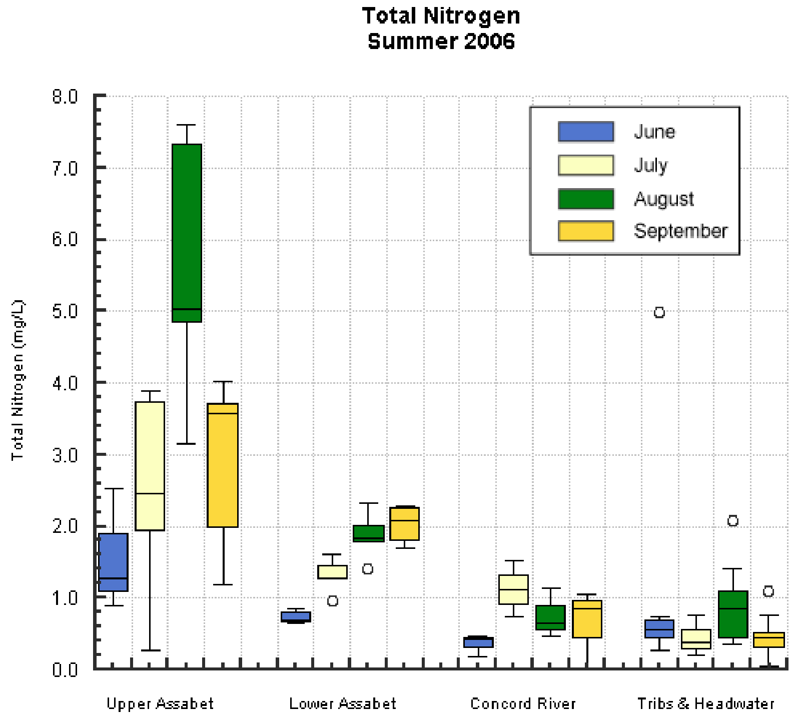


Figure 15: Nitrate Concentrations (2006)

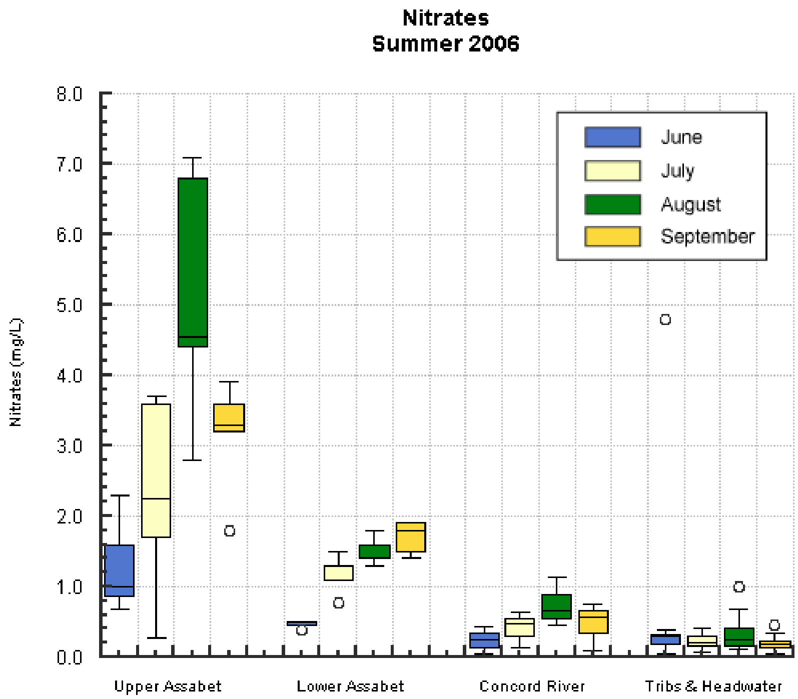
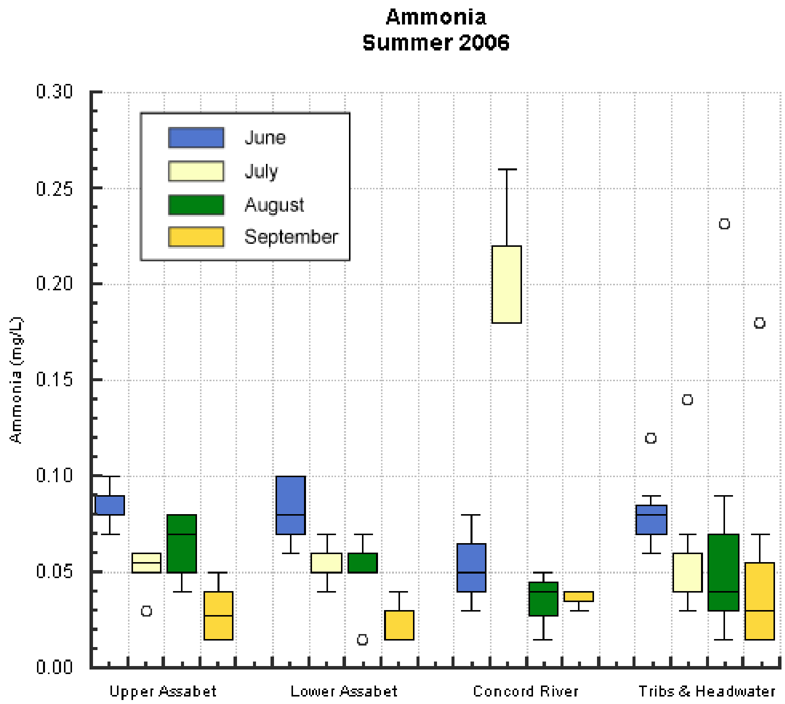


Figure 16: Ammonia (as N) Concentrations (2006)



Aquatic Plant Biomass Measurements

The aquatic plant biomass (as wet weight) per impoundment was assessed using a canoe-based visual survey of the large impoundments of the river (methods are detailed in OAR 2006a).

Plant species:
In the Assabet River impoundments, the dominant floating plants were duckweed (*Lemna*), watermeal (*Wollfia*), and filamentous green algae; the dominant submerged plants were coontail (*Ceratophyllum demersum*) and waterweed (*Elodia* sp.). Several large backwater sections had emergent arrowhead (*Sagittaria*), arrow arrum (*Peltandar virginica*) and pickerelweed (*Pontederia cordata*) and there were wide sections of emergent grass species (not included in the biomass assessment) along the edges of the Hudson impoundment. There were limited patches of the invasive species water chestnut in the Gleasondale impoundment which could, at this stage, be controled by hand-pulling the plants. In the Faulkner Mill impoundment on the Concord River the main channel of the impoundment was free of macrophytes but very turbid; the backwater section of the impoundment was choked with water chestnut (*Tapa natans*), coontail, and waterweed.

Biomass:
Visual assessments from field observations were converted to biomass using conversion factors developed in 2005 from field measurements of wet weights for each class (Table 8). Maps of biomass in each impoundment are presented in Appendix II.

Table 8: Volume/Biomass Conversion Factors

Visual Assessment Class	Percent of Water Column Filled	Biomass (g/m3)
0	0%	0
1	1 – 25%	427
2	25 – 50%	1186
3	50 – 75%	2000
4	75 – 99%	2855
5	100%	3782

Total biomass per impoundment calculated in 2006 was from 51% to 83% less than reported in 1999 (Table 9). Because different sampling and analysis methods may have been used in 1999/2000 than in 2005/2006, the measurements from 1999 and 2000 are also compared; biomass per impoundment in 2000 was from 1% to 39% less than in 1999. Much of the variability may be attributable to differences in climate. As an indicator of climate, it is useful to compare summertime (June 1 to Sept 30) streamflows as measured at the USGS gage on the Assabet River in Maynard. Summer streamflows in 1999 were about 30% of normal (as defined as the median of the daily mean streamflows for the period of record 1941 – 2005) (Figure 4). In comparison, summer streamflows were near normal in 2000 (88%) and 2005 (97%), but considerable higher than normal in 2006 (147%). The differences in total biomass calculated per impoundment among the years suggest that annual variation in biomass is relatively high, and that a long-term baseline of measurements will be needed to be able to detect future changes in biomass attributable to changes in watershed management. As more data is collected it may also be possible to better analyze the co-variance of biomass, streamflow, rainfall, temperature, and water column nutrient concentrations.

Table 9: Total Impoundment Biomass Comparison (1999, 2000, 2005, and 2006)

	Total biomass (kg)				% Difference		
Impoundment	TMDL (1999)[b]	TMDL (2000)[b]	OAR (2005)[c]	OAR (2006)	TMDL 1999/ TMDL 2000	TMDL 1999/ OAR 2005	TMDL 1999/ OAR 2006
Ben Smith[a]	73,008	71,994	35,875	12,442	-1%	-51%	-83%
Gleasondale	83,000	50,400	50,564	40,779	-39%	-39%	-51%
Rte 85/Hudson	118,000	85,400	72,885	22,458	-28%	-38%	-81%
Allen Street	5,960	3,720	3,211	1,340	-38%	-46%	-78%
Billerica	n/a	n/a	n/a	73,469	n/a	n/a	n/a

[a] TMDL Ben Smith biomass measurements adjusted to same sampling area as OAR data

[b] ENSR 2001.

[c] OAR 2006a.

Stream Health Index Readings

The Stream Health Index was used to assess conditions in six of the tributary streams from June to September in 2006. The index is designed to characterize summertime fish habitat conditions in the small streams of the watershed. A full description of the index is available on the project webpage (www.assabetriver.org/streamwatch/howindex.html). Briefly, an index brings information from multiple data sources together into a single number, like a grade, that can be understood at a glance. As such, an index is a useful tool in making water quality, habitat, and streamflow data accessible to the public and in assessing spatial and temporal trends.

For the Stream Health Index, measurements of streamflow, groundwater levels, channel flow status, dissolved oxygen, temperature, pH, total phosphorus, total nitrogen, and total suspended solids are scored from 1 (worst) to 100 (best). Streamflow data are scored against minimum streamflow recommendations of several standard-setting methods. Groundwater levels are scored against expected conditions from long-term records. Water quality metrics are scored against published fish tolerances, Massachusetts surface water quality standards, and EPA criteria. Nutrient concentrations are scored against expected conditions for Ecoregion XIV. Channel flow status is scored using EPA's Rapid Bioassessment Protocol. These parameter scores are aggregated to give streamflow, water quality and habitat availability index scores; these three index scores are then aggregated into an overall stream health index. For postings the index score was converted to a description: excellent (81 – 100), good (61 – 80), fair (41 – 60), poor (21 - 40), or very poor (1 – 20).

Figures 17 to 25 show Stream Health Readings and streamflow over the summer for each of nine stream locations. The full dataset is presented in Appendix III. The stream health was rated "excellent" or "good" for more than half of the weeks assessed in all of the streams: Assabet River Headwaters (11 of 16), Cold Harbor Brook (6 of 9); Danforth Brook (9 of 16), Elizabeth Brook (16 of 16), Fort Meadow Brook (16 of 16), Hop Brook (12 of 16), Nashoba Brook (14 of 16), North Brook (9 of 13), River Meadow Brook (8 of 10). Flow measurements in Cold Harbor Brook were disrupted by a beaver dam in the culvert just downstream of the gage by mid-August.

Figure 17: Stream Health & Streamflow – Assabet Headwaters (2006)

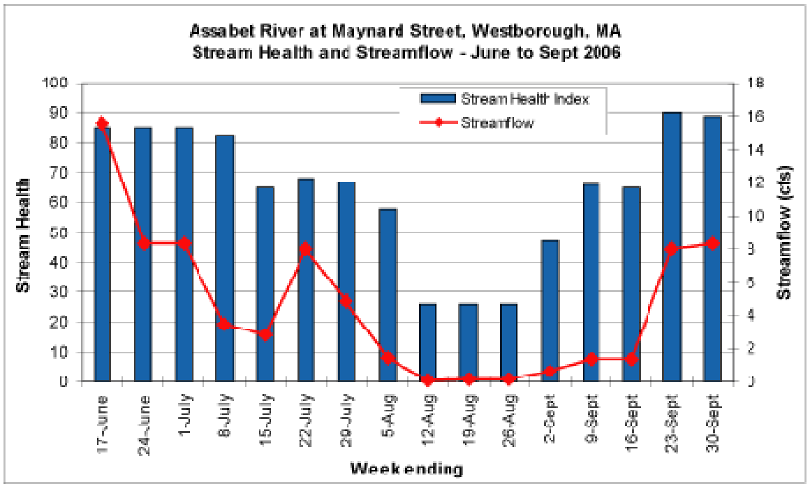


Figure 18: Stream Health & Streamflow – Cold Harbor Brook (2006)

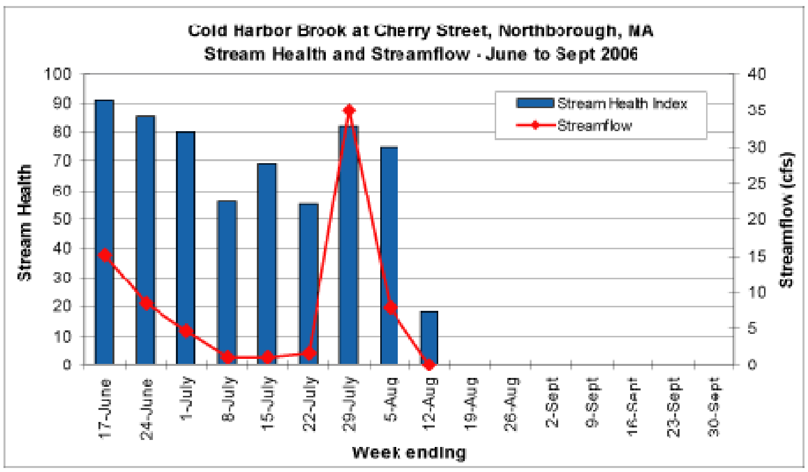


Figure 19: Stream Health & Streamflow – Danforth Brook (2006)

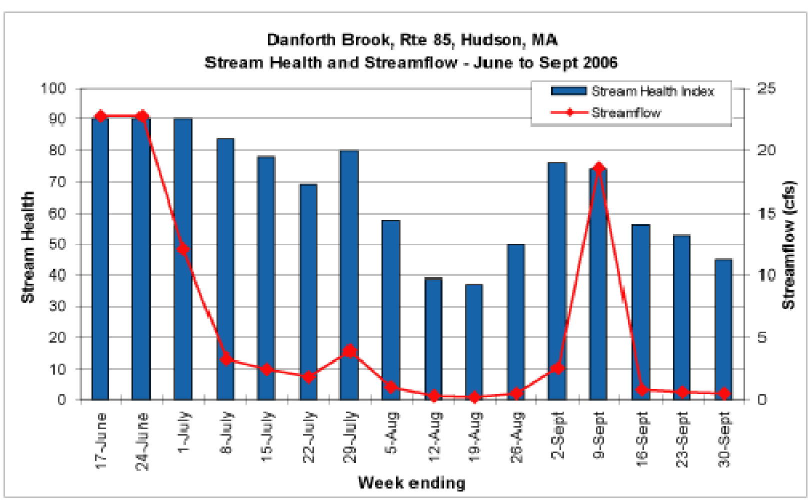


Figure 20: Stream Health & Streamflow – Elizabeth Brook (2006)

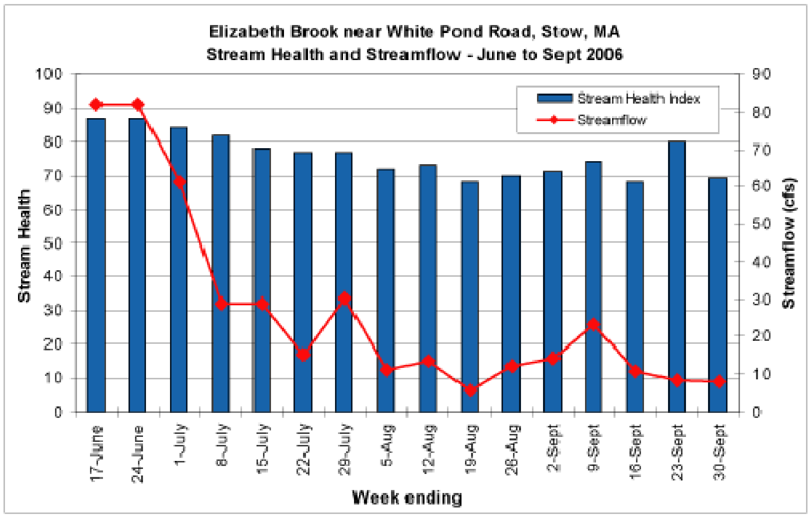


Figure 21: Stream Health & Streamflow – Fort Meadow Brook (2006)

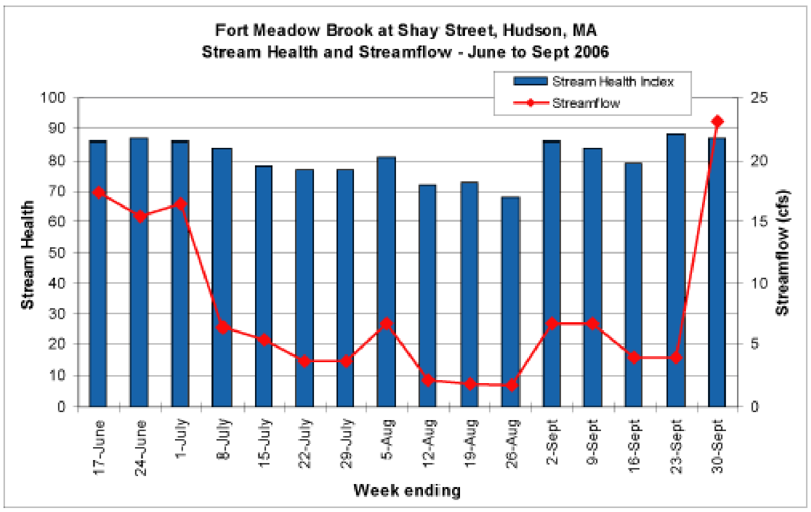


Figure 22: Stream Health & Streamflow – Hop Brook (2005)

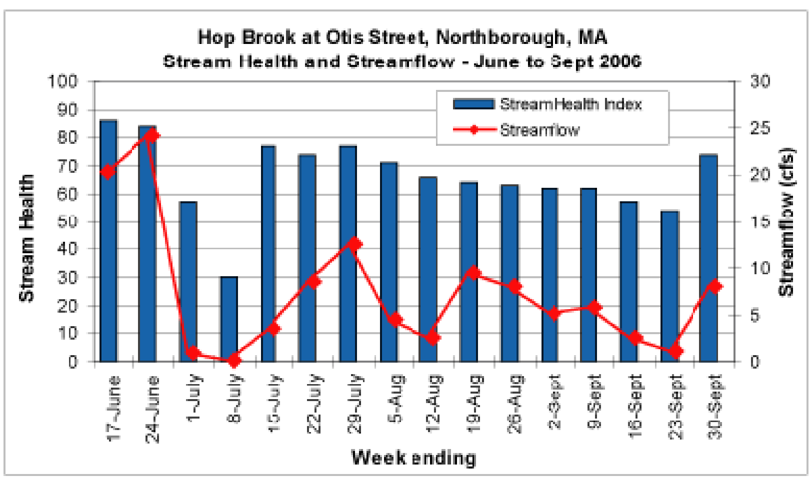


Figure 23: Stream Health & Streamflow – Nashoba Brook (2006)

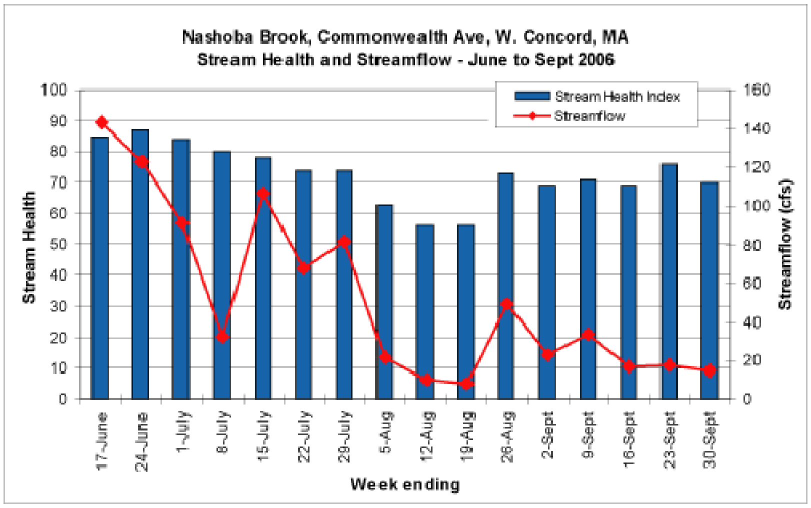


Figure 24: Stream Health & Streamflow – North Brook (2006)

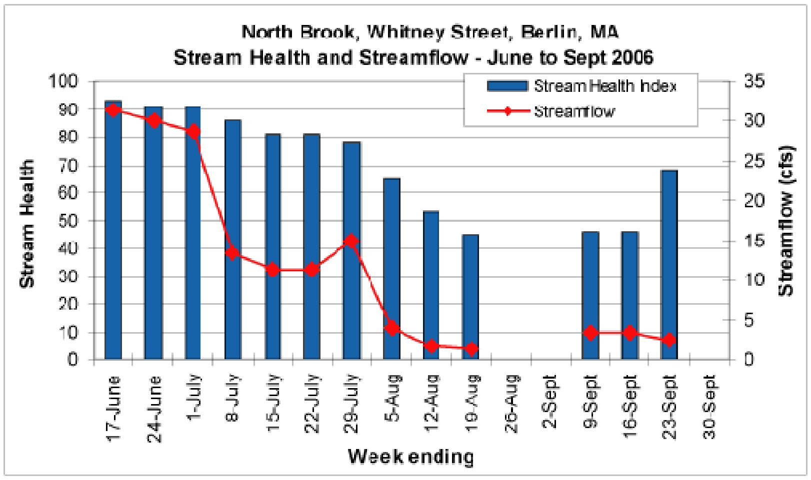
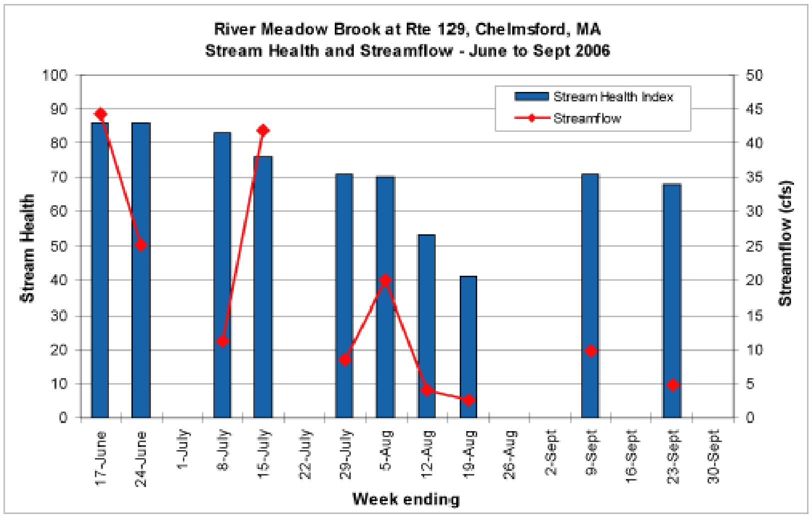


Figure 25: Stream Health & Streamflow – River Meadow Brook (2006)



Conclusions

OAR collected water quality, streamflow, and aquatic plant biomass on the Assabet and Concord Rivers and on tributary streams in the watershed between May and September 2006. Conditions over the summer of 2006 were wetter than normal; the Department of Conservation and Recreation reported that from April to September monthly rainfall for the Central Region of Massachusetts was 132% of normal; precipitation in the Northeast Region over the same period of time was 174% of normal. Rainfall was particularly high in May and June in 2006. Streamflows measured by the USGS gages on the Assabet River in Maynard and the Concord River in Lowell were above normal for most of May and June and near normal for the remainder of the summer. Weekly streamflows were recorded at eight tributary monitoring sites and near the headwaters of the Assabet River (above the first wastewater treatment plant discharge). Streamflows at these sites tended to be at their lowest in mid-August and again in mid- to late September.

Dissovled oxygen (DO) concentrations generally met water quality standards in 2006, ranging from 3.91 mg/L to 10.27 mg/L in the mainstem with the average about 7.45 mg/L. DO in the mainstem failed to meet water quality standards at one site and one date tested (the Concord River in Lowell, site CND-161, in July). In the tributaries the range of DO concentrations was 3.37 - 10.34 mg/L, failing to meet water quality standards at: Cold Harbor Brook (CLD-030) in July; Cold Harbor, Elizabeth (ELZ-004), and Hop (HOP-011) Brooks in August, and Cold Harbor and Elizabeth Brooks in September. The low readings at the Cold Harbor and Elizabeth Brooks are likely influenced by upstream beaver impoundments.

As in previous years, nutrient concentrations along the Assabet River mainstem below the first wastewater discharge (Westborough WWTP) were well above Ecoregion reference conditions (25^{th} percentile of the summertime data) for total phosphorus, total nitrogen, and nitrates. Nutrient concentrations at the three Concord River mainstem sites were generally lower than upstream concentration, but still exceeded Ecoregion reference conditions for total phosphorus, total nitrogen, and nitrates. Nutrient concentrations in the mainstem rivers (below the first WWTP input) tended to decrease from upstream to downstream. Nutrient concentrations in the tributaries were generally lower than mainstem concentrations.

Total phosphorus concentrations at the Assabet and Concord mainstem sites ranged from 0.025 mg/L to 0.610 mg/L, exceeding the Ecoregion reference condition (0.025 mg/L) in 55 of 56 measurements and exceeding the EPA “Gold Book” standard (0.050 mg/L) in 45 of 56 measurments. Ortho-phosphorus concentrations in the mainstem rivers ranged from 0.011 mg/L to 0.488 mg/L, exceeding 0.025 mg/L in 33 of 54 measurements and exceeding 0.050 mg/L in 13 of 54 measurements. Mainstem total nitrogen concentrations ranged from 0.03 mg/L to 7.59 mg/L, exceeding the reference condition (0.44 mg/L) in 51 of 56 measurements.

In the headwater and tributary stream sites, total phosphorus and ortho-phosphorus concentrations were generally lower than in the mainstem sites each month. Total phosphorus concentrations ranged from 0.012 mg/L to 0.131 mg/L, exceeding Ecoregion reference conditions (0.025 mg/L) in 33 of 54 measurements and exceeding EPA “Gold Book” standards (0.050 mg/L) in 17 of 54 measurements. Ortho-phosphorus concentrations ranged from <0.006

mg/L to 0.076 mg/L, exceeding 0.025 mg/L in 13 of 54 measurements and exceeding 0.050 mg/L in 2 of 54 measurements. Total nitrogen concentrations ranged from 0.05 mg/L to 4.98 mg/L, exceeding the Ecoregion reference condition (0.44 mg/L) in 27 of 54 measurements.

The aquatic plant biomass (as wet weight) per impoundment was assessed on four impoundments of the Assabet River and one impoundment of the Concord. Total biomass per impoundment calculated in 2006 was from 51% to 83% less than reported in 1999 as part of the Assabet River Nutrient TMDL. Because different sampling and analysis methods may have been used in 1999/2000 than in 2005/2006, the measurements from 1999 and 2000 are also compared; biomass per impoundment in 2000 was from 1% to 39% less than in 1999. Much of the variability may be attributable to differences in climate. As an indicator of climate, it is useful to compare summertime (June 1 to Sept 30) streamflows as measured at the USGS gage on the Assabet River. Summer streamflows in 1999 were about 30% of normal. In comparison, summer streamflows were near normal in 2000 (88%) and 2005 (97%), but considerable higher than normal in 2006 (147%). The differences in total biomass calculated per impoundment among the years suggest that annual variation in biomass is relatively high, and that a long-term baseline of measurements will be needed to be able to detect future changes in biomass attributable to changes in watershed management. As more data is collected it may also be possible to better analyze the co-variance of biomass, streamflow, rainfall, temperature, and water column nutrient concentrations.

Stream Health Readings were calculated at eight tributary sites and one site near the Assabet River headwaters (above the first wastewater discharge). The stream health was rated “excellent” or “good” for more than half of the weeks assessed at all of the sites tested: Assabet River Headwaters (11 of 16), Cold Harbor Brook (6 of 9); Danforth Brook (9 of 16), Elizabeth Brook (16 of 16), Fort Meadow Brook (16 of 16), Hop Brook (12 of 16), Nashoba Brook (14 of 16), North Brook (9 of 13), River Meadow Brook (8 of 10). Lowest stream health readings tended to be in mid-August when streamflows were the lowest. Flow measurements in Cold Harbor Brook were disrupted again this summer by a beaver dam in the culvert just downstream of the gage by mid-August.

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Glossary of Terms

Ammonia (NH_3): a form of nitrogen available for 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.

Channel Flow Status: an estimation of the amount of the streambed that is covered with water. Method from the EPA Rapid Bioassessment Protocol.

Conductivity: the ability of the water to conduct an electrical charge. Conductivity is a rough indicator of the presence of pollutants such as: wastewater from wastewater treatment plants or septic systems; non-point source runoff (especially road salts); and soil erosion. Reported in microSiemens per centimeter (µS/cm), conductivity is measured by applying a constant voltage to one nickel electrode and measuring the voltage drop across 1 cm of water. The flow of electrical current (I) through the water is proportional to the concentration of dissolved ions in the water - the more ions, the more conductive the water and the higher the “conductivity.” Since conductivity in water is also temperature dependent the results are often reported as “specific conductivity,” which is the raw conductivity measurement adjusted to 25° C.

Dissolved Oxygen: the presence of oxygen gas molecules (O_2) in the water, reported as percent saturation (% sat) or in milligrams per liter (mg/L). 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.

Ecoregion: An area over which the climate is sufficiently uniform to permit development of similar ecosystems on sites that have similar properties. Ecoregions contain many landscapes with different spatial patterns of ecosystems.

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

Impoundment: A body of water contained by a barrier such as a dam; characterized by an inlet and an outlet stream.

Mainstem: The main channel of a river, as opposed to the streams and smaller rivers that feed into it.

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.

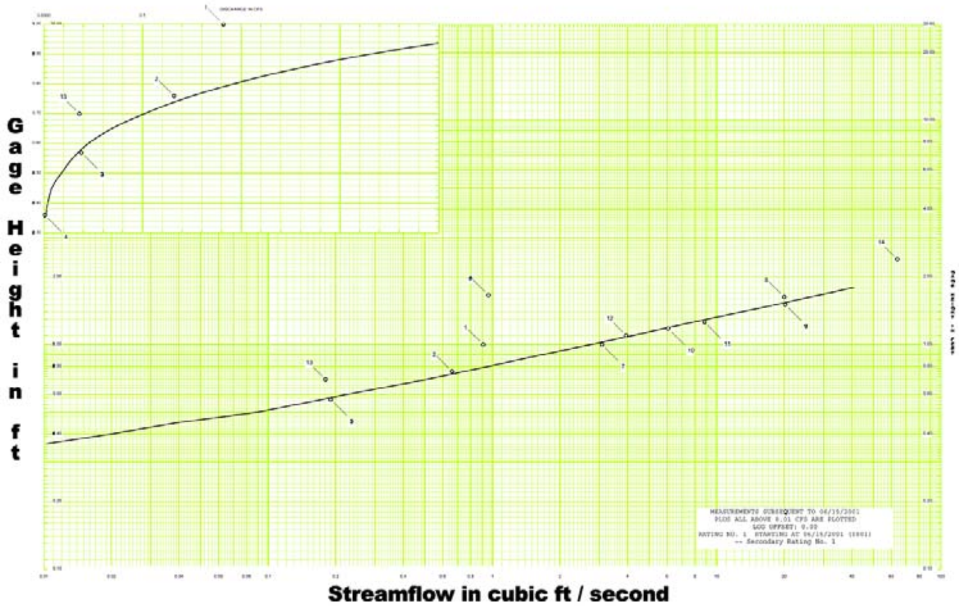
Oxidation/reduction potential provides a measure of the condition of the suspended solids: to what extent the organic material in them has been degraded by microorganisms.

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 (eutrophic conditions).

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 and play a role in the behavior of other pollutants such as heavy metals in the environment. Changes in pH can be the result of acid rain/snow, chemicals entering the waterways, or algal blooms.

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 mainstem river and at sites on eight tributaries. Streamflow (also called discharge) is the volume of water passing a given point in the river (reported in cubic feet per second, "cfs"). Streamflow is measured on the mainstem Assabet and Concord Rivers at the USGS gages in Maynard and Lowell, respectively, and reported on the USGS web page. Streamflow on the tributary streams is calculated using a rating curve from staff gage readings taken by OAR volunteers.

Stage-discharge rating (aka "rating curve"): the relationship between stage (water height) and discharge (streamflow). The rating curve is determined empirically by making a series of streamflow measurements at different stages and analyzing the graphed results (figure below).



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.

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.

Tributary: A stream or river whose water flows into a larger stream, river, or lake.

Appendix I: Data Summaries

Appendix II: Biomass Maps

Appendix III: Stream Health Index Readings & Tributary Data