Organization for the Assabet River

StreamWatch and Water Quality Monitoring Program
Final Report – 2007 & 2008 Field Seasons

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Abstract

This report presents the monthly water quality and streamflow data collected on the Assabet and Concord Rivers and tributary streams in 2007 (May, June, July, August, and September) and in 2008 (June, July, August, and October). Summer 2007 conditions were generally drier than average; as of October 2007 precipitation over the previous 6 months had been 86% of normal. Summer 2008, conditions were generally wetter than average; 122% of normal as of October 2008. Water quality conditions (as assessed using OAR's Stream Health Index and Water Quality Index) were generally better in 2008 than 2007, but this is likely annual variation due to differences streamflow and not reflective of long-term changes.

Introduction

The combined Assabet and Concord River watershed is about 236 square miles in eastern Massachusetts and is within EPA's Nutrient Ecoregion XIV subregion 59, the Eastern Coastal Plain. The mainstem rivers, particularly the Assabet, suffer 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 dissolved oxygen concentrations and pH, 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 Massachusetts Department of Environmental Protection (MA DEP, 2008) 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, 2008). Nashoba Brook and Mill Brook in Concord are 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").

The findings of the Assabet River Total Maximum Daily Loading Study (ENSR 2001, MA DEP 2004) confirmed 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. The study concluded that reductions in nutrient loads from both point and non-point sources will be required to restore the Assabet River to Class B conditions. MA DEP and EPA adopted a two-phased adaptive management plan to reduce phosphorous loads in the Assabet. In Phase I, lower total phosphorus discharge limits were imposed at the four major WWTPs. As a part of Phase I, ways of limiting nutrient flux from the nutrient-rich sediments which accumulate in the slower moving and impounded river sections were studied. The draft Assabet River, Massachusetts Sediment and Dam Removal Feasibility Study (ACOE 2009) examined sediment dredging, dam removal, and lower winter phosphorus discharge limits as ways of controlling the annual phosphorus loading from the sediments. The study concludes that dredging would achieve, at best,

short term improvements. Phosphorus discharge from the WWTPs in the winter contributes to the annual phosphorus budget for the Assabet and, therefore, decreased winter phosphorus discharge limits would be another way to control phosphorus loading to the system. Finally, the study's dam removal analysis showed that dam removal plus the Phase 1 WWTPs improvements would almost meet the 90 percent goal, achieving an estimated 80 percent reduction of sediment phosphorus load.

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 on the mainstems and large tributaries of the Assabet and Concord. The summer of 2008 was OAR's seventeenth consecutive summer collecting data at 12 mainstem Assabet River sites, including the longest standing sites above and below each major wastewater treatment plant, its seventh year collecting data at tributary sites, and its fifth year collecting data at mainstem Concord River sites, and its fourth 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; reapproved in 2007), and the Quality Assurance Program Plan for the StreamWatch Project (OAR 2003a; reapproved in 2007) 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. 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 (described at www.assabetriver.org/streamwatch/howindex.html). This report covers the water quality and streamflow data collected between May 2007 and October 2008. Water quality reports and data for 1999 – 2006 (OAR 2000b, OAR 2001, OAR 2002, OAR 2003b, OAR 2004, OAR 2005, OAR 2006b, OAR 2007) and 2005 biomass sampling project (OAR 2006a) are available on OAR's website (www.assabetriver.org/wq/).

Water Quality Sampling Methods

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

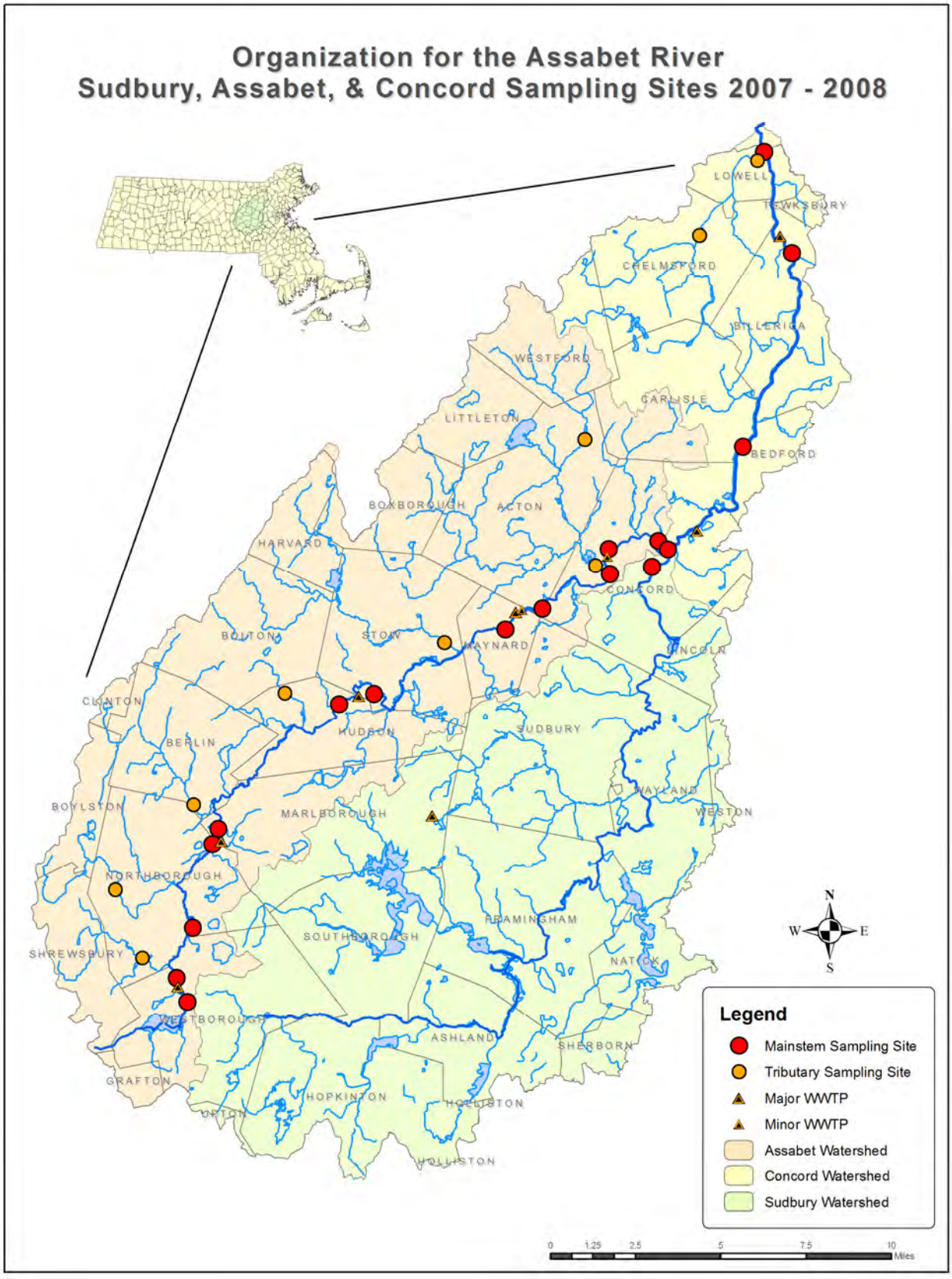
Table 1: Sampling Sites 2007 & 2008Monitoring Sites

Waterbody	**Sites**	Town	Years Sampled	OAR Site #	SARIS #	Lat/Long (d/m/s)	Measurements	
							Water Quality	Stream-flow
Concord River	Rogers Street	Lowell	2004-2008	CND-009	46500	42°35' 32"/ 71°17' 20"	√	(USGS Gage)
Concord River	Lowell Street	Billerica	2008	CND-045	46500	42°32' 05"/ 71°17' 58"	√	
Concord River	Route 4	Billerica	2004-2007 [a]	CND-093	46500	42°32' 05"/ 71°17' 58"	√	
Concord River	Rte 225	Bedford	2008	CND-110	46500	42°30' 33"/ 71°18' 50"	√	
Concord River	Lowell Rd. Bridge	Concord	2004-2008	CND-161	46500	42°27' 58"/ 71°21' 21"	√	
Sudbury River	Rte 62	Concord	2008	SUD-005	47650	42°27' 35"/ 71°21' 33"	√	
Assabet River	Lowell Road	Concord	1999-2008	ABT-010	46500	42°28' 13"/ 71°21' 45"	√	
Assabet River	Route 2	Concord	1992-2008	ABT-026	46775	42°27' 56"/ 71°23' 28"	√	
Assabet River	Route 62 (Pump Stn.)	W. Concord	1992-2008	ABT-033	46775	42°28' 34"/ 71°23' 02"	√	
Assabet River	Route 62 (Acton Ford)	Acton	1999-2008	ABT-063	46775	42°26' 27"/ 71°25' 46"	√	
Assabet River	USGS Maynard Gage	Maynard	1992-2008	ABT-077	46775	42°25' 56"/ 71°26' 58"	√	(USGS Gage)
Assabet River	Route 62 (Gleasondale)	Stow	1992-2008	ABT-144	46775	42°24' 18"/ 71°31' 35"	√	
Assabet River	Cox Street	Hudson	1992-2008	ABT-162	46775	42°24' 12"/ 71°32' 06"	√	
Assabet River	Robin Hill Road	Marlborough	2006-2008 [b]	ABT-238	46775	42°20' 44"/ 71°36' 50"	√	
Assabet River	Boundary Street	Marlborough	1992-2008	ABT-242	46775	42°20' 29"/ 71°36' 58"	√	
Assabet River	School Street	Northborough	1997-2008	ABT-280	46775	42°18' 17"/ 71°37' 42"	√	
Assabet River	Route 9	Westborough	1992-2008	ABT-301	46775	42°16' 59"/ 71°38' 18"	√	
Assabet River	Maynard Street	Westborough	1992-2008	ABT-311	46775	42°16' 26"/ 71°37' 56"	√	
River Meadow	Thorndike Street	Lowell	2004-2008	RVM-005	46525	42°37' 54"/ 71°18' 31"	√	
River Meadow	Route 129	Chelmsford	2004-2008	RVM-038	46525	42°35' 55"/ 71°20' 20"	√	√
Spencer Brook	Barrett's Mill Road	Concord	2004-2007	SPN-003	unnamed	42°28' 25"/ 71°22' 33"	√	√
Nashoba Brook	Commonwealth Ave.	Concord	1995-2008	NSH-002	unnamed	42°27' 32"/ 71°23' 49"	√	√
Nashoba Brook	Wheeler Lane	Acton	2008	NSH-047	46875	42°30' 37"/ 71°24' 24"	√	(USGS gage)
Elizabeth Brook (aka Assabet Brook)	White Pond Road	Stow	2002-2008	ELZ-004	47125	42°25' 21"/ 71°28' 38"	√	√
Fort Meadow Brook	Shay Road	Hudson	2002-2007	FTM-012	47200	42°23' 13"/ 71°31' 43"	√	√
Danforth Brook	Rte 85	Hudson	2002-2008	DAN-013	47275	42°23' 59"/ 71°33' 57"	√	√
North Brook	Pleasant St.	Berlin	2002-2008	NTH-009	47375	42°21' 16"/ 71°37' 36"	√	√
Cold Harbor Brook	Church Street	Northborough	2002-2008	CLD-012	47550	42°18' 54"/ 71°39' 30"	√	√
Hop Brook	Otis Street	Northborough	2002-2008	HOP-011	47600	42°17' 31"/ 71°39' 27"	√	√

[a] Concord River at Rte 4 sampling site replaced by upstream (Rte 225) and downstream (Lowell St.) sites; Rte 4 bridge under construction

[b] Assabet River at Robin Hill Road sampled upstream of the Tyler Dam from 1992-2005

Figure 1: Sudbury, Assabet, and Concord River Watershed and 2007/2008 Sampling Sites



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, September, and October (2008 only). Streamflow was calculated from the stage readings using stage/discharge rating curves developed in cooperation with USGS. There were several site changes in 2008: the Concord River sampling site at Rte 4/Billerica (CND-093) was replaced by sites upstream (Rte 225; CND-110) and downstream (Lowell St; Billerica) because the bridge at Rte 4 was under construction; the Fort Meadow Brook and Spencer Brook sites were discontinued because of difficulties maintaining a stage/discharge rating curve for those sites.

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 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. Ten percent of the samples taken were duplicate field samples and 10% were field blanks of distilled water. Table 2, below, summarizes 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, updated 2007) and the QAPP for the StreamWatch Project (OAR, 2003a, updated 2007).

Table 2: Sampling and Analysis Methods

Parameter	Analysis Method #	Equipment Range/ Reporting Limits	Sampling Equipment	Laboratory
Temperature	---	-5 - 45° C	YSI 6000-series	---
pH	---	0 to 14 units	YSI 6000-series	---
Dissolved oxygen	---	0 - 50 mg/L	YSI 6000-series	---
Conductivity	---	0 to 1000 μS/cm	YSI 6000-series	---
Total Suspended Solids	EPA 160.2	1.0 mg/L	bottle	Thorstensen Laboratory
Total phosphorus	EPA 365.2 (before 8.1.07) SM4500-P-E (after 8.1.07)	0.006 mg/L	bottle	Thorstensen Laboratory
ortho-Phosphate	EPA 365.2 (before 8.1.07) SM4500-P-E (after 8.1.07)	0.006 mg/L	bottle	Thorstensen Laboratory
Total Kjeldahl Nitrogen	EPA 351.3 (before 8.1.07) SM4500-NH3-F (after 8.1.07)	0.05 mg/L	bottle	Thorstensen Laboratory
Nitrates	EPA 300.0	0.01 mg/L	bottle	Thorstensen Laboratory
Ammonia	EPA 350.3 (before 8.1.07) SM4500-NH3-F (after 8.1.07)	0.03 mg/L	bottle	Thorstensen Laboratory

On March 12, 2007, the Environmental Protection Agency (EPA) published a Method Update Rule (EPA 2007), replacing a number of methodologies with updated versions. Thorstensen Laboratories started using the new methodologies by August 2007. Although the same quality control measures remained in place, Thorstensen Laboratories lost certification for a number of the new analysis methods in lab inspections between July 2007 and January 12, 2009 (pers. com. John Bardzik, DEP Laboratory Certification Program) (Table 3). On January 13, 2009 all certifications were revoked and the laboratory went out of business.

Table 3: Thorstensen Laboratory Inc. certification

Analyte	Original Method #	Replaced by Method #	Thorstensen Laboratory Inc. certification history	OAR Data Affected
Total Suspended Solids	EPA 160.2	SM 2540-D	Lost certification 8.23.07 (continued using EPA 160.2)	Affects data collected after 8.23.07
Total phosphorus	EPA 365.2	SM4500-P-E	Lost certification 2.10.08	Affects data collected after 2.10.08
ortho-Phosphate	EPA 365.2	SM4500-P-E	Not certified	Affects all data
Total Kjeldahl Nitrogen	EPA 351.3	SM4500-NH3-F	Certified through 4.22.08 Revoked 4.23.08 – 5.11.08 Certified 5.12.08 – 1.12.09	Does not affect data
Nitrates	EPA 300.0	----	Certified through 4.22.08 Revoked 4.23.08 – 5.11.08 Certified 5.12.08 – 1.12.09	Does not affect data
Ammonia	EPA 350.3	SM4500-NH3-F	Certified through 4.22.08 Revoked 4.23.08 – 5.11.08 Certified 5.12.08 – 1.12.09	Does not affect data

Water quality measurements were compared with the Massachusetts Water Quality Standards for Class B waters (MA DEP, 2007). All segments of the Assabet are designated Class B/warm water fisheries. All segments of the Concord River are designated Class B warm water fisheries except the last segment (below the last sampling site) from Rogers Street, Lowell, to its confluence with the Merrimack which is designated Class B (CSO)/warm water fishery. The Sudbury River from the outlet of Cedar Swamp Pond to Fruit Street, Hopkinton (not monitored as part of this project) is designated Class B/Outstanding Resource Water. From Fruit Street to the outlet of Saxonville Pond, Framingham, the Sudbury is designated Class B/warm water fishery. From the outlet of Saxonville Pond to its confluence with the Assabet, the Sudbury is designated Class B/aquatic life. All of the tributary streams assessed in this project are designated Class B waters. Although the tributary streams of the basin are not designated as cold water fisheries, most of the streams support or have supported cold water fisheries and it is, therefore, useful to compare dissolved oxygen and water temperature measurements on the tributaries with cold water fisheries standards. 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 4) and with summertime data for Ecoregion XIV subregion 59 streams (US EPA, 2000) (Table 5).

Table 4: Water Quality Standards and Guidance for Use Support

Parameter	Standard / Guidance
Dissolved oxygen[a]	≥ 5.0 mg/l for 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 [a]	"free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class"
Aesthetics [a]	All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.

[a] MA DEP. 2007.
[b] US EPA. 1986.

Table 5: Reference Conditions for Aggregate Ecoregion XIV Subregion 59 Streams

Parameter	Reference condition (25th percentile based on summer data for Nutrient 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. For data analysis, the sites are divided into sections: (1) the upper Assabet mainstem from ABT-301 (Route 9, Westborough) to ABT-144 (Gleasondale, Stow), (2) the lower Assabet mainstem, from ABT-077 (Route 62, Maynard) to ABT-010 (near Lowell Road, Concord), (3) the Concord River mainstem from CND-161 (below the confluence of the Assabet and Sudbury) to CND-009 (at Rogers Street in Lowell), (4) the Sudbury River mainstem (one site near the mouth), and (4) the Assabet headwater and all tributary sites (Table 1). 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 6 lists tributary and mainstem basin characteristics calculated using USGS's StreamStats program.

Table 6: StreamStats Drainage Basin Statistics

	Statistics at Mouth of Tributary[a]				
Headwater & Tributary Streams	Latitude/Longitude at Mouth of Tributary	Drainage Area (sq.mi.)	Stratified Drift Area (sq.mi.)	% area stratified drift	Slope [b] (%)
Assabet at Maynard St., Westboro	42.2741/-71.6322	6.79	1.64	24.15	3.61
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, Northboro/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 Rivers	**Statistics near Mouth of River**[a]				
Assabet River, Concord	42.4652/-71.3596	177.81	73.00	41.06	3.01
Sudbury River, Concord	42.4637/-71.3578	162	49.13	30.33	2.52
Concord River, Lowell	42.6351/-71.3015	400.0	197.97	49.49	2.63

[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.

Results and Discussion

Reach and tributary statistics are summarized in Table 7, below. The Water Quality Index readings (last column) for each sampling date are calculated on median water quality measurements for the section. A complete description of the Water Quality Index, a sub-index of OAR's Stream Health Index, is available on OAR's webpage at http://www.assabetriver.org/take-action/monitoring/interpre-data/stream-health-index. Full monthly summaries of the water quality data are attached in the Appendix I. Individual parameters are discussed below.

Table 7: Mainstem Reach and Tributary WQ Statistics – 2007 and 2008

				Mainstem Reach and Tributary Statistics* (morning readings between 5:30 – 9:00 am)												
Date	Reach	Sites	Stat -istic*	Water Temp (°C)	DO % Sat.	DO (mg/L)	Cond. (S/cm)	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Total N	Water Quality Index**
19-May-07	Headwater	ABT-311	Single reading	14.12	90.9	9.34	131	7.13	<1.0	<0.006	<0.006	0.08	0.03	0.13	0.21	96
	Tributaries	9 Sites	Median	9.49	86.6	9.74	169	6.85	3	0.014	0.015	0.24	0.035	0.12	0.33	98
16-June-07	Headwater	ABT-311	Single reading	18.84	91.0	8.45	159	7.18	<1	0.018	<0.006	0.12	0.06	0.34	0.46	80
	Upper Assabet	ABT-301 – ABT-144	Median	17.18	84.5	8.06	428	6.94	4.5	0.211	0.120	2.85	0.09	0.6	3.46	22
	Lower Assabet	ABT-077 – ABT-010	Median	17.87	92.2	8.74	321	7.06	6	0.101	0.038	0.91	0.07	0.33	1.28	60
	Concord River	CND-161 – CND-009	Median	19.07	59.0	5.51	282	6.78	4.5	0.070	0.020	0.32	0.08	0.42	0.74	68
	Tributaries	10 sites	Median	17.05	90.1	8.62	275	6.96	0.5	0.034	0.008	0.29	0.09	0.39	0.69	76
21-July-07	Headwater	ABT-311	Single reading	17.34	89.6	8.6	214	7.29	3	0.026	0.018	0.48	0.05	0.32	0.8	72
	Upper Assabet	ABT-301 – ABT-144	Median	19.56	73.2	6.58	719	7.01	0.5	0.164	0.134	5.9	0.06	0.44	6.31	6
	Lower Assabet	ABT-077 – ABT-010	Median	22.26	78.3	6.85	501	7.28	5.0	0.058	0.038	1.2	0.06	0.25	1.4	60
	Concord River	CND-161 – CND-009	Median	23.86	72.7	6.13	408	7.19	13	0.060	0.016	0.6	0.18	0.46	1.08	58
	Tributaries	10 sites	Median	20.10	77.3	6.76	382	7.04	1.5	0.038	0.016	0.24	0.075	0.29	0.53	68
18-August-07	Headwater	ABT-311	Single reading	16.68	90.9	8.84	239	7.45	<1.0	0.044	0.018	0.48	<0.03	0.2	0.68	75
	Upper Assabet	ABT-301 – ABT-144	Median	20.495	68.2	6.135	785	7.1	0.5	0.203	0.167	5.25	0.05	0.42	5.65	6
	Lower Assabet	ABT-077 – ABT-010	Median	20.79	79.7	7.39	581	7.39	1	0.056	0.020	1.6	0.07	0.29	1.89	54
	Concord River	CND-161 – CND-009	Median	23.92	95.4	8.26	445	7.72	14	0.061	0.016	0.21	0.06	0.32	0.53	67
	Tributaries	10 sites	Median	19.59	78.8	7.36	363	7.16	0.8	0.039	0.013	0.28	0.05	0.31	0.58	71

* calculated as ½ detection level where samples are BDL
** Index readings: 1 (very poor) to 100 (excellent); calculated on cold-water standards for Headwater and Tributaries; calculated on warm-water standards for mainsteam sections.

Table 7: Mainstem Reach and Tributary Statistics (continued)

Date	Reach	Sites	Stat -istic*	Water Temp (°C)	DO % Sat.	DO (mg/L)	Cond. (S/cm)	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Total N	Water Quality Index**
22-Sept-07	Headwater	ABT-311	Single Reading	15.68	87.2	8.66	252	7.41	<1	0.042	0.020	0.39	0.03	0.09	0.48	80
	Upper Assabet	ABT-301 – ABT-144	Median	18.22	63.6	6.24	677	6.93	2	0.321	0.268	7.30	0.05	0.17	7.41	5
	Lower Assabet	ABT-077 – ABT-010	Median	18.72	76.9	7.13	542	7.42	3	0.051	0.022	2.30	0.06	0.14	2.39	45
	Concord River	CND-161 – CND-009	Median	19.50	107.6	9.79	451	8.06	4	0.045	0.012	0.99	0.04	0.11	1.10	69
	Tributaries	10 sites	Median	17.28	75.0	7.21	351	7.23	3	0.035	0.007	0.23	0.04	0.21	0.41	76
14-June-08	Headwater	ABT-311	Single Reading	22.94	85.2	7.32	200	7.16	3	0.036	0.012	0.12	0.06	0.18	0.30	60
	Upper Assabet	ABT-301 - ABT-144	Median	20.40	74.3	6.74	712	6.96	5	0.181	0.118	3.34	0.09	0.18	3.52	19
	Lower Assabet	ABT-077 - ABT-010	Median	22.79	74.6	6.46	479	7.27	5	0.069	0.030	1.18	0.08	0.16	1.34	58
	Concord River	CND-161 - CND-009	Median	24.62	93.8	7.75	437	7.27	11	0.055	0.005	0.56	0.04	0.11	0.68	67
	Sudbury River	SUD-005	Single Reading	24.85	85.7	7.09	399	7.17	6	0.041	0.021	0.04	0.04	0.20	0.24	76
	Tributaries	9 sites	Median	21.01	65.5	5.93	409	6.97	6	0.050	0.007	0.26	0.10	0.25	0.50	60
19-July-08	Headwater	ABT-311	Single Reading	20.59	82.6	7.41	282	7.19	4	0.044	0.020	0.74	0.04	0.14	0.88	61
	Upper Assabet	ABT-301 - ABT-144	Median	21.98	71.0	6.01	827	6.83	3	0.140	0.085	4.17	0.09	0.21	4.39	6
	Lower Assabet	ABT-077 - ABT-010	Median	25.34	74.7	6.16	467	7.33	3	0.074	0.027	0.91	0.06	0.14	1.12	61
	Concord River	CND-161 - CND-009	Median	26.76	80.3	6.81	436	7.24	11	0.070	0.017	0.37	0.05	0.17	0.54	64
	Sudbury River	SUD-005	Single Reading	26.57	63.3	5.07	421	6.92	12	0.056	0.007	0.01	0.03	0.12	0.12	64
	Tributaries	9 sites	Median	23.49	72.2	6.13	429	7.02	5	0.049	0.019	0.15	0.07	0.17	0.36	53

* calculated as ½ detection level where samples are BDL

** Index readings: 1 (very poor) to 100 (excellent); calculated on cold-water standards for Headwater and Tributaries; calculated on warm-water standards for mainstem sections.

Table 7: Mainstem Reach and Tributary Statistics (continued)

Date	Reach	Sites	Stat -istic*	Water Temp (°C)	DO % Sat.	DO (mg/L)	Cond. (S/cm)	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Total N	Water Quality Index**
16-August-08	Headwater	ABT-311	Single Reading	22.75	91.9	7.92	159	7.2	<1	0.017	<0.006	0.02	0.04	0.19	0.21	67
	Upper Assabet	ABT-301 - ABT-144	Median	20.29	82.1	7.21	348	6.9	5	0.132	0.093	1.23	0.07	0.19	1.36	54
	Lower Assabet	ABT-077 - ABT-010	Median	21.12	87.0	7.68	275	6.8	7	0.100	0.054	0.66	0.06	0.19	0.84	64
	Concord River	CND-161 - CND-009	Median	21.59	64.2	5.65	264	6.6	7	0.077	0.037	0.25	0.09	0.24	0.48	66
	Sudbury River	SUD-005	Single Reading	21.58	19.5	1.71	258	6.4	6	0.059	0.024	0.04	0.04	0.11	0.15	22
	Tributaries	9 sites	Median	19.47	74.3	6.82	328	6.7	3	0.043	0.011	0.18	0.11	0.25	0.35	69
25-Oct-08	Headwater	ABT-311	Single Reading	10.40	90.4	10.11	126	7.07	3	0.018	<0.006	0.08	<0.03	0.16	0.24	92
	Lower Assabet	ABT-077	Single Reading	8.72	94.6	10.99	329	7.03	6	0.053	0.031	1.73	0.05	0.23	1.96	85
	Concord River	CND-009	Single Reading	8.91	92.5	10.69	297	6.45	4	0.045	0.018	0.95	<0.03	0.16	1.11	67
	Tributaries	8 Sites	Median	6.97	82.2	9.84	258	6.45	2.5	0.023	0.008	0.23	0.04	0.14	0.35	87

* Calculated as ½ detection level where samples are BDL

** Index readings: 1 (very poor) to 100 (excellent); calculated on cold-water standards for Headwater and Tributaries; calculated on warm-water standards for mainstem sections

Precipitation and Streamflow

Precipitation, and the associated increased stormwater runoff, is correlated with increased concentrations of total suspended solids, total phosphorus, and nitrate/nitrites. 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. Wet/dry determinations are shown in Table 8 (below).

Rainfall data downloaded from the National Weather Service's Worcester Airport station (http://www7.ncdc.noaa.gov/CDO/cdo) are shown in Figure 2 (2007) and Figure 3 (2008).

Table 8: Precipitation vs. sampling days 2007 & 2008

Sampling Date	Wet/dry	Inches precip. 24 to 48 hrs. before sampling	Inches precip. 24 hrs. before sampling	Inches precip. on sampling day (incl. hrs. after sampling)
May 19, 2007	Wet	0	0.64	0.38
June 16, 2007	Dry	0	0	0.73 (<0.1 before sampling)
July 21, 2007	Wet	0.18	0.15	0.09
Aug 18, 2007	Dry	0	0.08	0.02
Sept 22, 2007	Dry	0	0	0
June 14, 2008	Dry	0	0	0
July 19, 2008	Dry	0	0.04	0.26 (<0.1 before sampling)
Aug 16, 2008	Wet	0.10	0.68	0
Oct 25, 2008	Wet	0	0	0.76

Figure 2: NWS rainfall data (May to October 2007)

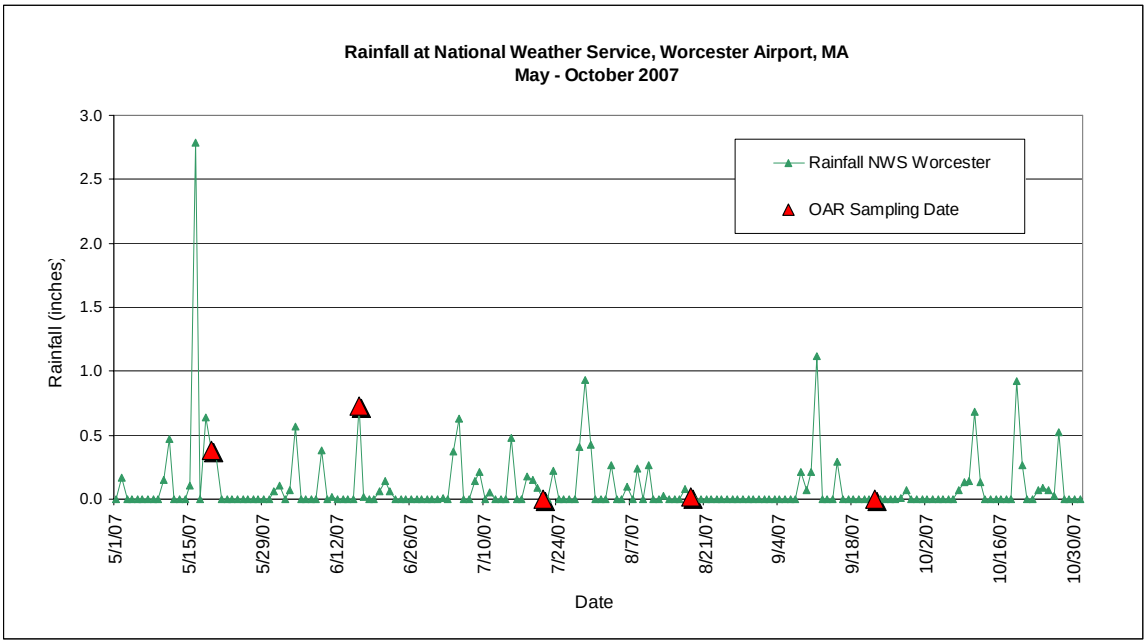


Figure 3: Assabet River streamflow and rainfall data (May to October 2008)

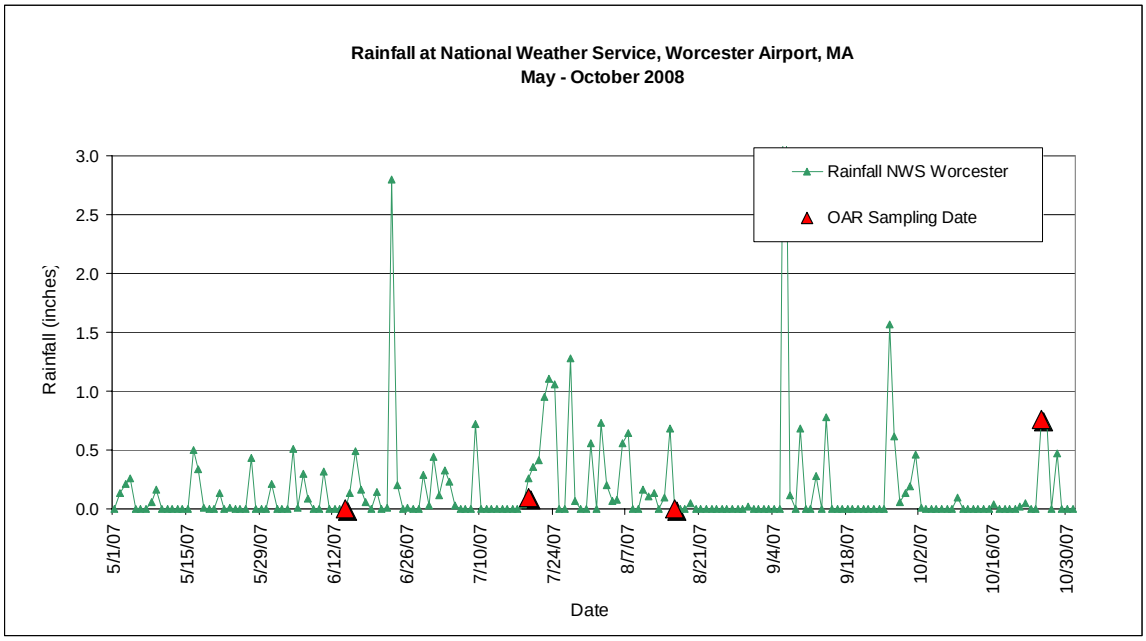


Table 9 shows composite monthly rainfall for the Central Region of Massachusetts as reported by the Department of Conservation and Recreation. Summer 2007 conditions were generally drier than average; as of October 2007 precipitation over the previous 6 months had been 86% of normal. Summer 2008, conditions were generally wetter than average; 122% of normal as of October 2008.

Table 9: Composite Rainfall Data (May/June to October 2007 & 2008)

2007 & 2008 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 2007	4.11	3.89	0.22	106	107
June 2007	2.72	3.88	-1.16	70	106
July 2007	5.46	3.75	1.71	146	118
August 2007	1.61	3.87	-2.26	42	112
Sept 2007	2.16	3.88	-1.72	56	101
Oct 2007	3.49	3.89	-0.40	90	86
June 2008	3.62	3.91	-0.29	93	124
July 2008	6.63	3.80	2.83	174	143
August 2008	4..27	3.91	0.36	109	115
Sept 2008	9.03	3.93	5.10	230	129
Oct 2008	2.51	3.91	-1.40	64	122

* Accessed December 2009, http://www.mass.gov/dcr/waterSupply/rainfall/

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. Figures 4 - 7 show mean daily 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.

Figure 4: Mean Daily Streamflows at USGS gage, Assabet River: May – Oct 2007

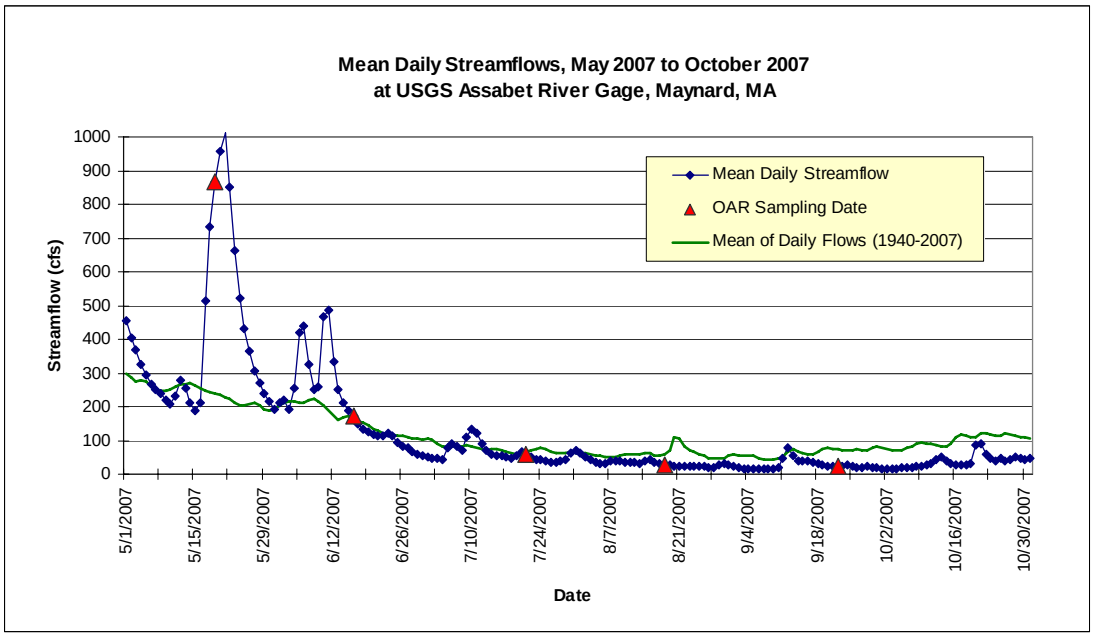


Figure 5: Mean Daily Streamflows at USGS gage, Assabet River: May to Oct 2008

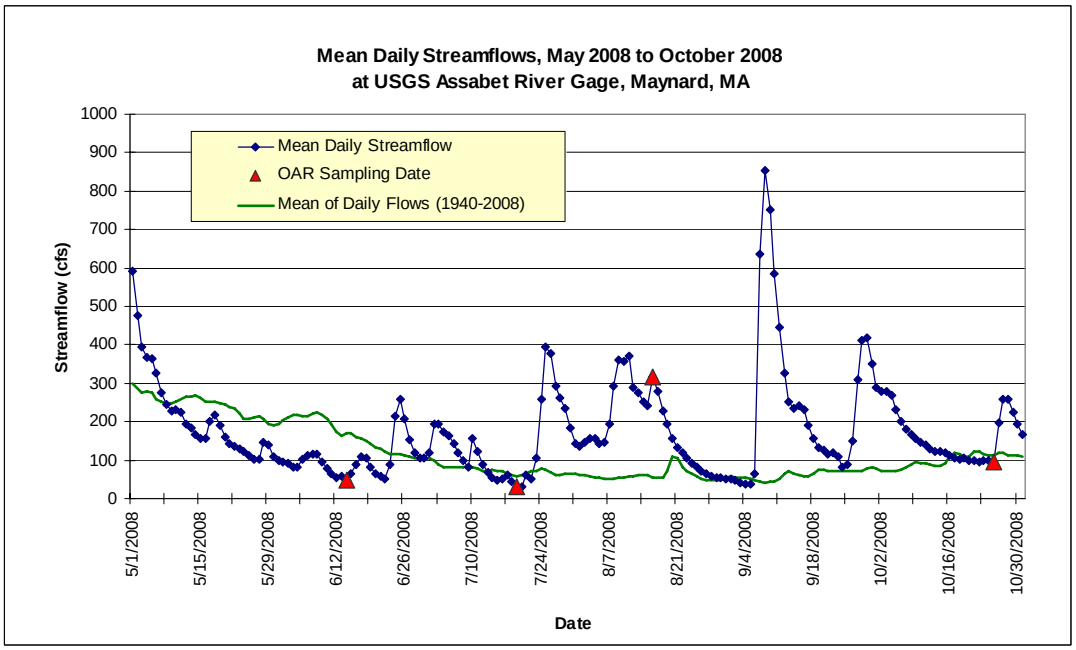
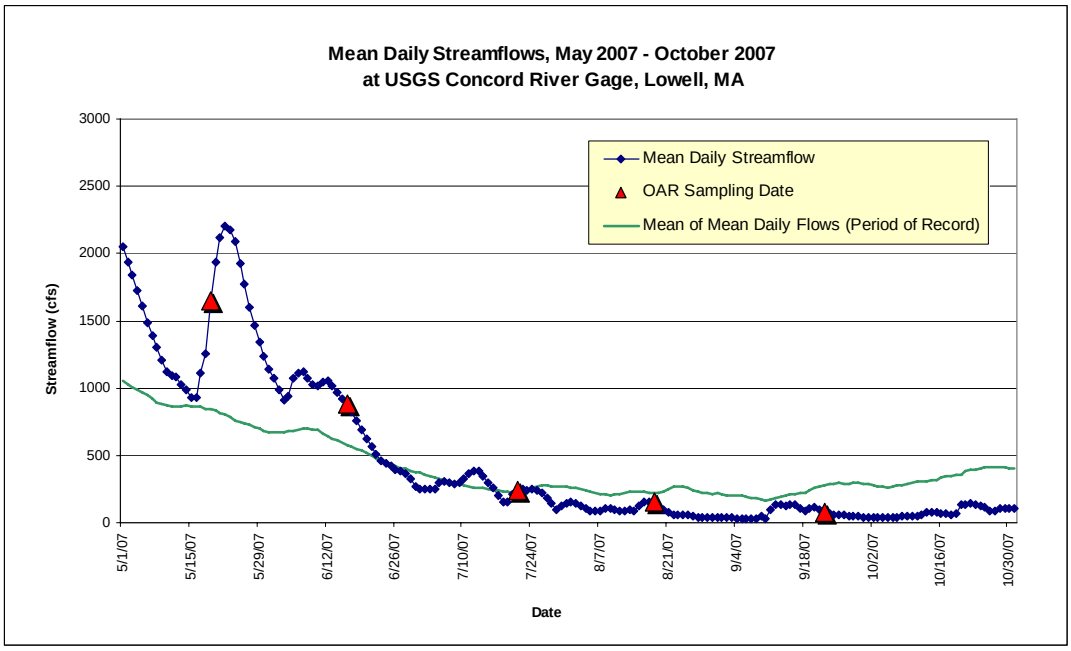
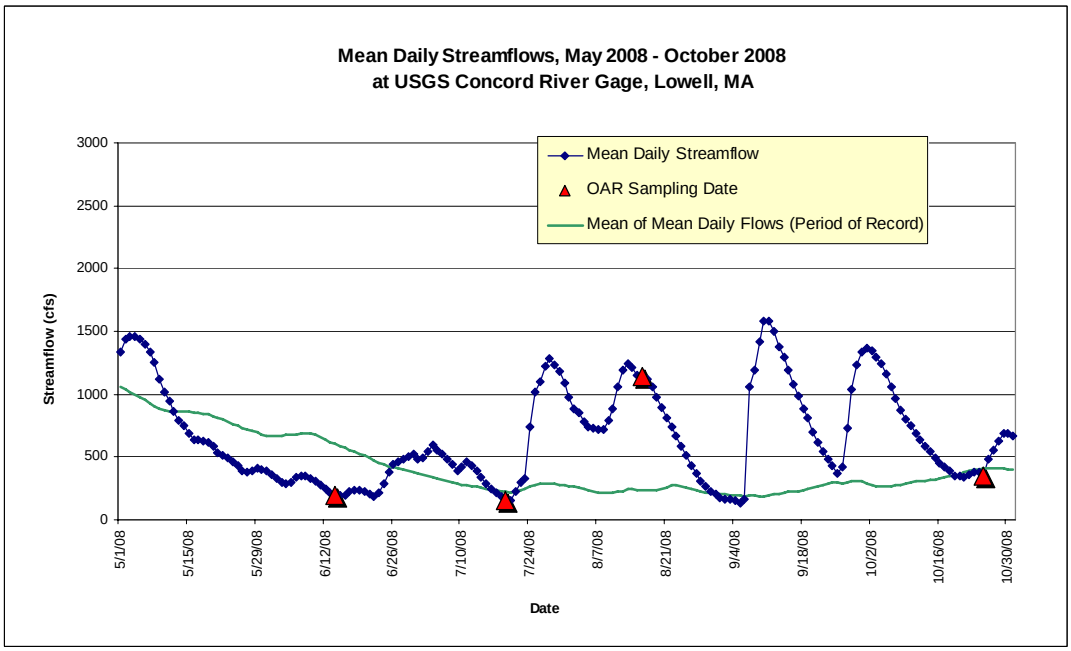


Figure 6: Mean Daily Streamflows at USGS gage, Concord River: May - Oct 2007



Monthly 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 7: Mean Daily Streamflows at USGS gage, Concord River: May - Oct 2008

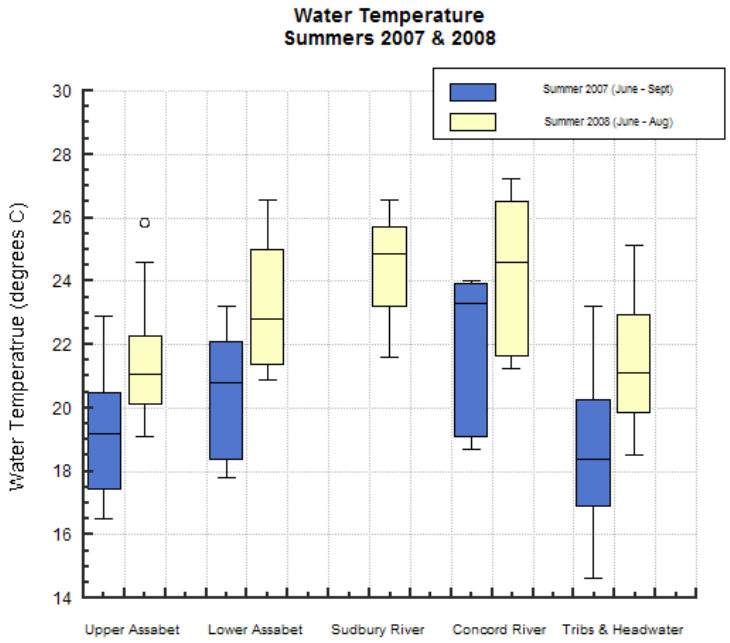


Water Temperature, pH, and Conductivity

In-situ readings (including dissolved oxygen, water temperature, pH, and conductivity) were taken 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 (Figure 8). Because the tributary streams support or have supported cold water fisheries, tributary and headwater temperature readings were also compared with the cold water standard (20.0°C). The recommended single-reading maxima for brook trout is 20.0°C and for brown trout is 23.9°C. In 2007, five of the tributary or headwater site readings exceeded 20.0°C in July, and four exceeded 20.0°C in August; none of the 2007 readings exceeeded 23.9°C. In 2008, seven of the tributary or headwater site readings exceeeded 20.0°C in June (one exceeded 23.9°C), nine readings exceeded 20.0°C in July (four exceeded 23.9°C), and two readings exceeded 20.0°C in August.

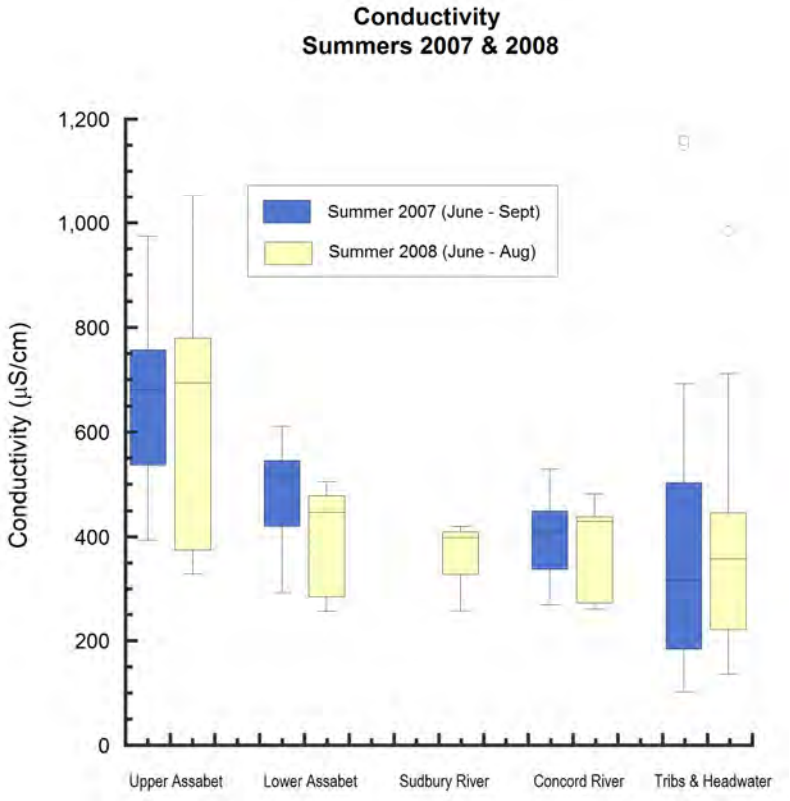
Figure 8: Water temperature readings (Summers 2007 & 2007)



pH readings in the mainstem varied from 6.56 – 9.04 in 2007 and 6.42 -7.15 in 2008, with two readings failing to meet standards (Concord River at Rte 4 in June and July 2007). Tributary pH readings ranged from 6.26 – 7.71 in 2007 and 7.20 – 7.31 in 2008, with four tributary readings below pH 6.50 in October 2008.

Conductivity is an indirect indicator of pollutants such as effluent, non-point source runoff (especially road salts) and erosion. The range of mainstem conductivity readings was 269 - 975 µS/cm in 2007 and 126 – 408 µS/cm in 2008 (Figure 9). The range of tributary conductivity readings was 80 – 1159 µS/cm in 2007 and 121 – 984 µS/cm in 2008. The highest readings were consistently measured in River Meadow Brook at Thorndike Street in Lowell.

Figure 9: Conductivity readings (Summers 2007 & 2008)

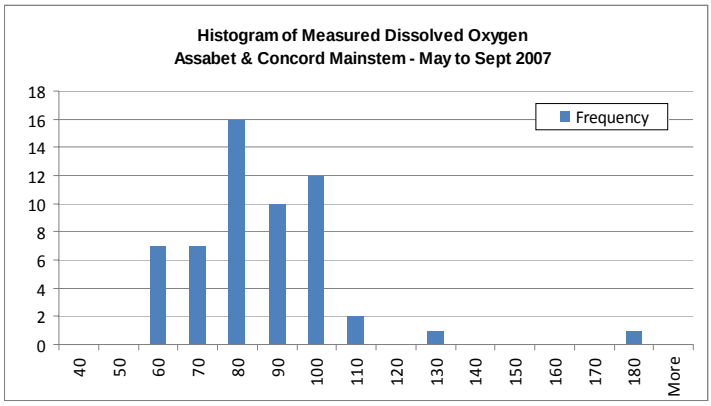


Dissolved Oxygen

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 and full data are in Appendix I. DO readings were taken between 5:30 am and 9:15 am.

DO concentrations generally met water quality standards in 2007 and 2008. Mainstem readings ranged from 4.67 mg/L to 16.04 mg/L in 2007 and from 1.71 mg/L to 10.99 mg/L in 2008. Mainstem readings failed to meet Class B warm water standards 2 out of 56 readings in 2007 and 2 of 54 readings in 2008. The lowest mainstem reading was taken on the Sudbury River at Rte 62 in Concord in August 2008 (note that the Sudbury site had not been sampled as part of this program before June 2008). In the tributaries the range of DO concentrations was 4.20 mg/L to 10.97 mg/L in 2007 and 4.00 mg/L to 12.27 mg/L in 2008. Tributary DO readings failed to meet Class B warm water standards 3 of 54 readings in 2007 and 4 of 35 readings in 2008. Tributary DO reading were also compared with the cold-water fishery standard (>6.0 mg/L); tributary DO readings failed to meet cold-water standards 8 of 54 readings in 2007 and 12 of 35 readings. Figures 10-11 show the histograms of DO % saturation measurements for 2007 and 2008.

Figure 10: % Dissolved Oxygen Measurements (May to Sept 2007)



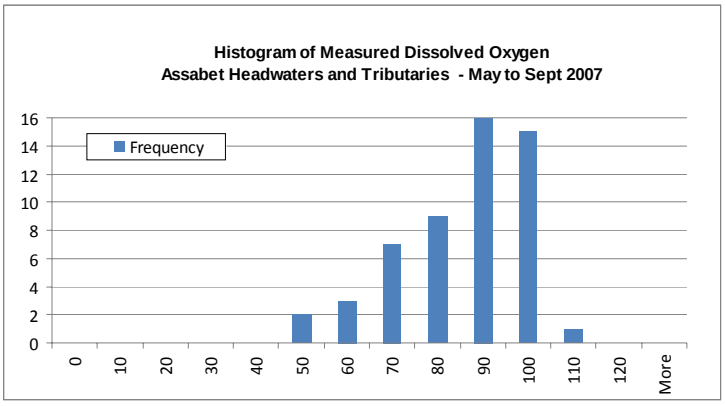
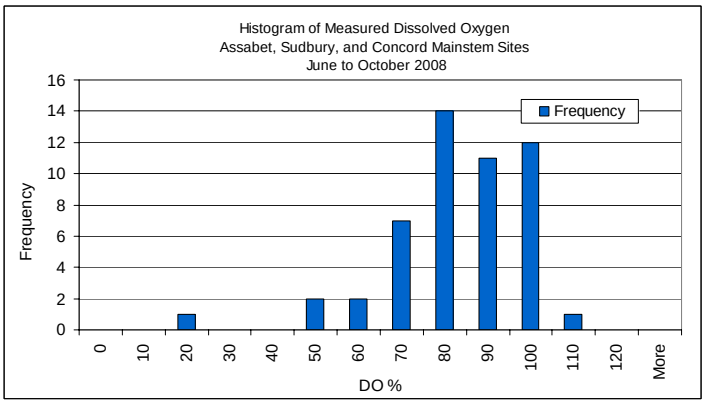
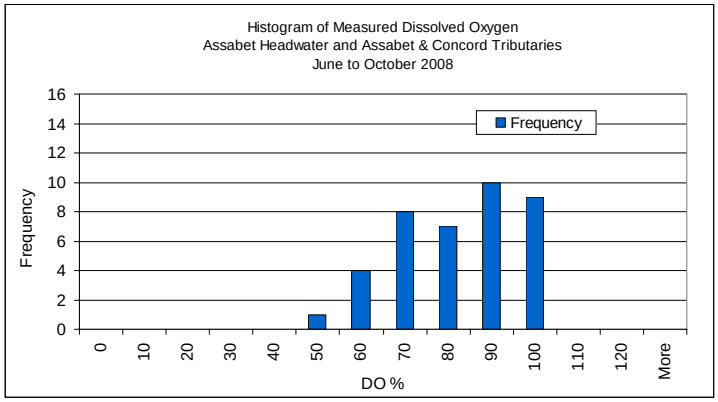


Figure 11: % Dissolved Oxygen Measurements (June to Oct 2008)





Nutrients and Suspended Solids

Summary statistics for nutrient concentrations are in Table 7, above. Median nutrient concentrations over the summer were calculated for the upper and lower Assabet mainstem, the Sudbury mainstem site, 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 in the Concord River mainstem was generally lower than upstream concentrations, but still exceeded Ecoregion reference conditions for total phosphorus, total nitrogen, and nitrates in 2007 and for total phosphorus in 2008. 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 (Figure 12) at the Assabet, Sudbury (2008 only), and Concord mainstem sites ranged from 0.023 mg/L to 0.643 mg/L in 2007 and 0.041 mg/L to 0.671 mg/L in 2008. The median summer TP concentrations were highest in the upper Assabet, where they

exceeded the Ecoregion reference condition (0.025 mg/L) by 10-fold in 2007 and almost 7-fold in 2008 (Table 10). Ortho-phosphorus concentrations in the mainstem rivers (Figure 13) ranged from <0.006 mg/L to 0.568 mg/L in 2007 and <0.006 mg/L to 0.601 mg/L in 2008. Mainstem total nitrogen concentrations ranged from 0.4 mg/L to 12.66 mg/L in 2007 and 0.12 mg/L to 8.33 mg/L in 2008. Median summer TN concentrations (Figure 14) were highest in the upper Assabet, exceeding the reference condition (0.44 mg/L) by 13-fold in 2007 and 8-fold in 2008. Nitrate concentrations (Figure 15) ranged from 0.08 mg/L to 12.40 mg/L in 2007 and <0.01 mg/L to 3.33 mg/L, with median summer concentrations exceeding the reference condition (0.34 mg/L for nitrate/nitrite combined) in the upper Assabet by 16-fold in 2007 and almost 10-fold in 2008. Ammonia (ammonia as N) concentrations (Figure 16) ranged from <0.03 mg/L to 0.23 mg/L in 2007 and <0.03 mg/L to 0.21 mg/L in 2008. Total suspended solids ranged from <1 mg/L to 22 mg/L in 2007 and 1 mg/L to 16 mg/L in 2008.

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 <0.006 mg/L to 0.094 mg/L in 2007 and <0.006 mg/L to 0.125 mg/L in 2008; the summer median exceeding Ecoregion reference conditions (0.025 mg/L) by only 1.3-fold in 2007 and 1.6-fold in 2008. Ortho-phosphorus concentrations ranged from <0.006 mg/L to 0.051 mg/L in 2007 and <0.006 mg/L to 0.073 mg/L in 2008. Total nitrogen (Figure 14) concentrations ranged from 0.15 mg/L to 1.36 mg/L in 2007 and 0.14 mg/L to 1.23 mg/L in 2008, with the summer median exceeding the Ecoregion reference condition (0.44 mg/L) by 1.1-fold in 2007 and not exceeding in 2008. Nitrate concentrations (Figure 15) ranged from 0.06 mg/L to 0.60 mg/L in 2007 and 0.02 mg/L to 0.74 mg/L in 2008, with summer median concentrations not exceeding 0.34 mg/L either summer. Ammonia (as N) concentrations (Figure 16) ranged from <0.03 mg/L to 0.26 mg/L in 2007 and <0.03 mg/L to 0.52 mg/L in 2008 (Figure 19). Total suspended sediment concentrations ranged from <1 mg/L to 14 mg/L in 2007 and <1 mg/L to 27 mg/L in 2008.

Table 10: Summer nutrient evaluation – 2007 & 2008

	Exceeds TP criteria (0.025 mg/L) by		**% P as ortho-phosphorus**		**Exceeds NO3 criteria (0.34 mg/L) by**		**Exceeds TN criteria (0.44 mg/L) by**	
Reach & Statistic	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
Upper Assabet Summer Median	**10x**	**6.6x**	**70%**	**80%**	**16x**	**10x**	**13x**	**8x**
Lower Assabet Summer Median	**3x**	**3x**	**50%**	**40%**	**4x**	**1.7x**	**4x**	**2.5x**
Sudbury (1 site) Summer Median	**----**	**2x**	**----**	**37%**	**----**	**1.7x**	**----**	**<0.44**
Concord Summer Median	**3x**	**2.5x**	**26%**	**26%**	**1.5x**	**1.1x**	**2x**	**1.1x**
Head. & Tribs. Summer Median	**1.3x**	**1.6x**	**30%**	**20%**	**<0.34**	**<0.34**	**1.1x**	**<0.44**

Figure 12: Total Phosphorus Concentrations (Summers 2007 & 2008)

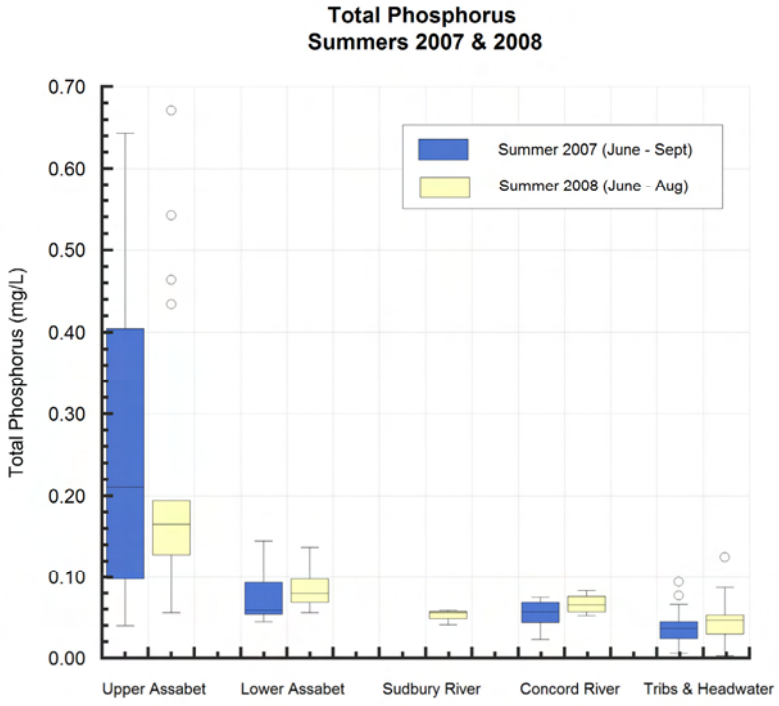


Figure 13: Ortho-Phosphorus Concentrations (Summers 2007 & 2008)

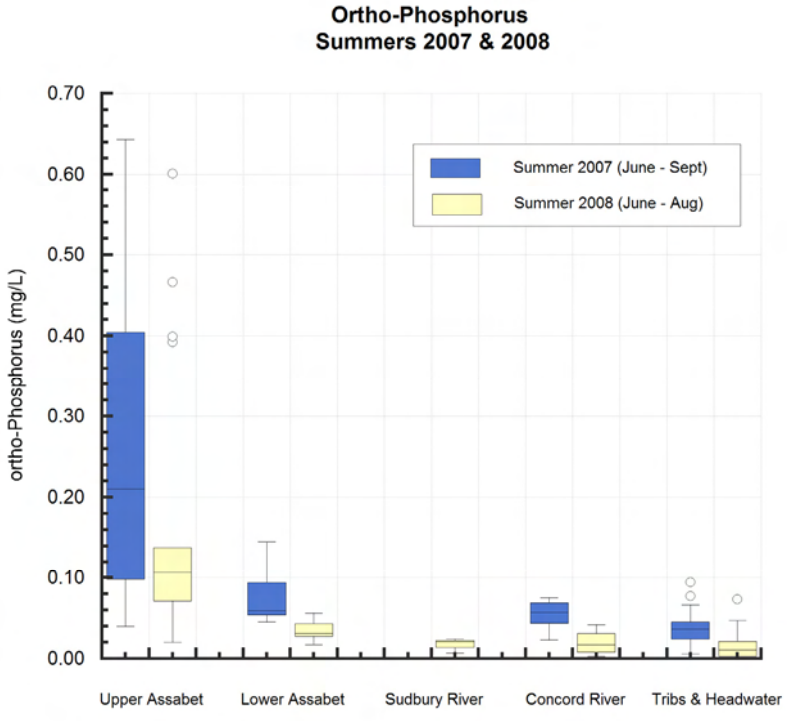


Figure 14: Total Nitrogen Concentrations (Summers 2007 & 2008)

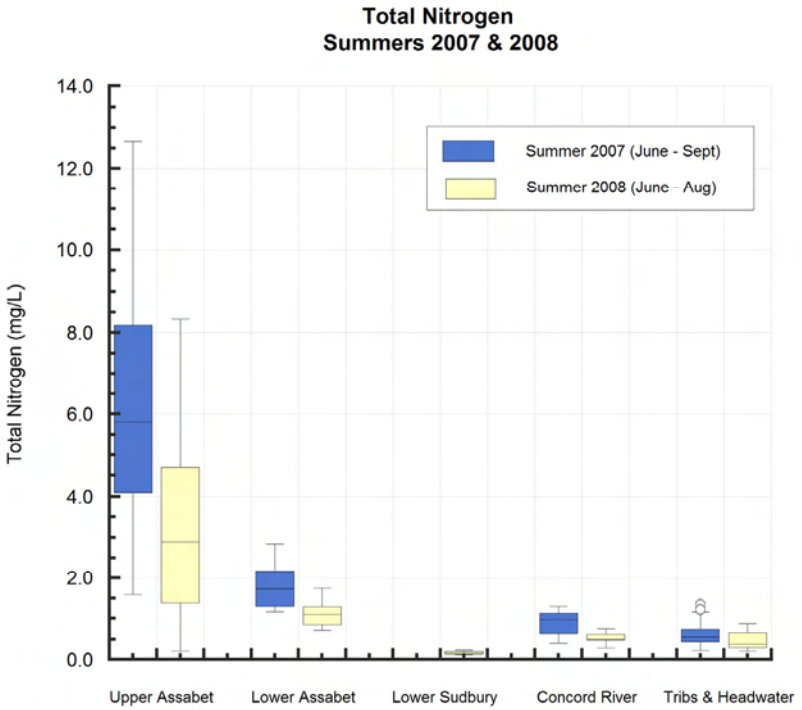


Figure 15: Nitrate Concentrations (Summers 2007 & 2008)

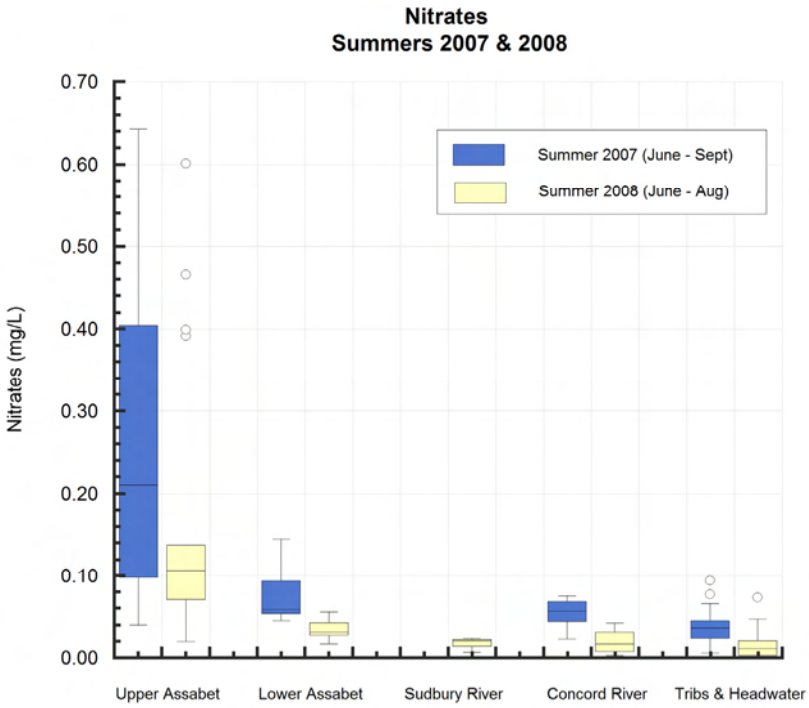
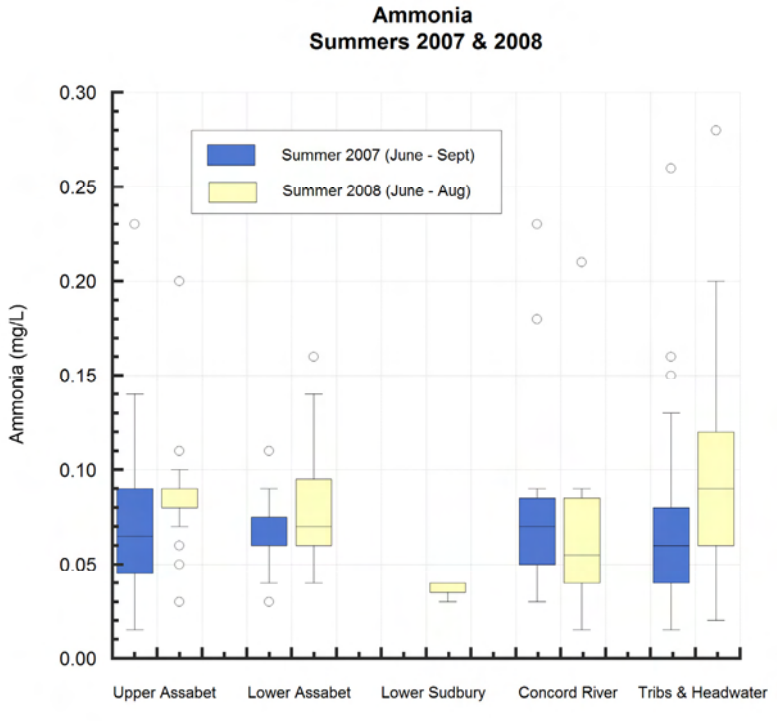


Figure 16: Ammonia (as N) Concentrations (Summers 2007 & 2008)



Water Quality and Stream Health Index Calculations

The Stream Health Index was used to assess conditions in eight of the tributary streams for each of the monthly sampling results. The Water Quality Index (a sub-index of the overall Stream Health Index) was also used to assess water quality in the mainstem sections based on median measurements for the section.

OAR's Stream Health 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 OAR webpage. 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 summertime streamflow recommendations of several standard-setting methods. 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. For tributary streams, which support or have supported cold-water fish populations, temperature and dissolved oxygen readings were compared with Class B cold water standards. For mainstem

sections, temperature and DO readings were compared with Class B warm water standards. 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), and very poor (1 – 20).

Tributaries

Table 11 shows Water Quality, Streamflow, and Habitat Availability sub-index readings and the overall Stream Health Index readings for eight tributary locations in 2007 and 2008. The full dataset is presented in Appendix II. In general, with higher precipitation and streamflows, Stream Health Index readings were higher in 2008 than in 2007. The lowest scoring sub-index was generally streamflow in 2007 and water quality in 2008.

WQI Mainstem Reaches

Water Quality Index calculations for median measurements on each river section (Assabet headwater, upper Assabet, lower Assabet, Concord River, and tributaries) on each sampling date are shown on Table 7. For comparison between years, it is useful to look at water quality conditions in August (generally the lowest flow and poorest water quality conditions for the year) (Table 12).

Water quality at the Assabet headwaters (as measured at Maynard Street, Westborough, upstream of the first wastewater discharge) was rated "good' in both August 2007 and August 2008. The upper Assabet section was rated "very poor" in August 2007 and "fair" in August 2008, with total phosphorus and total nitrogen the lowest scoring parameters. The lower Assabet section was rated "fair" in August 2007 and "good" in August 2008, with TP and TN the lowest scoring parameters. The Concord River was rated "good" in both August 2007 and August 2008, with total suspended solid the lowest scoring parameter, followed by TP and TN. The tributaries were rated "good" in both August 2007 and August 2008, with water temperature the lowest scoring parameter, followed by TP and TN.

The Sudbury River (one site) was not assessed with the Stream Health Index because the Sudbury River from below the Saxonville Dam in Framingham to the river's confluence with the Assabet in Concord is designated "Class B, Aquatic Life," which means that Class C dissolved oxygen and temperature criteria apply. This designation is made only where background conditions prevent the attainment of a higher use designation. Class C criteria for DO: not less than 5.0 mg/l at least 16 hours of any 24-hour period and not less than 3.0 mg/l at any time, or not lower than natural background levels. The criteria for water temperature is: shall not exceed 85°F (29.4°C) nor shall the rise due to a discharge exceed 5°F (2.8°C). (MA DEP 2007).

Table 11: Stream Health Index Readings - 2007 and 2008

Stream Health Index Readings - 2007 and 2008

	19-May-07	16-June-07	21-July-07	18-Aug-07	22-Sept-07		14-June-08	19-July-08	16-Aug-08	25-Oct-08
Danforth Brook, Rte 85, Hudson										
Water Quality Index	100	80	71	63	85		73	65	74	90
Flow Index	100	96	39	10	8		44	37	92	*nr*
Habitat Index	100	85	70	15	5		90	75	100	70
Stream Health Index	100	87	55	16	9		63	54	87	*nr*
Elizabeth Br., near White Pond Road, Stow										
Water Quality Index	96	71	66	58	67		56	50	68	82
Flow Index	100	99	84	44	30		81	80	92	94
Habitat Index	100	85	70	40	75		90	90	100	80
Stream Health Index	99	83	73	46	49		73	69	84	85
Fort Meadow Brook, Shay Road, Hudson										
Water Quality Index	95	84	76	83	89		*(Site discontinued in 2008)*			
Flow Index	100	99	87	73	60					
Habitat Index	100	85	65	50	85					
Stream Health Index	98	89	75	65	76					
Assabet Headwater, Maynard St., Westborough										
Water Quality Index	95	79	72	75	80		60	60	66	92
Flow Index	100	97	23	12	11		77	11	92	91
Habitat Index	100	90	55	50	35		75	55	100	85
Stream Health Index	98	88	40	25	22		70	24	84	89
Hop Brook, Otis Street, Northborough										
Water Quality Index	96	64	64	62	73		48	43	68	86
Flow Index	100	99	76	61	44		80	49	92	92
Habitat Index	100	95	70	75	50		90	80	100	90
Stream Health Index	98	83	70	66	53		68	53	84	89
Nashoba Br., Commonwealth Ave, W. Concord										
Water Quality Index	87	70	57	69	78		49	38	62	82
Flow Index	100	99	64	41	31		64	63	92	92
Habitat Index	100	90	55	75	65		85	85	100	95
Stream Health Index	95	85	58	57	50		63	55	81	89
North Brook, Whitney Ave, Berlin										
Water Quality Index	99	82	66	70	80		66	54	81	85
Flow Index	100	99	58	43	27		65	47	92	90
Habitat Index	100	82	75	50	50		86	85	100	85
Stream Health Index	100	86	66	52	43		71	58	90	87
River Meadow Br., Rte 129, Chelmsford										
Water Quality Index	81	79	68	54	56		62	55	61	83
Flow Index	99	99	59	21	17		66	46	92	95
Habitat Index	100	85	65	70	60		80	65	100	100
Stream Health Index	93	87	64	38	32		68	54	80	92

Key:	81 – 100 = Excellent	61 – 80 = Good	41 – 60 = Fair	21 – 40 = Poor	1 – 20 = Very Poor

Table 12: Water Quality Index Readings - Mainstem Reaches 2007 / 2008

River Section	Water Quality Parameter Reading for August 2007						Water Quality Index Reading
	Temp	DO	pH	TSS	TP	TN	
Assabet Headwater	66	90	100	100	61	59	75
Upper Assabet	98	66	100	100	28	1	6
Lower Assabet	97	80	100	83	55	21	54
Concord River	81	88	100	44	53	71	67
Tributaries	48	74	100	100	64	66	71

River Section	Water Quality Parameter Reading for August 2008						Water Quality Index Reading
	Temp	DO	pH	TSS	TP	TN	
Assabet Headwater	28	81	100	100	87	28	67
Upper Assabet	99	75	93	64	35	99	54
Lower Assabet	95	83	94	59	42	95	64
Concord River	93	60	85	59	47	93	66
Tributaries	49	68	88	76	61	49	69

Key:	81 – 100 = Excellent	61 – 80 = Good	41 – 60 = Fair	21 – 40 = Poor	1 – 20 = Very Poor

Conclusions

This report presents the monthly water quality and streamflow data OAR collected on the Assabet and Concord Rivers and tributary streams in 2007 (May, June, July, August, and September) and in 2008 (June, July, August, and October). Summer 2007 conditions were generally drier than average; as of October 2007 precipitation over the previous 6 months had been 86% of normal. Summer 2008, conditions were generally wetter than average; 122% of normal as of October 2008. Water quality conditions (as assessed using OAR's Stream Health Index and Water Quality Index) were generally better in 2008 than 2007, but this is likely annual variation due to differences streamflow and not reflective of long-term changes.

Mainstem dissolved oxygen readings failed to meet Class B warm water standards 2 out of 56 readings in 2007 and 2 of 54 readings in 2008. The lowest mainstem reading was taken on the Sudbury River at Rte 62 in Concord in August 2008 (note that the Sudbury site had not been sampled as part of this program before June 2008). Tributary DO readings failed to meet Class B warm water standards (>5.0 mg/L) 3 of 54 readings in 2007 and 4 of 35 readings in 2008. Tributary DO reading were also compared with the cold-water fishery standard (>6.0 mg/L); tributary DO readings failed to meet cold-water standards 8 of 54 readings in 2007 and 12 of 35 readings.

Water temperatures at both mainstem and tributary sites met Class B warm water fisheries standards on all dates tested. Because the tributary streams support or have supported cold water fisheries, tributary temperature readings were also compared with cold water standards. Tributary or headwater readings exceeding 20.0°C included: five sites in July 2007, four sites in August 2007, seven sites in June 2008, nine sites in July 2008, two sites in August 2008.

Two pH readings in the mainstem failed to meet standards (Concord River at Rte 4 in June and July 2007). Four tributary pH readings were below pH 6.50 in October 2008.

Conductivity is an indirect indicator of pollutants such as effluent, non-point source runoff (especially road salts) and erosion. The highest readings were consistently measured in River Meadow Brook at Thorndike Street in Lowell. The site should be investigated further to determine the source of the high conductivity readings.

Nutrient samples were analyzed by Thorstensen Laboratory Inc. Although Thorstensen Laboratory lost laboratory certification for various of the analyses between July 2007 and January 2009 (when the laboratory went out of business), the data reported here passed internal and external quality control measures.

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 in the Concord River mainstem was generally lower than upstream concentrations, but still exceeded Ecoregion reference conditions for total phosphorus, total nitrogen, and nitrates in 2007 and for total phosphorus in 2008. In general nutrient concentrations in the mainstem rivers (below the first WWTP input) decrease from upstream to downstream. Nutrient concentrations in the tributaries were generally lower than mainstem concentrations.

The Stream Health Index was used to assess conditions in eight of the tributary streams for each of the monthly sampling results. The Water Quality Index (a sub-index of the overall Stream Health Index) was also used to assess water quality in the mainstem sections based on median measurements for the section. In general, with higher precipitation and streamflows, Stream Health Index readings were higher in 2008 than in 2007. The lowest scoring sub-index was generally streamflow in 2007 and water quality in 2008.

To compare mainstem water quality conditions between years, it is useful to look at Water Quality Index readings in August (generally the lowest flow and poorest water quality conditions for the year). Water quality at the Assabet headwaters (as measured at Maynard Street, Westborough, upstream of the first wastewater discharge) was rated "good' in both August 2007 and August 2008. The upper Assabet section was rated "very poor" in August 2007 and "fair" in August 2008, with total phosphorus and total nitrogen the lowest scoring parameters. The lower Assabet section was rated "fair" in August 2007 and "good" in August 2008, with TP and TN the lowest scoring parameters. The Concord River was rated "good" in both August 2007 and August 2008, with total suspended solid the lowest scoring parameter, followed by TP and TN. The tributaries were rated "good" in both August 2007 and August 2008, with water temperature the lowest scoring parameter, followed by TP and TN.

With upgrades to the four major wastewater treatment plant discharging to the Assabet River coming online in the next several years (2010 and 2011), continued monitoring will be critical to measuring the effect of the upgrade.

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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.

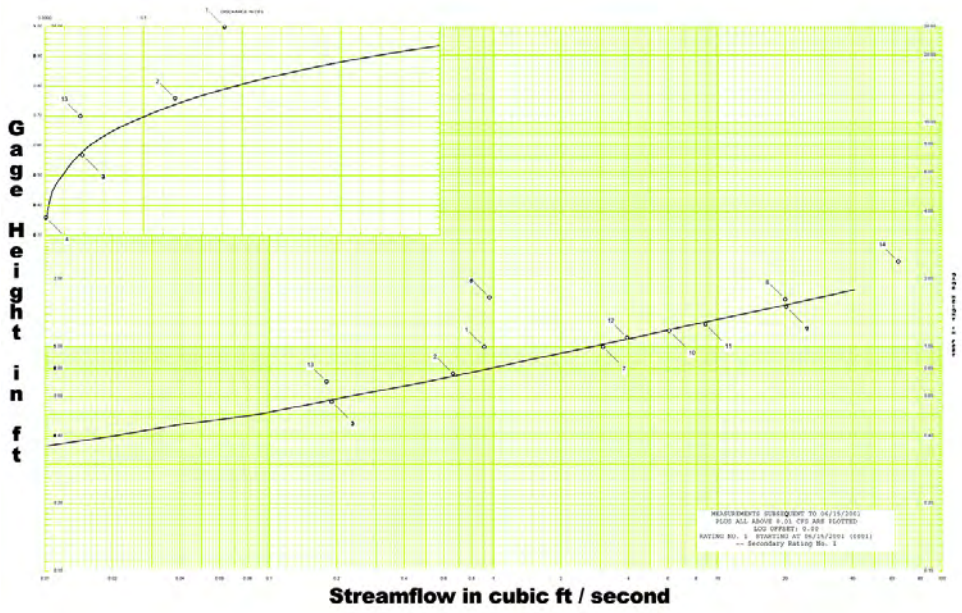
Oxidation/reduction potential provides a measure of the condition of the suspended solids: to what extent the organic material in them has been degraded by microorganisms.

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: Stream Health Index Readings & Tributary Data