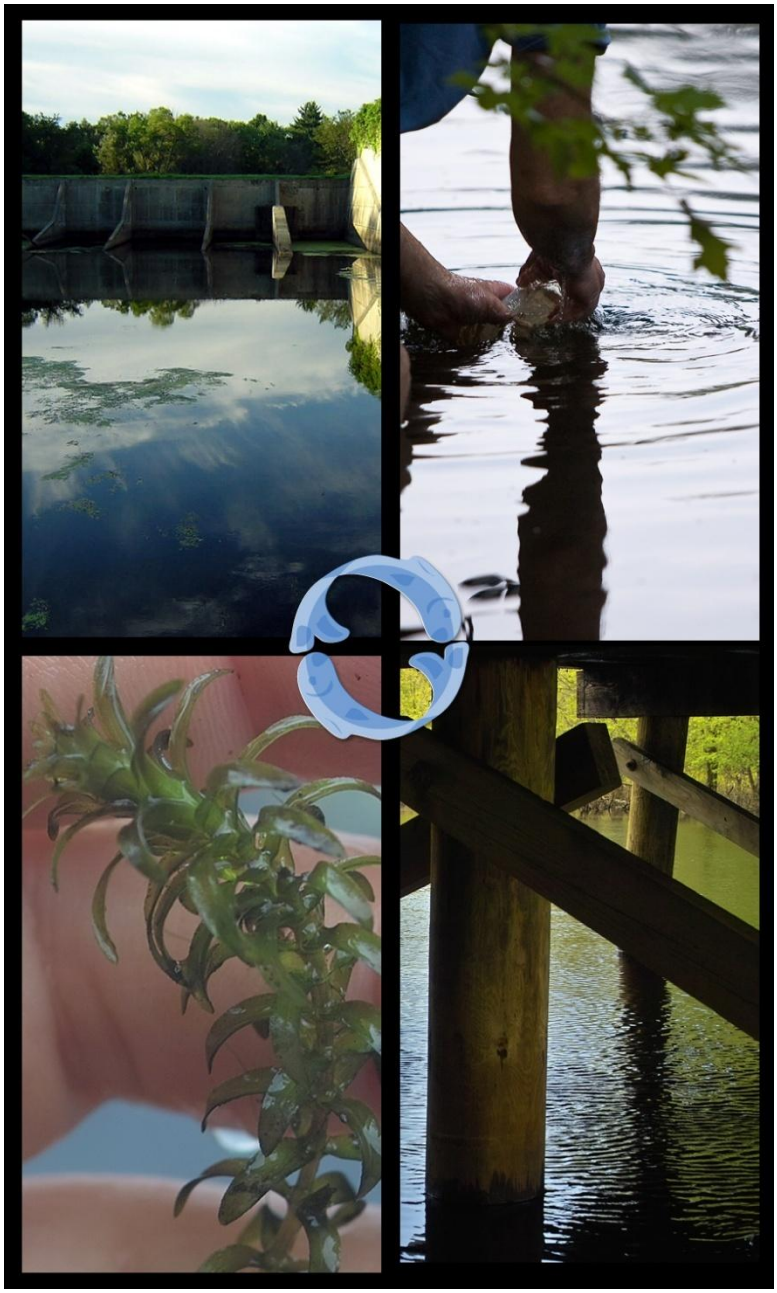
OARS

FOR THE ASSABET SUDBURY & CONCORD RIVERS

Water Quality Monitoring Program
Final Report – 2011 Field Season



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Abstract

This report presents the monthly water quality and streamflow data collected on the Assabet, Sudbury, and Concord Rivers and tributary streams in 2011 (March, May, June, July, August, September, and November), OARS' twentieth year of data collection on the Assabet mainstem.

Introduction

The combined Assabet, Sudbury, and Concord River watershed is about 399 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, can dramatically lower dissolved oxygen levels in the water column, and impair aesthetics and use of the rivers.

Under the federal Clean Water Act (Section 305b), states are required to evaluate the condition of the state's surface and ground waters with respect to their ability to support designated uses (such as fishing and swimming) as defined in each of the state's surface water quality standards. In their 2010 assessment, Massachusetts Department of Environmental Protection (MA DEP, 2010) 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, on the Impaired Waters List- Category 5 Water, "Waters Requiring a TMDL" for a variety of impairments. A Total Maximum Daily Loading Study (TMDL) for nutrients on the Assabet River was completed in 2004. The Sudbury River upstream of Fruit Street bridge in Hopkinton/Westborough is listed as Category 3 "No uses assessed." All sections of the Sudbury River from Fruit Street downstream to the confluence with the Assabet in Concord are listed as Category 5 for metals. Seven of the tributaries in the basin are also listed as Category 5 Waters (MA DEP, 2010): Eames Brook (cause unknown, taste/odor, noxious aquatic plants), Hop Brook in Marlborough/ Sudbury (nutrients, pathogens, dissolved oxygen, and noxious aquatic plants), Pantry Brook (pathogens), Elizabeth Brook (cause unknown), Nashoba Brook (fisheries bioassessment), and River Meadow Brook (pathogens). Mill Brook in Concord 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").

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 wastewater treatment plants (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 *Assabet River, Massachusetts, Sediment and Dam Removal Feasibility* Study (ACOE 2010) examined sediment dredging, dam removal, and lower winter phosphorus discharge limits as ways of controlling the annual phosphorus loading from the sediments. The study concluded 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 (MA DEP 2004), achieving an estimated 80 percent reduction of sediment phosphorus load.

Upgrades to the Hudson wastewater treatment plant were completed in September 2009, and upgrades to the Maynard WWTP were completed in spring 2011, allowing those plants to meet summer total phosphorus discharge limits of 0.1 mg/L and a winter limit of 1.0 mg/L. Upgrades to the Westborough and Marlborough Westerly wastewater treatment plants discharging to the Assabet River will come on-line in early 2012 allowing those plants to also meet summer total phosphorus discharge limits of 0.1 mg/L and a winter limit of 1.0 mg/L in 2012. The Marlborough Easterly plant discharging to Hop Brook (tributary to the Sudbury River) is required to be upgraded by January 31, 2014.

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, OARS (formerly the Organization for the Assabet River) conducts water quality, streamflow, and biomass monitoring on the mainstems and large tributaries of the Assabet, Sudbury, and Concord rivers. Without the support and work of its volunteers, OARS would not be able to conduct such an extensive monitoring program. The summer of 2011 was OARS' twentieth consecutive summer collecting data at mainstem Assabet River sites, including the longest standing sites below each major wastewater treatment plant, its tenth year collecting data at tributary sites, its eighth year collecting data at mainstem Concord River sites, its third summer collecting Sudbury River data, and its seventh year assessing aquatic plant biomass in the large impoundments of the Assabet River. Water quality data collected under OARS' *Quality Assurance Program Plan for the Assabet & Concord* (OAR 2009a, approved 7/20/2009) or Sudbury (OAR 2009b, approved 8/14/09) may be used by EPA and DEP in making regulatory decisions. The goals of OARS' 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.

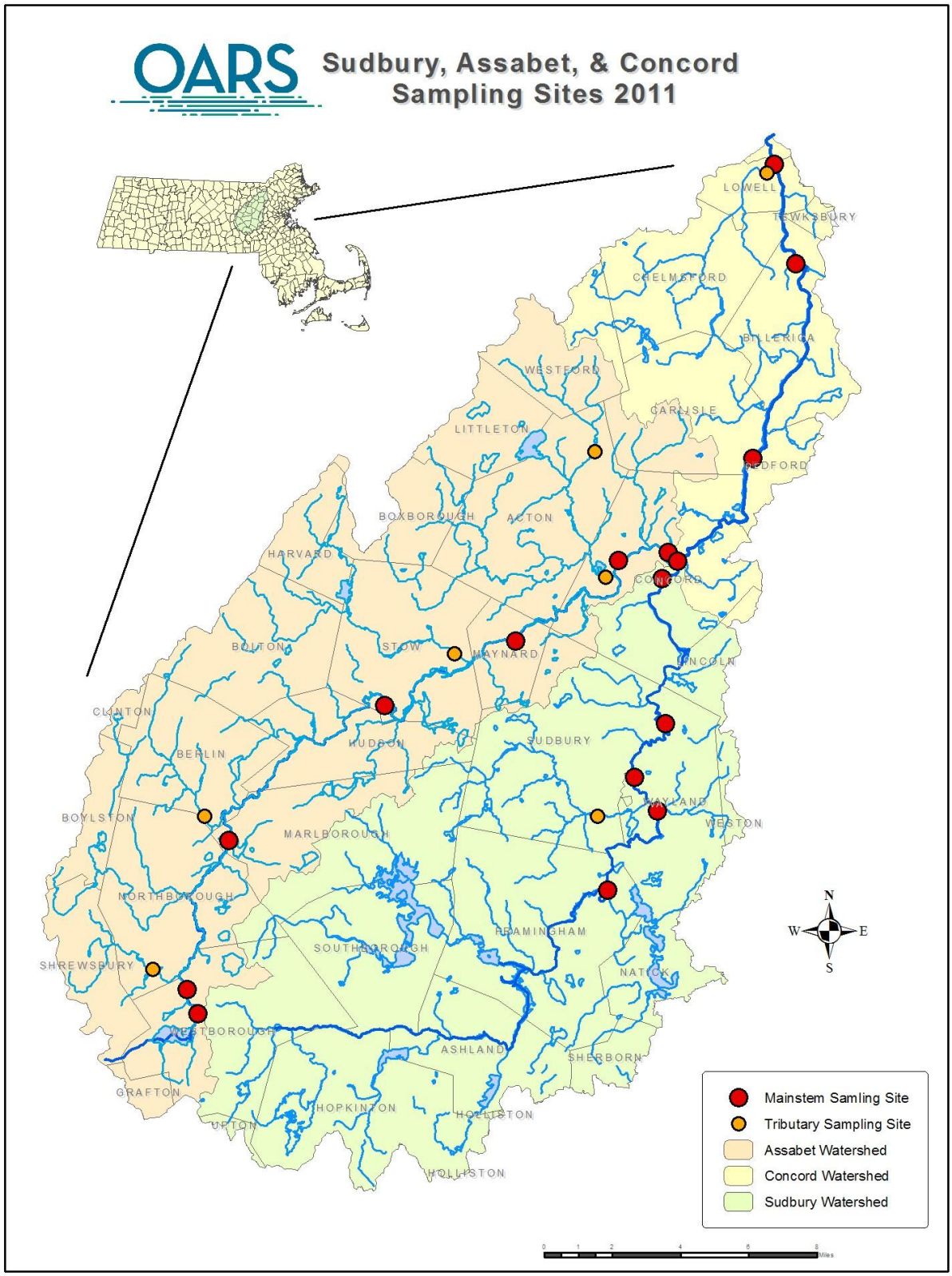
The data collected are also used to characterize fish habitat conditions in the main tributary sub-basins. Streamflow and habitat availability data were collected at eight tributary sites (Assabet headwaters, Hop Brook, North Brook, Fort Meadow Brook, Elizabeth Brook, Danforth Brook, Nashoba Brook, and River Meadow Brook) to calculate OARS' "Stream Health Index" readings for those streams (described at http://www.oars3rivers.org/our-work/monitoring/interpret-data).

This report covers the water quality and streamflow data collected between March 2011 and November 2011. Water quality reports and data for 1999 – 2010 (OAR 2000b, OAR 2001, OAR 2002, OAR 2003b, OAR 2004, OAR 2005, OAR 2006b, OAR 2007, OAR 2009, OARS 2011) and 2005 biomass sampling project (OAR 2006a) are available on OARS' website (http://www.oars3rivers.org/river/waterquality/reports).

Table 1: Sampling Sites 2011

Waterbody / Section	**Site Location**	Town	OARS Site #	SARIS #	Months Sampled	Lat/Long (d/m/s)	Measurements	
							WQ	Flow
Concord River	Rogers Street	Lowell	CND-009	46500	Mar, May – Sept, Nov	42°38' 08.89" / -71°18' 06.45"	√	(USGS)
Concord River	Lowell Street	Billerica	CND-045	46500	June - Aug	42°35'35.5"/ -71°17' 20.04"	√	
Concord River	Rte 225	Bedford	CND-110	46500	June - Aug	42°30' 33.0"/ -71°18' 48.6"	√	
Concord River	Lowell Rd. Bridge	Concord	CND-161	46500	Mar, May – Sept, Nov	42°27' 58.56"/- 71°21' 20.43"	√	
Sudbury River	Rte 62 / Boat House	Concord	SUD-005	47650	Mar, May – Sept, Nov	42°27' 29.8"/ -71°21' 58.8"	√	
Sudbury River	Sherman Bridge Rd.	Wayland	SUD-064	47650	May - Sept	42°23' 47.21" /- 71°21' 50.00"	√	
Sudbury River	River Road	Wayland	SUD-086	47650	May - Sept	42°22' 25.26"/ -71°22' 55.17"	√	
Sudbury River	Pelham Island Road	Wayland	SUD-098	47650	May - Sept	42°21' 33.3" / - 71°22' 09.1"	√	
Sudbury River	Sudbury Landing	Framingham	SUD-144	47650	May - Sept	42°19' 32.1" /- 71°23' 50.8"	√	(USGS)
Assabet River / Lower	Lowell Road	Concord	ABT-010	46500	June - Aug	42°28' 12.43"/- 71°21' 44.65"	√	
Assabet River / Lower	Route 2	Concord	ABT-026	46775	Mar, May – Sept, Nov	42°27' 56.96"/ -71°23' 27.92"	√	
Assabet River / Lower	Rte 62 / Canoe access	Acton	ABT-063	46775	June - Aug	42°26' 28.29"/ -71°25' 48.65"	√	
Assabet River / Lower	Rte 62/ USGS Gage	Maynard	ABT-077	46775	Mar, May – Sept, Nov	42°25' 56.00"/ -71°26' 58.55"	√	(USGS)
Assabet River / Upper	Rte 62 / Gleasondale	Stow	ABT-144	46775	June - Aug	42°24' 16.26"/ -71°31' 34.70"	√	
Assabet River / Upper	Robin Hill Road	Marlborough	ABT-238	46775	June - Aug	42°20' 42.61"/ -71°36' 50.92"	√	
Assabet River / Upper	Route 9	Westborough	ABT-301	46775	Mar, May – Sept, Nov	42°16' 59.61"/ -71°38' 19.44"	√	
Assabet River / Headwater	Maynard Street	Westborough	ABT-311	46775	Mar, May – Sept, Nov	42°16' 26.07"/ -71°37' 57.34"	√	OARS
River Meadow Brk	Thorndike Street	Lowell	RVM-005	46525	June - Aug	42°37' 54.54"/ -71°18' 30.70"	√	
Nashoba Brook	Commonwealth Av.	Concord	NSH-002	unnamed	Mar, May – Sept, Nov	42°27' 32.05"/ -71°23' 49.35"	√	OARS
Nashoba Brook	Wheeler Lane	Acton	NSH-047	46875	Mar, May – Sept, Nov	42°30' 46.71"/ -71°24' 15.83"	√	(USGS)
Elizabeth Brook	White Pond Road	Stow	ELZ-004	47125	Mar, May – Sept, Nov	42°25' 36.96"/ -71°29' 07.01"	√	OARS
Danforth Brook	Rte 85	Hudson	DAN-013	47275	Mar, May – Sept, Nov	42°24' 13.65"/ -71°34' 28.64"	√	OARS
North Brook	Pleasant St.	Berlin	NTH-009	47375	Mar, May – Sept, Nov	42°21' 25.67"/ -71°37' 45.48"	√	OARS
Hop Brook	Otis Street	Northborough	HOP-011	47600	Mar, May – Sept, Nov	42°17' 31.27"/ -71°39' 27.04"	√	OARS
Hop Brook	Landham Road	Sudbury	HBS-016	47825	May - Sept	42°21' 26.5" / -71°24' 11.7"	√	

Figure 1: Sudbury, Assabet, and Concord River Watershed and 2011 Sampling Sites



Water Quality Sampling Methods

Trained volunteers and OARS staff monitored water quality at sites along the mainstem Assabet, Sudbury, and Concord Rivers and 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 North Brook site at Pleasant Street in the Berlin, 0.9 miles upstream of the confluence of the brook with the Assabet River, is designated "NTH-009." Water quality monitoring (bottle samples, *in-situ* measurements, and observations) was conducted one weekend each month in March, May, June, July, August, September, and November. Because of funding limitations, not all sites are sampled each month: in November and March, only the gaged sites and mainstem top and bottom of the rivers (ABT-301, ABT-026, CND-161, and SUD-005) were sampled; in May through September, Sudbury River sites were included; all sites were sampled in the summer months (June, July, and August). From May to September (the growing season) monitoring is conducted between 5:00am and 8:30am, to capture the diurnal low in dissolved oxygen readings. In the non-growing season when dissolved oxygen does not vary as dramatically over the day, monitoring is conducted between about 6:00am and 1:00pm. In-streamflow was calculated from the stage readings of OARS' gages using stage/discharge rating curves developed in cooperation with USGS.

Nutrient and suspended solids samples were taken using bottles supplied by the state certified laboratory under contract with OARS and were stored in the dark on ice during transport from the field to the lab. Samples were delivered to the laboratory within twenty four hours of collection and analyzed within their respective hold-times. Chlorophyll-*a* samples were delivered to the laboratory within 4 hours of sampling. *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 meter 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 Quality Assurance Project Plan *for StreamWatch: OAR's Water Quality and Quantity Monitoring Program* (OAR 2009a, approved 7/20/09) and *Quality Assurance Project Plan for OAR's Lower Sudbury River Water Quality Monitoring Program* (OAR 2009b, approved 8/14/09).

Table 2: Sampling and Analysis Methods

Parameter	Analysis Method #	Equipment Range/ Reporting Limits	Sampling Equipment	Laboratory
Temperature	---	-5 – 45 degrees 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	SM 2540D	1 mg/L	bottle	Nashoba Analytical
Total Phosphorus	SM4500-P-E	0.01 mg/L	bottle	Nashoba Analytical
ortho-Phosphate	SM4500-P-E	0.01 mg/L	bottle	Nashoba Analytical
Nitrates	EPA 300.0	0.05 mg/L	bottle	Nashoba Analytical
Ammonia	SM4500-NH3-D	0.1 mg/L	bottle	Nashoba Analytical

Water quality measurements were compared with the Massachusetts Water Quality Standards (MA DEP, 2007). All segments of the Assabet are designated Class B/warm water fisheries. The Concord

River from the confluence of the Assabet and Sudbury to the Billerica drinking water withdrawal is designated Class B warm water fishery/ treated drinking water supply. From the Billerica withdrawal to Roger's Street in Lowell, the Concord is designated Class B warm water fishery and the last segment (below OARS' last sampling site) from Rogers Street in 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. (For a full list of the SuAsCo stream segment designations, see Appendix I.)

Although only two the tributary streams (an unnamed tributary of the Assabet River and the upper portion of Jackstraw Brook) of the basin are designated as cold water fisheries by MA DEP, a majority of the streams support or have supported cold water fisheries (Schlotterbeck 1954) 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 national criteria (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 (MA DEP 2007)

Parameter	**Standard / Guidance Class B**	**Standard / Guidance Class B "Aquatic Life"**
Dissolved oxygen	≥ 5.0 mg/l for warm water fisheries ≥ 6.0 mg/l for cold water fisheries	≥5.0 mg/l at least 16 hours of any 24-hour period and ≥ 3.0 mg/l at any time
pH	6.5 – 8.3 inland waters	
Nutrients	"control cultural eutrophication" / Gold Book standard TP < 0.05 mg/L for rivers entering an lake or impounded section	
Temperature	≤28.3° C and Δ < 2.8° C for warm water fisheries ≤20.0° C and Δ < 1.7° C for cold water fisheries	≤29.4 ° C and $\Delta \leq$ 2.8° C
Suspended Solids	"free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class"	
Aesthetics	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.	

Table 4: Reference Conditions for Ecoregion XIV (59) Streams (US EPA 2000)

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

River Reaches and Tributaries

All the sites tested were in relatively free-flowing sections, where the water column is assumed to be well-mixed. 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 from SUD-144 (Danforth Ct, Framingham) to SUD-005 (Rte 62, Concord), 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), ELZ-004 (Elizabeth Brook), NSH-047 (Nashoba Brook in Acton), and NSH-002 (Nashoba Brook) are all on tributaries to the Assabet River; RVM-005 (River Meadow Brook at Lowell) is on the largest tributary to the Concord River. HBS-016 (Hop Brook in Sudbury), a tributary to the Sudbury River, is reported separately from the other tributaries because it receives the discharge from the Marlborough Easterly wastewater treatment plant. 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]				
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, Northboro	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
Hop Brook, Sudbury	42.3627/-71.3733	22.0	13.4	61.14	2.44
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
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 sub-basin.

Results and Discussion

Reach and tributary statistics are summarized in Table 6, below. Full monthly summaries of the water quality data are attached in Appendix II. Individual parameters are discussed below.

Table 6: Mainstem Reach and Tributary Statistics – 2011

	Reach Statistics 2011 (calculated on 1/2 detection level where sample is Below Detection Limit)														
	Reach	# Sites	statistic	Time	Temp (°C)	DO % Sat	DO Conc (mg/L)	Cond (µS/cm)	pH	TSS (mg/L)	TP (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Chl (mg/L)
27-Mar-11	Upper Assabet Mainstem	1	Single reading	8:20	5.03	90.3	11.50	413	6.99	4	0.10	0.06	4.0	0.5	nr
	Lower Assabet Mainstem	2	Median	13:06	4.81	104.1	13.84	269	6.98	1.5	0.02	0.01	1.10	0.08	nr
	Sudbury Mainstem	2	Median	7:15	3.89	104.8	13.75	271	7.09	1.5	<0.01	<0.01	0.38	<0.1	nr
	Concord Mainstem	2	Median	8:14	3.95	103.7	13.59	258	7.00	1.5	<0.01	<0.01	0.55	<0.1	nr
	Headwater & Tribs	9	Median	8:15	3.16	98.4	13.05	177	7.03	1	<0.01	<0.01	0.37	<0.1	nr
	Hop Brook, Sudbury	1	Single reading	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
22-May-11	Upper Assabet Mainstem	1	Single reading	7:40	14.25	90.5	9.26	425	7.04	1.0	0.19	0.11	3.70	0.10	nr
	Lower Assabet Mainstem	2	Median	7:00	16.61	95.7	9.46	328	7.02	4.5	0.05	0.02	0.75	<0.1	nr
	Sudbury Mainstem	5	Median	6:38	16.70	73.2	7.24	371	6.77	1.0	0.01	0.01	0.12	<0.1	nr
	Concord Mainstem	2	Median	6:47	16.19	93.9	9.20	336	6.97	5.0	0.03	<0.01	0.27	<0.1	nr
	Headwater & Tribs	8	Median	7:12	15.85	95.3	9.48	276	7.00	1.0	0.03	<0.01	0.2	<0.1	nr
	Hop Brook, Sudbury	1	Single reading	7:14	15.33	36.0	3.59	335	6.69	<1	0.03	0.01	0.68	<0.1	nr
19-June-11	Upper Assabet Mainstem	3	Median	7:30	19.96	78.9	7.16	671	7.17	4.0	0.10	0.07	3.4	0.1	nr
	Lower Assabet Mainstem	4	Median	7:06	21.81	90.6	7.95	452	7.17	6.5	0.08	0.03	1.3	0.1	nr
	Sudbury Mainstem	5	Median	6:51	22.25	61.7	5.38	454	6.76	7.0	0.04	<0.01	0.16	0.1	nr
	Concord Mainstem	4	Median	7:09	22.10	86.6	7.53	430	6.95	8.5	0.06	0.01	0.42	<0.1	nr
	Headwater & Tribs	9	Median	7:17	20.08	87.3	7.90	357	7.05	2.5	0.06	0.01	0.25	<0.1	nr
	Hop Brook, Sudbury	1	Single reading	7:28	20.29	30.4	2.74	455	6.74	6.0	0.13	0.07	0.43	0.1	nr
17-Jul-11	Upper Assabet Mainstem	3	Median	7:12	20.68	63.5	5.68	942	7.11	3.5	0.20	0.12	2.35	1.88	nr
	Lower Assabet Mainstem	4	Median	6:51	24.50	77.2	6.43	603	7.33	6.5	0.08	0.03	1.30	0.1	nr
	Sudbury Mainstem	5	Median	6:52	24.83	71.3	5.91	524	7.08	7.0	0.04	<0.01	0.16	0.1	6.48
	Concord Mainstem	4	Median	7:05	26.03	87.3	7.02	554	7.21	8.5	0.06	0.01	0.42	<0.1	nr
	Headwater & Tribs	9	Median	7:31	22.31	81.4	6.88	415	7.03	2.5	0.06	0.01	0.25	0.1	nr
	Hop Brook, Sudbury	1	Single reading	7:33	21.48	18.2	1.53	475	6.86	6.0	0.13	0.07	0.43	0.1	<2.0

	Reach Statistics 2011 (calculated on 1/2 detection level where sample is BDL)														
	Reach	# Sites	statistic	Time	Temp (°C)	DO % Sat	DO Conc (mg/L)	Cond (µS/cm)	pH	TSS (mg/L)	TP (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Chl (µg/L)
14-Aug-11	Upper Assabet Mainstem	3	Median	7:32	22.13	70.0	6.09	510	6.80	2.8	0.07	0.05	3.90	0.1	nr
	Lower Assabet Mainstem	4	Median	7:00	23.17	85.7	7.33	379	7.07	4.5	0.07	0.06	0.74	0.1	nr
	Sudbury Mainstem	5	Median	6:32	23.31	49.1	4.15	425	6.50	9.5	0.04	0.04	0.03	0.1	3.94
	Concord Mainstem	4	Median	6:58	24.11	81.9	6.87	411	6.88	9.5	0.05	0.04	0.30	<0.1	nr
	Headwater & Tribs	9	Median	7:15	21.23	81.5	6.97	345	6.88	5.3	0.04	0.04	0.16	0.1	nr
	Hop Brook, Sudbury	1	Single reading	7:10	20.76	11.2	1.00	463	6.75	13	0.22	0.17	0.12	0.1	2.48
11-Sep-11	Upper Assabet Mainstem	1	Single reading	7:25	18.76	73.1	6.81	265	6.82	1.5	0.04	0.03	0.43	<0.1	nr
	Lower Assabet Mainstem	2	Median	7:39	18.17	87.6	8.27	234	6.58	4.0	0.06	0.05	0.33	<0.1	nr
	Sudbury Mainstem	5	Median	7:00	19.65	41.2	3.78	313	6.63	3.0	0.02	0.02	0.09	<0.1	nr
	Concord Mainstem	2	Median	7:10	18.29	69.7	6.56	270	6.63	5.5	0.06	0.05	0.28	<0.1	nr
	Headwater & Tribs	8	Median	7:36	16.77	79.7	7.79	221	6.50	2.0	0.04	0.02	0.15	<0.1	nr
	Hop Brook, Sudbury	1	Single reading	7:29	16.88	50.2	4.38	331	6.69	1.0	0.05	0.05	0.1	<0.1	nr
13-Nov-11	Upper Assabet Mainstem	1	Single reading	9:28	7.68	98.1	11.70	131	7.18	<1	0.01	<0.01	0.31	<0.1	nr
	Lower Assabet Mainstem	2	Median	8:19	7.51	101.2	12.12	235	6.88	2.3	0.09	0.02	0.78	<0.1	nr
	Sudbury Mainstem	2	Median	8:55	7.97	86.2	10.22	264	7.00	1.8	0.09	<0.01	0.28	<0.1	nr
	Concord Mainstem	2	Median	4:39	8.18	86.0	10.13	253	6.89	3.5	0.02	0.01	0.42	<0.1	nr
	Headwater & Tribs	7	Median	8:40	6.23	94.7	11.58	153	6.82	0.75	0.04	0.01	0.24	<0.1	nr
	Hop Brook, Sudbury	1	Single reading	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr

nr = not sampled / not recorded

Precipitation and Streamflow

Precipitation, and the associated increased stormwater runoff and streamflow changes, are correlated with concentrations of total suspended solids, total phosphorus, and nitrate/nitrites. For the purposes of this project, sampling dates were classified by visual inspection of the hydrograph of the nearest available real-time USGS gage as rising, falling, or flat hydrograph (Table 7). Note that flow at the Sudbury River gage in Framingham is sometimes affected by dam manipulations upstream. Samples collected on a rising hydrograph are likely to include stormwater runoff and the associated pollutants. Rainfall data was downloaded from the National Weather Service's Worcester Airport station (http://www7.ncdc.noaa.gov/CDO/cdo) (Table 7 and Figure 2).

Table 7: Hydrograph and precipitation on sampling days 2011

	Hydrograph at USGS gage			Precip (inches) before sampling day	
Sampling Date	Assabet River at Maynard	Sudbury at Framingham	Concord at Lowell	5 days	2 days
27-Mar-11	falling	falling	falling	0	0
22-May-11	falling	rising	falling	1.07	0.11
19-Jun-11	falling	falling	falling	0.38	0.28
17-Jul-11	flat	flat	flat	0.13	0
14-Aug-11	flat	rising	falling	2.43	0
11-Sept-11	falling	rising	peak	4.88	0
13-Nov-11	flat	flat	rising	0.82	0

Figure 2: NWS rainfall data (2011)

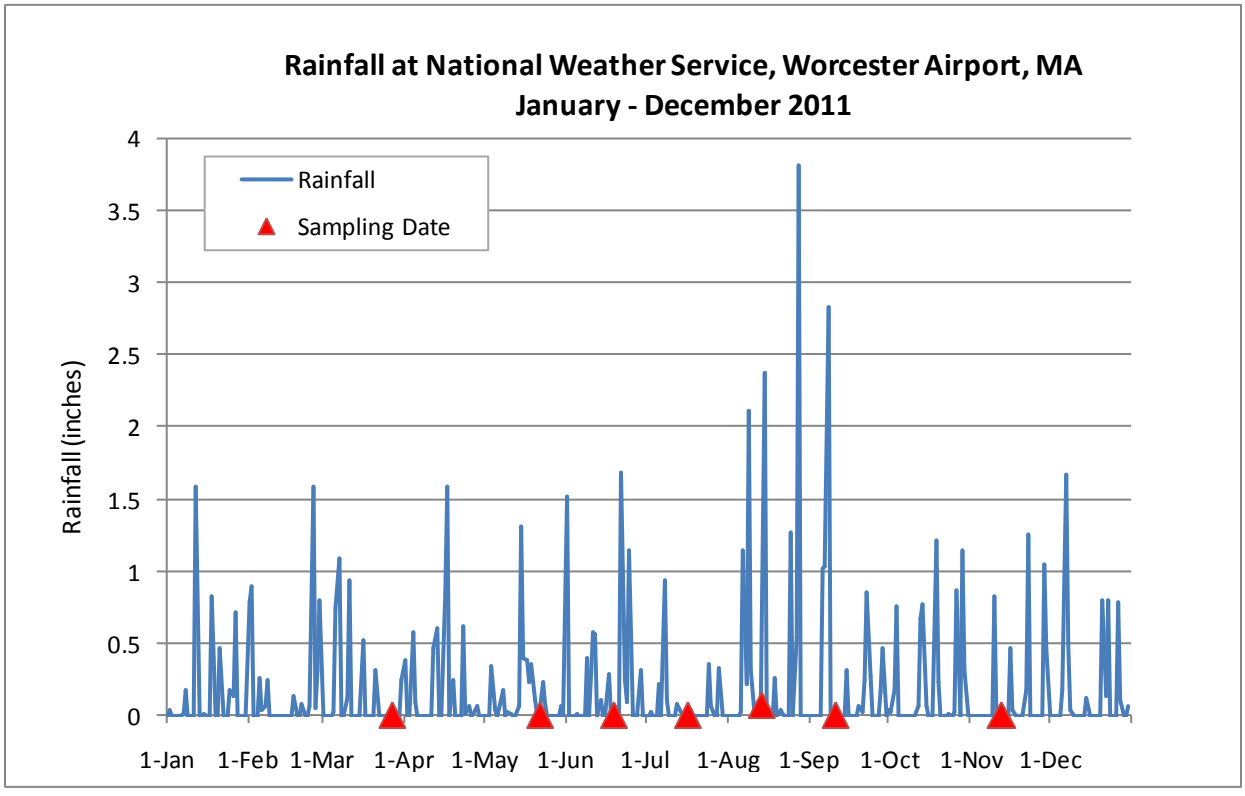


Figure 3 shows groundwater levels from the USGS monitoring well in Acton (USGS 422812071244401 MA-ACW 158 ACTON, MA). Changes in groundwater levels reflect precipitation and evapo-transpiration rates and, in turn, affect baseflow to the streams. In 2011 precipitation, groundwater levels and streamflows were low in January and February, near the mean over the summer and high starting in early September.

Figure 3: Groundwater levels (USGS Monitoring well Acton, MA) 2011

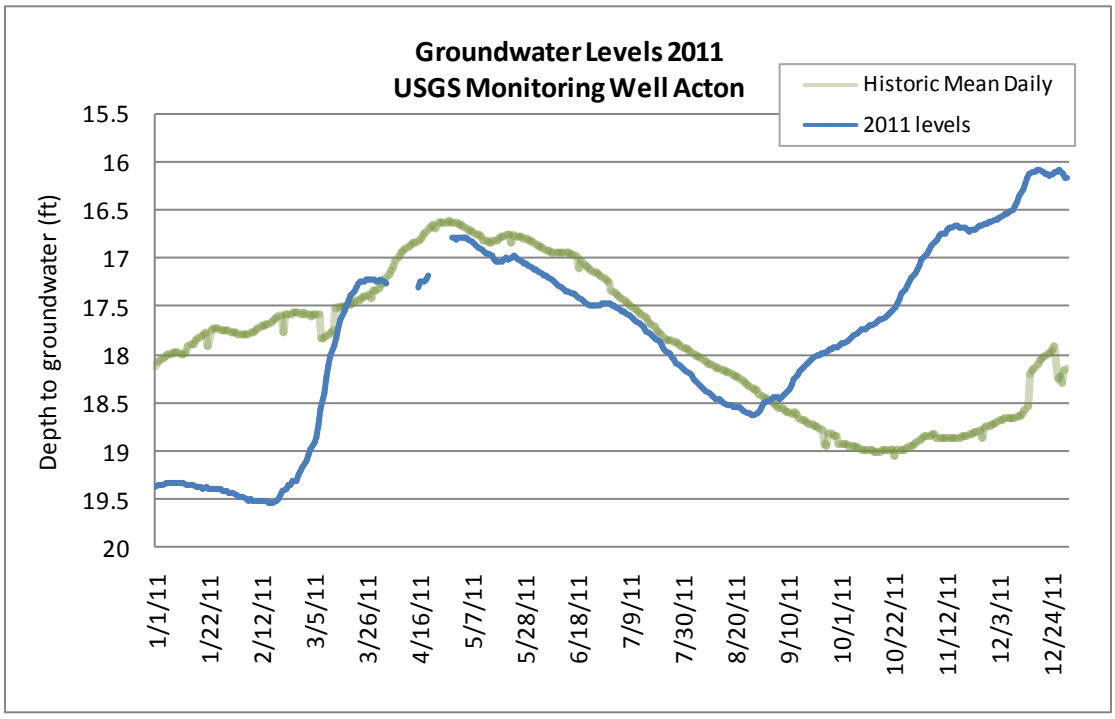


Table 8 shows composite monthly rainfall for the Central Region of Massachusetts as reported by the Department of Conservation and Recreation. In 2011, June, August and September had more rainfall than normal.

Table 8: Composite Rainfall Data for Sampling Months 2011

Rainfall Data from DCR Rainfall Program – Central Region *			
Sampling Month	Rainfall (inches)	Normal (inches)	Percent of normal for the month (%)
March 2011	4.73	4.04	117
May 2011	3.45	3.85	90
June 2011	6.35	3.95	162
July 2011	1.88	3.94	48
August 2011	11.70	3.86	303
Sept 2011	7.05	3.90	181
Nov 2011	4.46	4.17	107

* Accessed April 2012, 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. For example, Figures 4 and 5 show mean daily streamflows at the Assabet River gage in Maynard compared with the historic mean of the daily streamflows (calculated on the period of record for the gage) for the whole year and for the summer period (Fig 5). During the 2011summer sampling season streamflows were slightly lower than the historic mean flows; starting in late August streamflows were higher than mean flows. Summer hydrographs for the Concord River gage in Lowell, the Sudbury River gage in Saxonville/Framingham, and the Nashoba Brook gage in Acton (see Appendix I) are similar to the Assabet River's for 2011. Figure 6 shows a comparison of the mean monthly streamflows for 2009, 2010, and 2011.

Monthly streamflows were also recorded at six tributary monitoring sites established by OARS and near the Assabet River headwaters, above the first wastewater discharge (data in Appendix I).

Figure 4: Mean Daily Streamflows Assabet River: Jan - Dec 2011

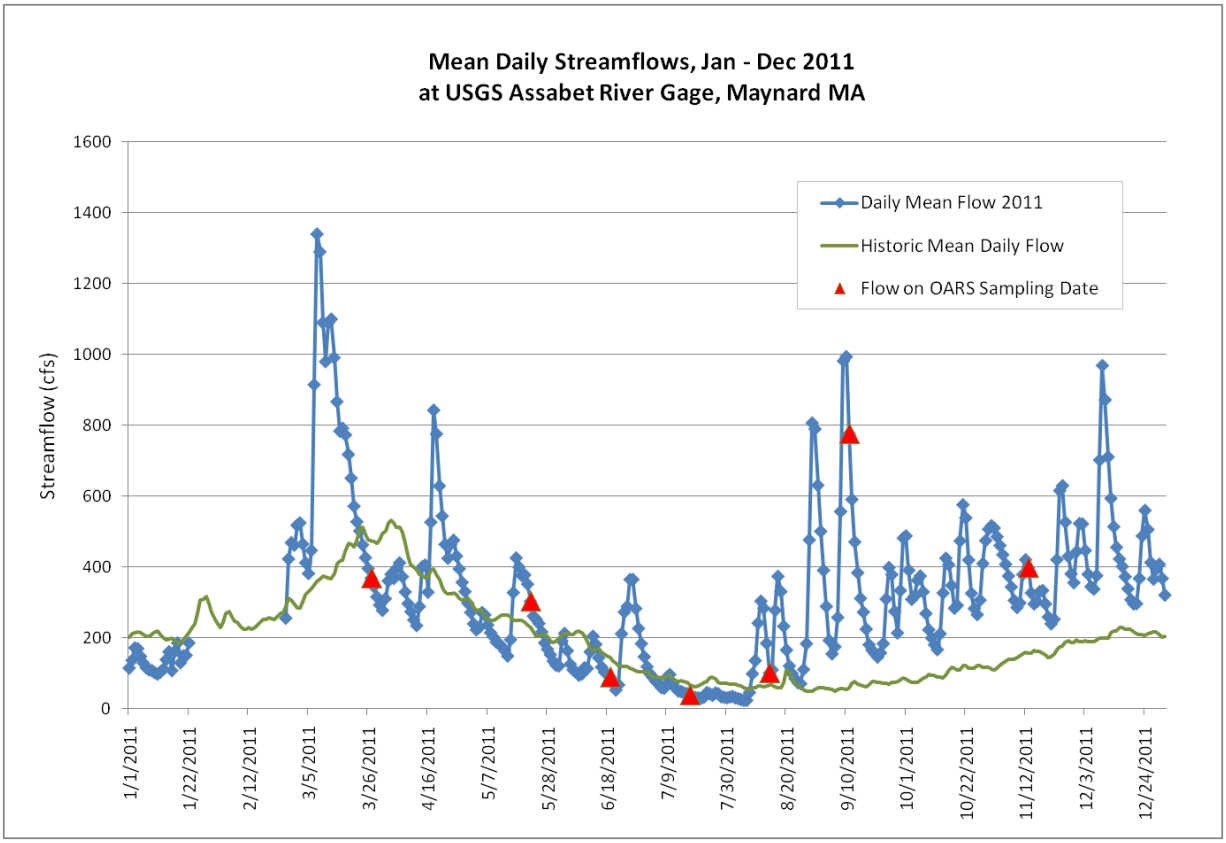


Figure 5: Mean Daily Streamflows Assabet River: May – Sept 2011

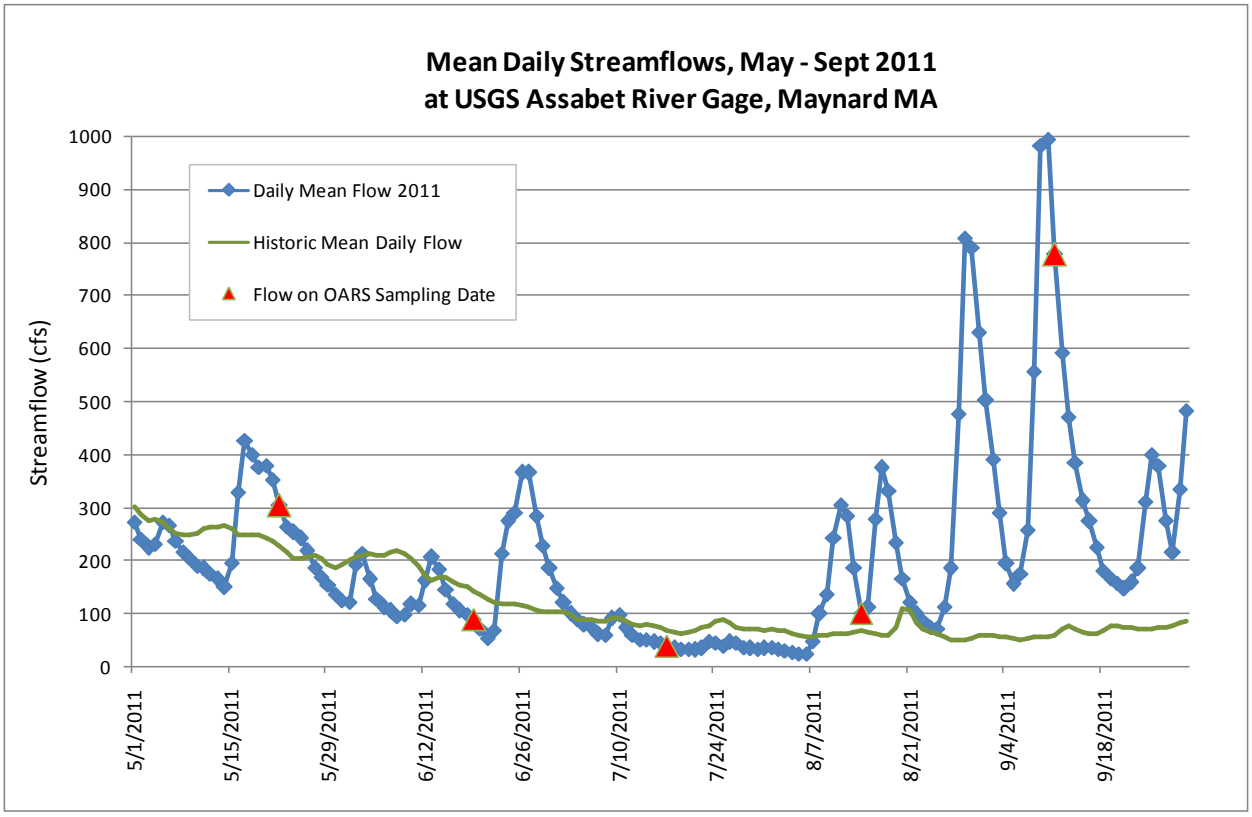
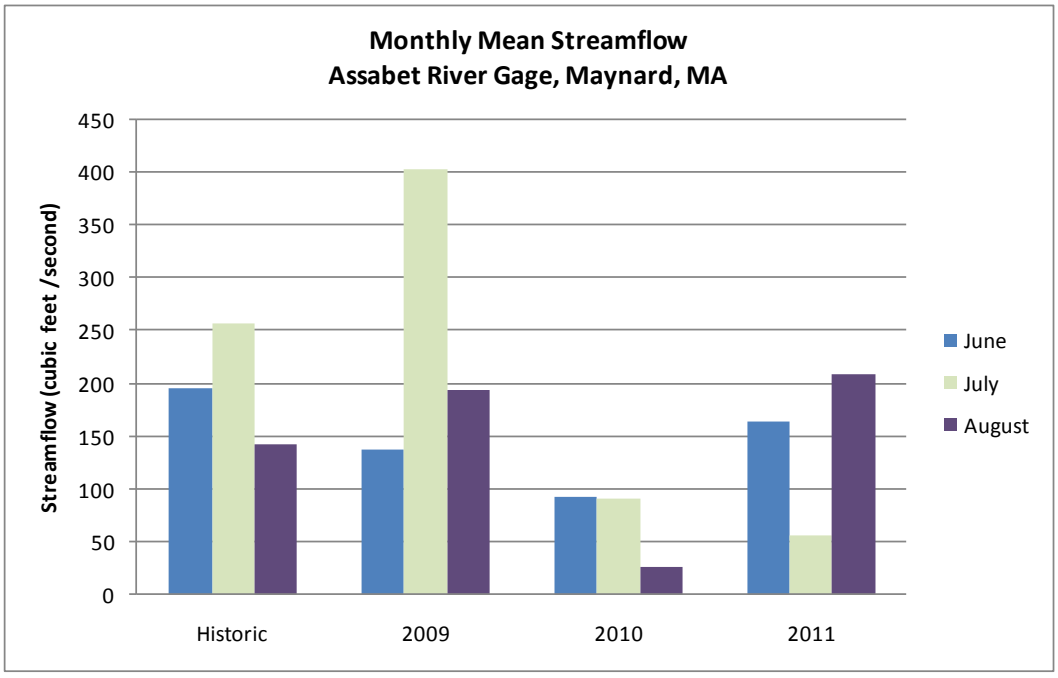


Figure 6: Monthly Mean Streamflows June, July, and August 2009 - 2011

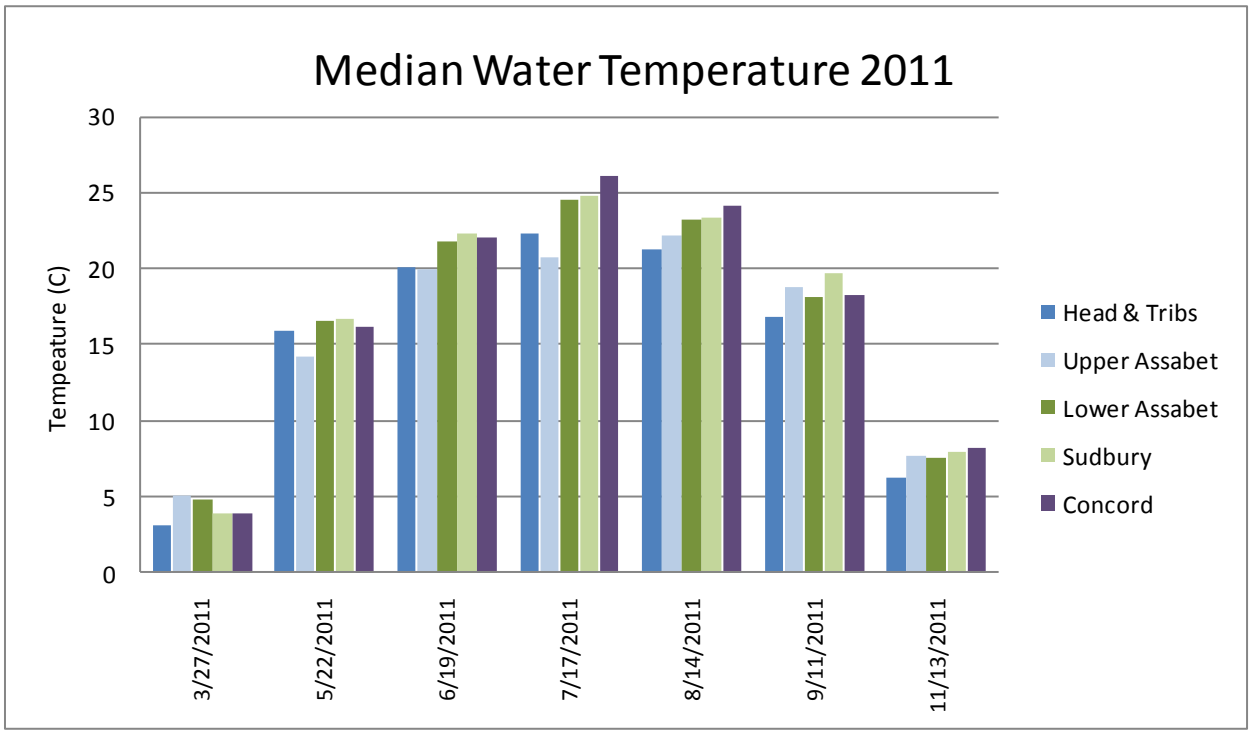


Water Temperature, pH, and Conductivity

In-situ readings (including dissolved oxygen, water temperature, pH, and conductivity) in the summer months (May to Sept) 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. Readings during the non-growing season (November and March) were taken between 7:00 am and 1:00 pm. Summary statistics for all in-situ readings are in Table 6 (above) and full data set is in Appendix A.

Figure 7 shows median water temperatures by river section for summer 2011. Water temperatures at both mainstem and tributary sites met Class B warm water fisheries standard (28.3°C) on all dates tested. Many of the tributary streams support or have supported cold water fisheries (13 of 25 tributary streams surveyed in 1954 contained Eastern Brook Trout; Schlotterbeck 1954); therefore, tributary and headwater temperature readings were also compared with the cold water standard (20.0°C). Of the 9 tributary/headwater sites tested, the majority had water temperatures exceeding 20.0°C on the summer testing dates : 6 sites in June, 7 sites in July, and 8 sites in August. The recommended single-reading maxima for brook trout is 20.0°C and for brown trout is 23.9°C. One tributary site in July and the Assabet headwater site in August exceeded 23.9°C.

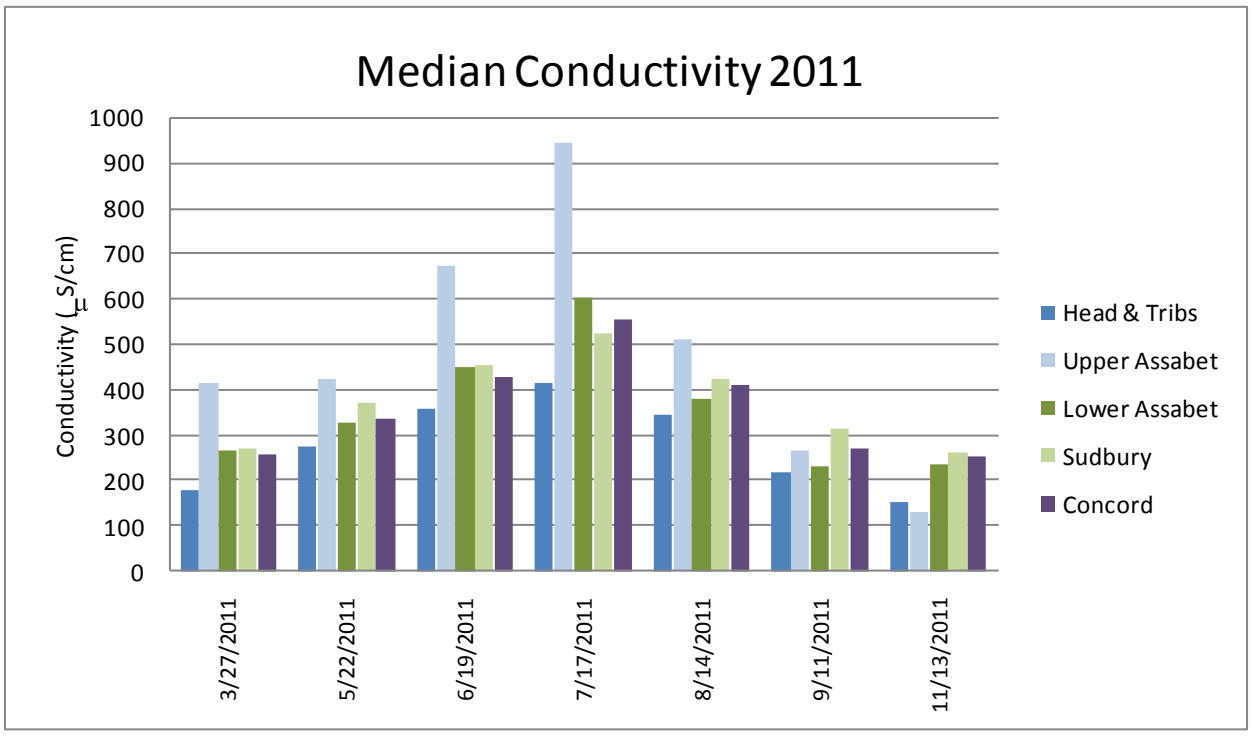
Figure 7: Water temperature readings (Summer 2011)



The pH readings in the mainstem ranged from 6.36 to 7.57 SU. Sites not meeting the Class B 6.5- 8.3 SU standard range:SUD-005 and SUD-064 were below 6.5 SU in August; CND-161, SUD-064, ELZ-004, NSH-047, NSH-002, and NTH-009 were below 6.5 SU in September.

Conductivity is an indirect indicator of pollutants such as effluent, non-point source runoff (especially road salts) and erosion. EPA (http://water.epa.gov/type/rsl/monitoring/vms59.cfm) studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µS/cm. The range of mainstem conductivity readings was from 98 µS/cm to 1063 µS/cm in 2011. The lowest reading (98 µS/cm) was recorded at North Brook in November. The highest readings were recorded at ABT-301 in July (1063 µS/cm) and at River Meadow Brook in Lowell in July (914 µS/cm) and August (915 µS/cm). (Figure 8).

Figure 8: Median conductivity readings (2011)



Dissolved Oxygen

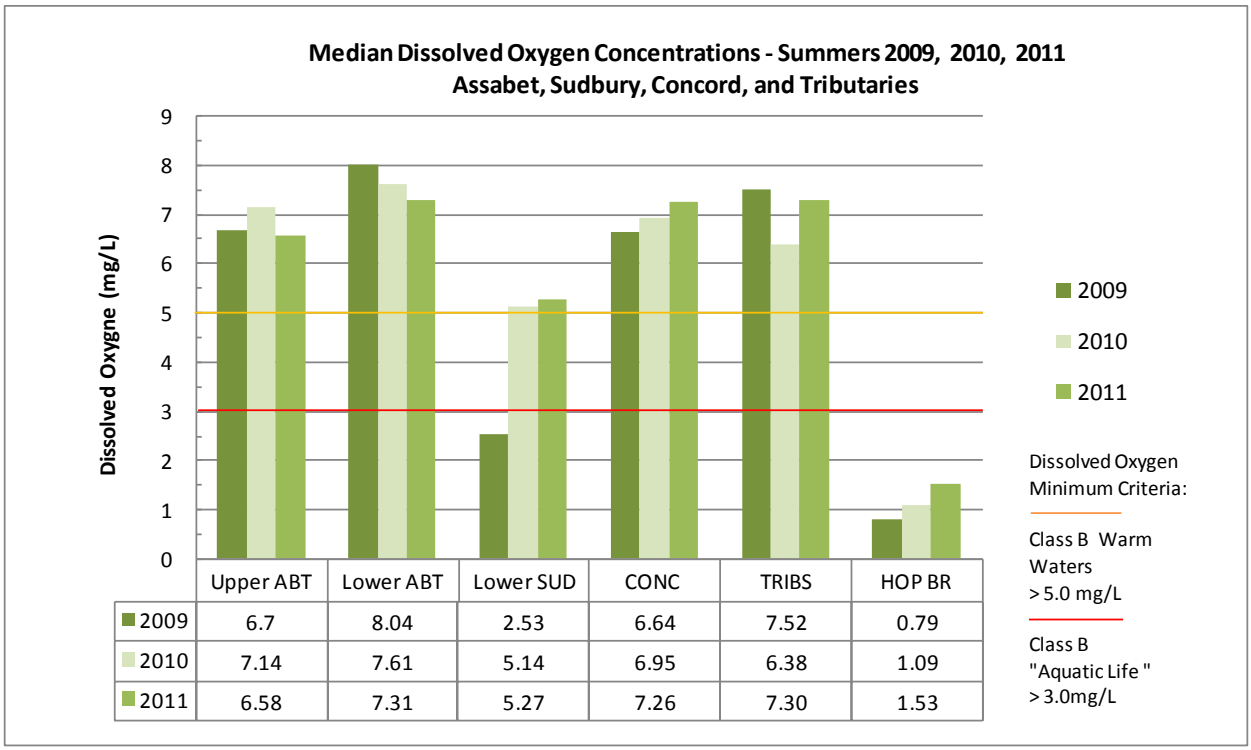
Dissolved oxygen (DO) concentrations during the growing season are generally lowest between 5am and 8am after plant and microbial respiration has removed oxygen from the water column overnight. Low minimum DO concentrations and large diurnal variations in DO can indicate eutrophic conditions. Summary statistics for DO readings are in Table 6 and full data are in Appendix I. Water quality standards (WQS) violations (<5.0 mg/L for Class B; < 3.0 mg/L for Class B Aquatic Life for mainstem Sudbury sites) are listed in Table 9. Note that low DO measurements may not constitute a violation of WQS if caused by natural conditions.

Table 9: Dissolved Oxygen Violations

Date	Site	Dissolved Oxygen (mg/L)
5/22/2011	HBS-016	3.59
6/19/2011	HBS-016	2.74
7/17/2011	ABT-237	4.77
	ELZ-004	3.72
	HBS-016	1.53
8/14/2011	CND-161	4.67
	ELZ-004	4.33
	HBS-016	1.00
9/11/2011	CND-161	4.56
	SUD-005	2.18
	SUD-064	1.93
	HBS-016	4.38

For comparison between years, Figure 9 shows median summer (June, July, and August) dissolved oxygen measurements for mainstem and tributary sections in 2009, 2010, and 2011. Hop Brook at Landham Road, Sudbury, has consistently low dissolved oxygen concentrations. The orange line indicates the Class B water quality standard (5.0mg/l) and the red line indicates the Class B Aquatic Life water quality standard (3.0mg/L).

Figure 9: Dissolved Oxygen Measurements (median summer) 2009 - 2011



	Upper ABT	Lower ABT	Lower SUD	CONC	TRIBS	HOP BR
2009	6.7	8.04	2.53	6.64	7.52	0.79
2010	7.14	7.61	5.14	6.95	6.38	1.09
2011	6.58	7.31	5.27	7.26	7.30	1.53

Nutrients and Suspended Solids

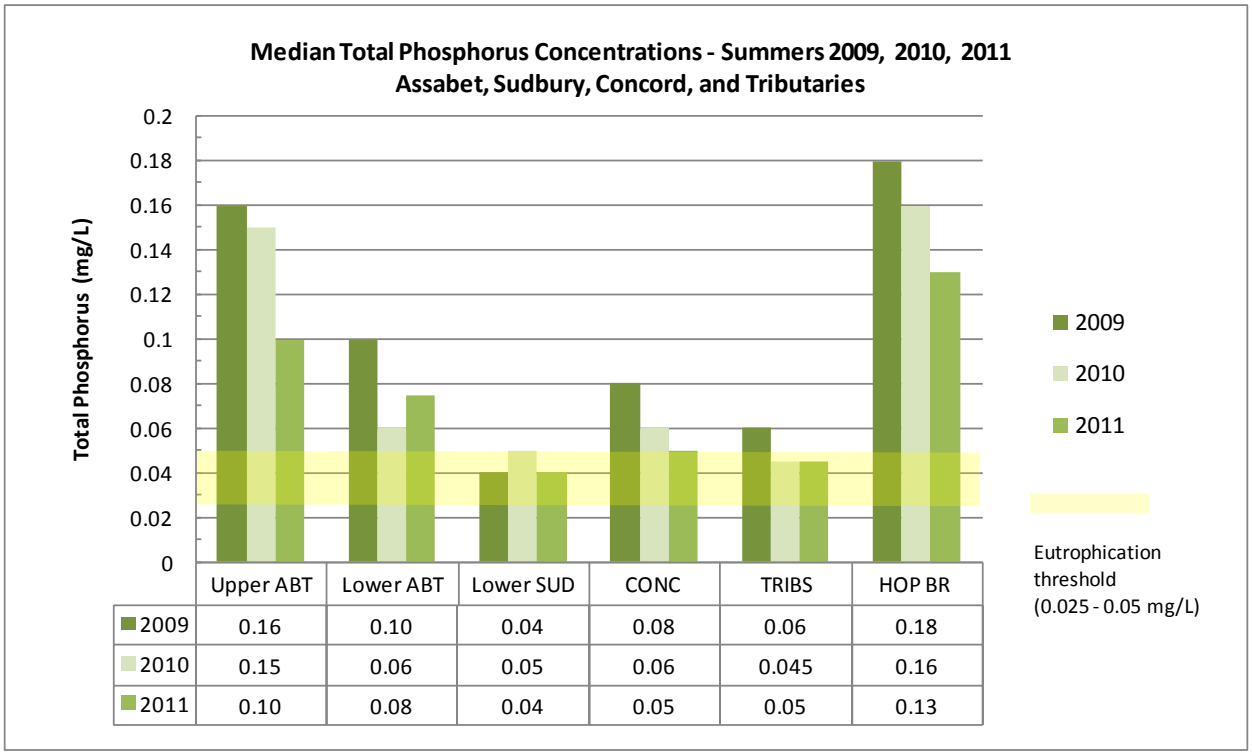
Summary statistics for nutrient concentrations are in Table 6, above. Median summer nutrient concentrations are shown (Figures 10 & 11) for the upper and lower Assabet mainstem reaches (see Table 1 for reach definitions), Sudbury mainstem sites, Concord mainstem sites, combined Assabet headwaters and tributary sites, and Hop Brook in Sudbury.

Median nutrient concentrations along the Assabet River mainstem below the first wastewater discharge (Westborough WWTP) were well above Ecoregion reference conditions (25th percentile of the summertime data) for total phosphorus and nitrates in all three summers. TP concentrations along the Assabet also exceeded the EPA "Gold Book" TP recommendation (0.05mg/L TP).

Median nutrient concentrations in the Concord River mainstem were generally lower than Assabet River concentrations, but still exceeded Ecoregion reference conditions for TP all three summers and for nitrates in 2010 and 2011.

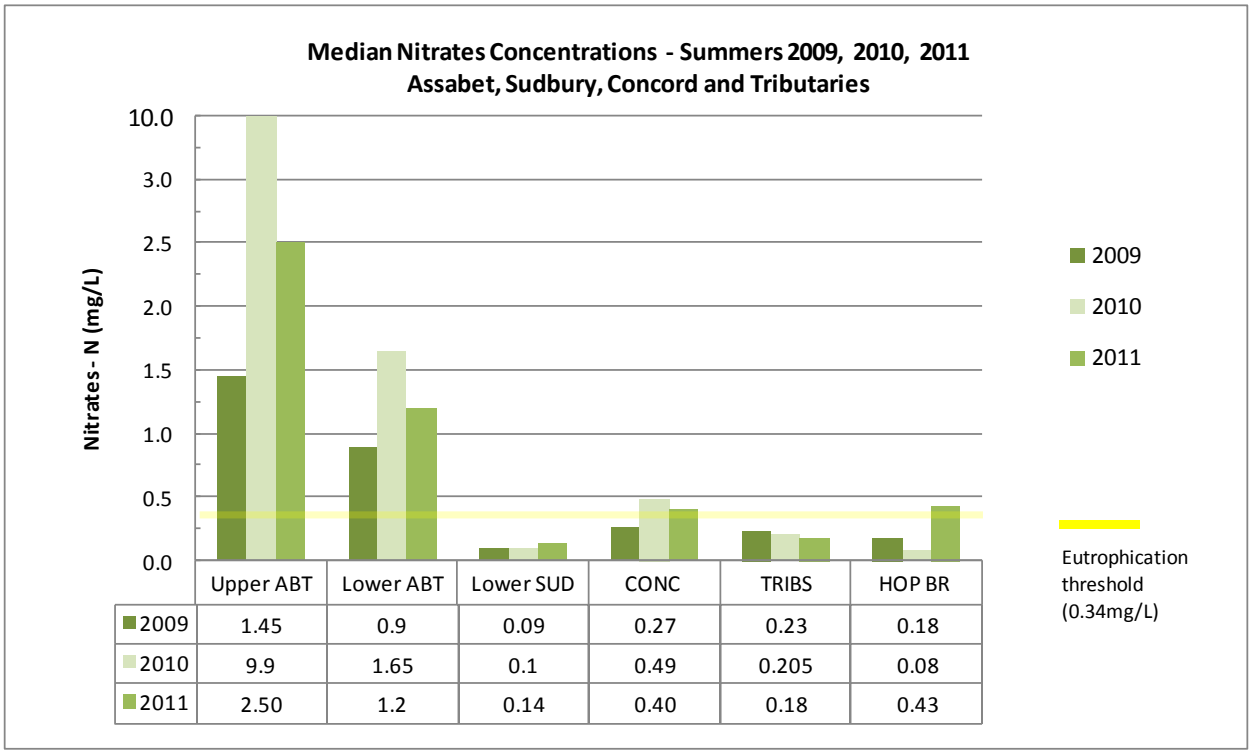
Median TP concentrations in the Sudbury River and in the tributaries of all three rivers (excluding Hop Brook, Sudbury) were slightly elevated but lower than in either the Assabet or Concord Rivers: above 0.025mg/L but below 0.05mg/L. Hop Brook, Sudbury, which is affected by the wastewater discharge from Marlborough Easterly WWTP, and has total phosphorus concentrations 6-7 times the recommended concentrations.

Figure 10: Median Total Phosphorus Concentrations (Summers 2009- 2011)



	Upper ABT	Lower ABT	Lower SUD	CONC	TRIBS	HOP BR
2009	0.16	0.10	0.04	0.08	0.06	0.18
2010	0.15	0.06	0.05	0.06	0.045	0.16
2011	0.10	0.08	0.04	0.05	0.05	0.13

Figure 10: Median Nitrate Concentrations (Summers 2009- 2011)



	Upper ABT	Lower ABT	Lower SUD	CONC	TRIBS	HOP BR
2009	1.45	0.9	0.09	0.27	0.23	0.18
2010	9.9	1.65	0.1	0.49	0.205	0.08
2011	2.50	1.2	0.14	0.40	0.18	0.43

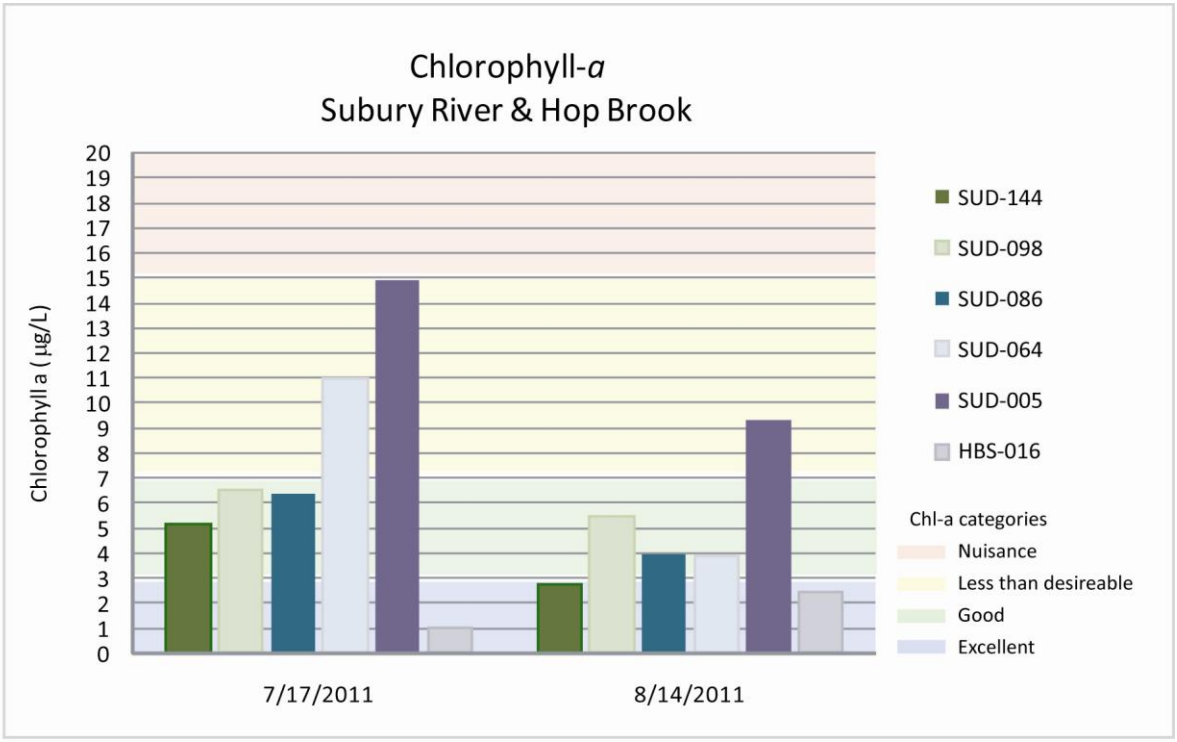
Chlorophyll a

Chlorophyll *a* is the principle photosynthetic pigment in algae and vascular plants; chlorophyll *a* concentrations gives an estimate of the biomass of planktonic algae in the river and is one indicator of eutrophication. Rivers, like the Assabet, whose vegetation is dominated by larger rooted and floating aquatic plants may have low chlorophyll a concentrations although they are eutrophied. Chlorophyll *a* was measured in the Sudbury River and Hop Brook in Sudbury in July and August in 2011. There is no numeric standard for chlorophyll in Massachusetts waters. The New Hampshire Department of Environmental Services categorizes chlorophyll *a* concentrations in rivers as follows (http://www2.des.state.nh.us/OneStop/docs/river_parm_desc.pdf) :

Chlorophyll *a* Categories	
< 3 µg/L	Excellent
3 – 7 µg/L	Good
7 – 15 µg/L	Less than desirable
> 15 µg/L	Nuisance

Chlorophyll *a* was measured on the Sudbury River and Hop Brook/Sudbury, in July and August of 2011. (The Concord and Assabet Rivers are not sampled for chlorophyll *a* because of budget constraints.) Concentrations ranged from <2 to 14.9 µg/L with most readings in the "good" to "excellent" range. The highest readings were at the downstream-most Sudbury River mainstem sites (SUD-005 at 14.9 µg/L in July and 9.31 µg/L in August; SUD-064 at 11.0 µg/L in July) and fall into the "less than desirable" range.

Figure 11: Chlorophyll-*a* at Sudbury River sites



Water Quality and Stream Health Index Calculations

The Stream Health Index was used to assess conditions at seven of the tributary stream sites for each of the monthly sampling results (Table 10). The Water Quality Index (a sub-index of the overall Stream Health Index) was also used to assess water quality at selected mainstem sites (Table 11) and Hop Brook, Sudbury, which don't have streamflow data available.

OARS' 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 OARS 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, nitrates, and total suspended solids are scored from 1 (worst) to 100 (best). In 2009, the index calculation was updated to use nitrates (instead of total nitrogen, since TKN is no longer being analyzed) and to include Class B "Aquatic Life" standards for dissolved oxygen and temperature in the Water Quality Index for the Sudbury River mainstem sites. 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 all tributary

stream sites, which support or have supported cold-water fish populations, temperature and dissolved oxygen readings were compared with Class B cold water standards. For mainstem Assabet and Concord sites, temperature and DO readings were compared with Class B warm water standards and Sudbury sites were compared with Class B "Aquatic Life" 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 posting, 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).

Stream Health Index: The tributary Stream Health Index readings were generally "excellent" to "good" in 2011. The lowest scoring parameters were streamflow and habitat availability in Danforth Brook and Nashoba Brook at Commonwealth Ave. in July and August. Streamflows in September were above the highest measured flow on the rating curves for the established flow gages (i.e. cannot be correlated with a flow volume).

Water Quality Index: Table 11 shows Water Quality Index readings for selected sites on the mainstem Assabet, Sudbury and Concord Rivers and on Hop Brook in Sudbury. Total phosphorus and nitrates were the lowest scoring parameters, driving the overall WQI score, at the Assabet River sites. At the Concord River sites, total phosphorus, nitrates, and total suspended solids were the lowest scoring parameters (although higher scoring than at the Assabet sites). Dissolved oxygen was the lowest scoring parameter at the Sudbury River sites below Saxonville in June, July and August. Dissolved oxygen and total phosphorus were the lowest scoring parameters at the Hop Brook site in Sudbury.

Table 10: Stream Health Index Readings – Summer 2011

	Stream Health Index Readings – 2011				
	22-May-11	19-June-11	17-Jul-11	14-Aug-11	11-Sept-11
Assabet River Headwater, Maynard St., Westborough					
Water Quality Index	91	60	59	48	80
Flow Index	95	89	40	80	83
Habitat Index	90	95	60	70	100
Stream Health Index	92	78	51	63	87
Danforth Brook, Rte 85, Hudson					
Water Quality Index	89	76	73	65	81
Flow Index	95	58	22	26	83
Habitat Index	100	70	85	40	100
Stream Health Index	94	67	43	38	87
Elizabeth Br., near White Pond Road, Stow					
Water Quality Index	83	67	48	56	79
Flow Index	95	89	75	66	83
Habitat Index	100	80	80	50	100
Stream Health Index	92	77	65	57	87
Hop Brook, Otis Street, Northborough					
Water Quality Index	78	65	56	64	61
Flow Index	95	92	67	81	83
Habitat Index	95	100	70	65	100
Stream Health Index	88	83	64	69	78
Nashoba Br., Commonwealth Ave, W. Concord					
Water Quality Index	81	64	48	55	73
Flow Index	95	92	79	80	82
Habitat Index	100	80	55	75	100
Stream Health Index	91	77	58	68	84
Nashoba Brook, Wheeler Ave, Acton					
Water Quality Index	77	57	57	57	69
Flow Index	95	85	32	19	83
Habitat Index	95	100	90	100	100
Stream Health Index	88	76	50	38	82
North Brook, Whitney Ave, Berlin					
Water Quality Index	92	73	52	64	81
Flow Index	95	72	69	54	83
Habitat Index	100	80	65	60	100
Stream Health Index	96	75	61	59	88

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

Table 11: Water Quality Index Readings – Selected Mainstem Sites Summers 2011

Assabet at Rte 9 Westboro (ABT-301)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	3.7	0.19	1	9.26	7.04	14.25	34
19-June-2011	1.2	0.3	3	7.16	7.29	19.96	48
17-July-2011	9.5	0.35	2	6.59	7.14	20.80	5
14-Aug-2011	5.3	0.03	3	6.58	6.74	22.93	24
11-Sept-2011	0.78	0.07	1	6.81	6.82	18.76	66

Assabet at Rte 27 Maynard (ABT-077)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	0.78	0.04	4	9.79	7.08	16.59	70
19-June-2011	1.3	0.07	5	7.97	7.19	21.66	58
17-July-2011	0.88	0.03	2.5	6.61	7.50	24.99	65
14-Aug-2011	0.70	0.07	4.5	7.46	7.06	23.25	64
11-Sept-2011	0.35	0.06	4	8.11	6.50	18.10	72

Concord at Rte 225 Bedford (CND-110)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	--	--	--	---	--	--	--
19-June-2011	0.43	0.06	9	6.37	6.85	22.05	65
17-July-2011	0.43	0.04	9	7.25	7.18	26.18	66
14-Aug-2011	0.26	0.06	10	5.89	6.66	23.85	65
11-Sept-2011	--	--	--	--	--	--	--

Concord at Rogers Street Lowell (CND-009)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	0.46	0.03	6	9.64	7.04	15.65	76
19-June-2011	0.73	0.09	12	7.78	7.08	21.93	59
17-July-2011	0.78	0.04	11	7.39	7.28	25.87	61
14-Aug-2011	0.57	0.04	10	8.00	7.32	24.51	66
11-Sept-2011	0.28	0.06	9	8.55	6.77	17.81	71

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

Sudbury at Saxonville Framingham (SUD-144)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	0.26	0.02	<1	10.13	7.15	14.59	90
19-June-2011	0.24	0.03	1	8.20	7.21	21.77	86
17-July-2011	0.18	0.04	1.5	7.19	7.18	23.76	82
14-Aug-2011	0.08	0.03	3.5	7.91	7.36	24.42	84
11-Sept-2011	0.55	0.01	4	7.67	6.95	19.93	78

Sudbury at Sherman Bridge Rd, Wayland (SUD-064)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	0.05	0.01	1	6.21	6.69	17.40	92
19-June-2011	0.14	0.05	7	3.92	6.54	22.41	66
17-July-2011	0.12	0.05	6	5.27	7.02	25.77	72
14-Aug-2011	<0.05	0.05	9.5	3.21	6.38	22.99	60
11-Sept-2011	0.07	0.04	3	1.93	6.47	19.65	48

Sudbury at Rte 62, Concord (SUD-005)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	0.06	0.01	2	7.86	6.77	16.97	92
19-June-2011	<0.05	0.04	7	6.40	6.89	22.25	77
17-July-2011	<0.05	0.05	12	4.91	6.97	25.77	67
14-Aug-2011	<0.05	0.04	11	4.15	6.38	23.83	65
11-Sept-2011	<0.05	0.05	3	2.18	6.70	18.43	53

Hop Brook at Landham Road, Sudbury (HBS-016)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
22-May-2011	0.68	0.03	<1	3.59	6.69	15.33	51
19-June-2011	0.43	0.13	6	2.74	6.74	20.29	26
17-July-2011	0.36	0.10	1	1.53	6.86	21.48	6
14-Aug-2011	0.12	0.22	13	1.00	6.75	20.76	5
11-Sept-2011	0.10	0.05	1	4.38	6.69	16.88	64

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

Summary

This report presents the monthly water quality and streamflow data OARS collected on the Assabet, Sudbury, and Concord Rivers and tributary streams in 2011 (March, May, June, July, August, September, and November). All sites are sampled in June, July, and August; a subset of the sites are sampled in other months.

In 2011, June, August and September had more rainfall than normal. Streamflows, as measured at the USGS gages on the Assabet River in Maynard, the Sudbury River in Framingham, and the Concord River in Lowell, were near the historic mean in the early part of the year, except for higher flows in March. From late August through December, streamflows were higher than the mean.

Water temperatures at both mainstem and tributary sites met Class B warm water fisheries standard (28.3°C) on all dates tested. 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). Of the eight tributary sites tested, most had water temperatures exceeding 20.0°C during the summer months: 6 sites in June, 7 sites in July, and 8 sites in August.

pH readings in the mainstem ranged from 6.36 to 7.57 SU. Sites not meeting standards:SUD-005 and SUD-064 were below 6.5 in August; CND-161, SUD-064, ELZ-004, NSH-047, NSH-002, and NTH-009 were below 6.5 in September.

The range of mainstem conductivity readings was from 98 µS/cm to 1063 µS/cm in 2011. The lowest reading (98 µS/cm) was recorded at North Brook in November. The highest readings were recorded at ABT-301 in July (1063 µS/cm) and at River Meadow Brook in Lowell in July (914 µS/cm) and August (915 µS/cm).

Mainstem dissolved oxygen readings failed to meet Water Quality Standards at: 1 site in July, 1 site in August, and 3 sites in September. The lowest mainstem reading was taken on the Sudbury River at Sherman Bridge Road, Wayland, in September (1.93 mg/L). The lowest tributary readings were consistently at Hop Brook at Landham Road, Sudbury, with readings below 5.00 mg/L all months tested and the lowest reading of 1.00 mg/L in August.

Median nutrient concentrations were compared over the last three summers. Median summer nutrient concentrations along the Assabet River mainstem (both upper and lower sections) were well above Ecoregion reference conditions (25^{th} percentile of the summertime data) for both total phosphorus (TP) and nitrates all three summers. TP concentrations along the Assabet also exceeded the EPA "Gold Book" TP recommendation (0.05mg/L TP).

Median nutrient concentrations in the Concord River mainstem were generally lower than Assabet River concentrations, but still exceeded Ecoregion reference conditions for TP all three summers and for nitrates in 2010 and 2011.

Median TP concentrations in the Sudbury River and in the tributaries of all three rivers (excluding Hop Brook, Sudbury) were slightly elevated but lower than in either the Assabet or

Concord Rivers: above 0.025mg/L but below 0.05mg/L. Hop Brook, Sudbury, which is the receiving water for the Marlborough Easterly WWTP wastewater discharge, and has total phosphorus concentrations 6-7 times the recommended concentrations.

Chlorophyll *a* concentrations in the Sudbury River, the only river tested for chlorophyll a, ranged from <2 to 14.9 μg/L with most readings in the "good" to "excellent" range. The highest readings were at the downstream-most Sudbury River mainstem sites in July and August, falling into the "less than desirable" range.

The Stream Health Index was used to assess conditions at seven tributary/headwater stream sites for each of the summer sampling results. (Because the index is designed to assess summer conditions, it is not used for the winter months.) In May, June, and September all seven tributary sites had "good" to "excellent" ratings. In July, four sites were scored "fair" including: Assabet headwaters, Danforth Brook, Nashoba Brook at Commonwealth Ave., and Nashoba Brook at Wheeler Lane. In August (typically the month with the lowest streamflows): Danforth Brook and Nashoba Brook at Wheeler Lane were rated "poor" with the Flow sub-index scoring the lowest; Assabet headwaters, Elizabeth Brook, and North Brook were rated "fair."

The Water Quality Index (a sub-index of the overall Stream Health Index) was also used to assess water quality in at selected mainstem sites. The Assabet River at Rte 9 (the site immediately below the Westborough WWTP discharge) and Hop Brook in Sudbury (which receives the discharge from the Marlborough Easterly WWTP) scored "fair" to "very poor" in May, June, July and August. The lowest scoring water quality parameters for the Assabet at Rte 9 were nitrates followed by total phosphorus. The lowest scoring parameters for Hop Brook in Sudbury were dissolved oxygen followed by total phosphorus and nitrates. The Sudbury River at Saxonville scored "good" to "excellent" on all months. Further downstream, the Sudbury River at Sherman Bridge Road in Wayland and Rte 62 in Concord scored "fair" to "good" all months; the lowest scoring parameter was dissolved oxygen in August and September. The two Concord River sites assessed were rated "fair" to "good" all months tested; the lowest scoring parameter was nitrates at Rogers Street, Lowell, in July.

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Glossary of Terms

Adaptive Management: the process by which new information about a watershed is incorporated into the watershed management plan. Ideally, adaptive management is a combination of research, monitoring, and practical management that allows "learn by doing." It is a useful tool because of the uncertainty about how ecosystems function and how management affects ecosystems. More: http://www.epa.gov/owow/watershed/wacademy/wam/step5.html

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.

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

Class B: Massachusetts Class B, sometimes referred to as "fishable, swimmable," is one of the state's designations of "appropriate water uses to be achieved and protected" under the federal Clean Water Act. For more information about the federal requirements on water quality standards: http://water.epa.gov/scitech/swguidance/standards/index.cfm. For the Massachusetts Surface Water Quality Standards: http://www.mass.gov/dep/service/regulations/314cmr04.pdf.

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. According to EPA, the ecoregions are "designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components." More information on the New England Ecoregions: http://www.epa.gov/wed/pages/ecoregions/new_eng_eco.htm

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

Hydrograph: A graph showing stage, flow, velocity, or other property of water with respect to time. More hydrographic definitions: http://water.usgs.gov/wsc/glossary.html#TOC

Gold Book: EPA's 1986 publication of recommended water quality standards. http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/upload/2009_01_13_criteria_goldbook.pdf

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)**, **nitrite (NO_2)ammonia (NH_3)**, and **total Kjeldahl nitrogen (TKN**). **Total nitrogen** is calculated as the sum of TKN and nitrates. **Available nitrogen**, calculated as the sum of nitrate and ammonia, gives a measure of the nitrogen readily available for absorption by plants. Once absorbed, nitrogen is incorporated into proteins, amino acids, nucleic acids, and other molecules. Although most aquatic plant growth in rivers is limited by the availability of phosphorus, increased nitrogen availability can also lead to algal blooms.

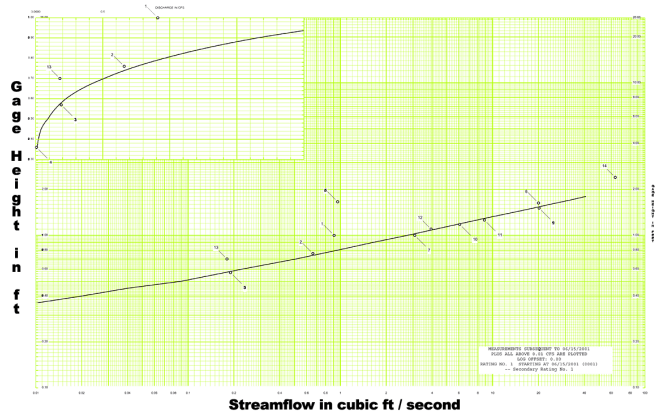
Oligotrophic: having a small supply of nutrients, low production of organic matter, low rates of decomposition, and high dissolved oxygen in the lower layers of the water column.

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

TMDL: Total Maximum Daily Loading, defined under the federal Clean Water Act, is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. More: http://www.epa.gov/owow/tmdl/overviewoftmdl.html

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: Water Quality Designations for the SuAsCo Rivers and Streams

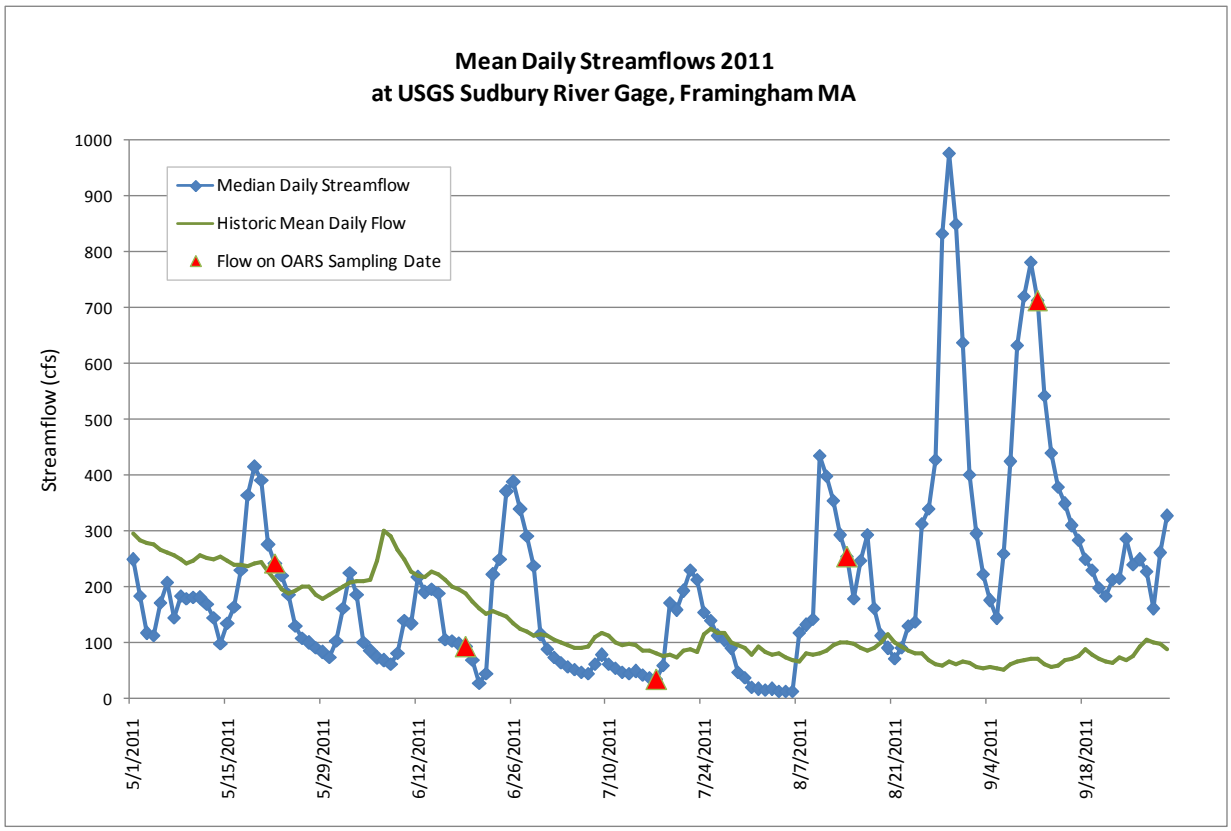
Excerpted from 314 CMR 4.00 : DIVISION OF WATER POLLUTION CONTROL
(http://www.mass.gov/dep/water/laws/tblfig.pdf)

SuAsCo River Basin (Table 18)

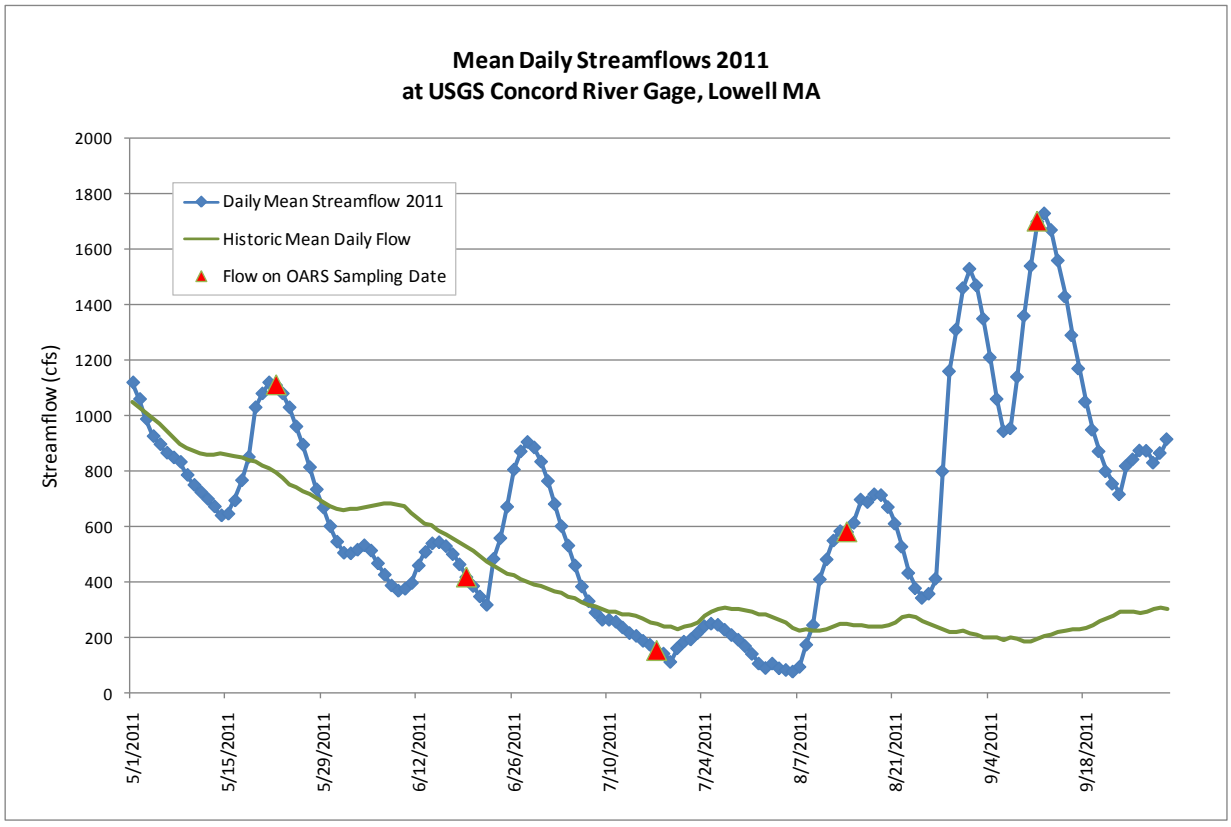
Sudbury River			
Boundary	Mile Point	Class	Qualifiers
Source to Fruit Street Bridge, Hopkinton	29.1	B	Warm Water Outstanding Resource Water
Fruit Street Bridge to Outlet to Saxonville Pond	29.1 - 16.2	B	Warm Water High Quality Water
Outlet Saxonville Pond to Hop Brook confluence	16.2 - 10.6	B	Aquatic Life High Quality Water
Hop Brook confluence to Assabet River confluence	10.6 - 0.00	B	Aquatic Life
Denney Brook, Jackstraw Brook, Picadilly Brook, Rutters Brook and Whitehall Brook		B	Outstanding Resource
Hop Brook source to Sudbury River confluence	9.7 – 0.0	B	Warm water
Concord River			
Confluence of the Assabet and Sudbury to Billerica water supply intake	15.4 – 5.9	B	Warm Water Treated Water Supply
Billerica water supply intake to Rogers St.	5.9 – 1.0	B	Warm Water
Rogers Street to confluence Merrimack River	1.0 – 0.0	B	Warm Water CSO
Assabet River			
Source to Westborough WWTF	31.8 - 30.4	B	Warm Water High Quality Water
Westborough WWTF to outlet of Boones Pond	30.4 – 12.4	B	Warm Water
Outlet Boones Pond to confluence with Sudbury River	12.4 – 0.0	B	Warm Water
Tributaries			
Unnamed tributary to Assabet River	entire length		Cold Water
Jackstraw Brook Source to Upton Rd 1st crossing south of Hopkinton Rd.			Cold Water

Appendix II: Streamflow Data from USGS Gages

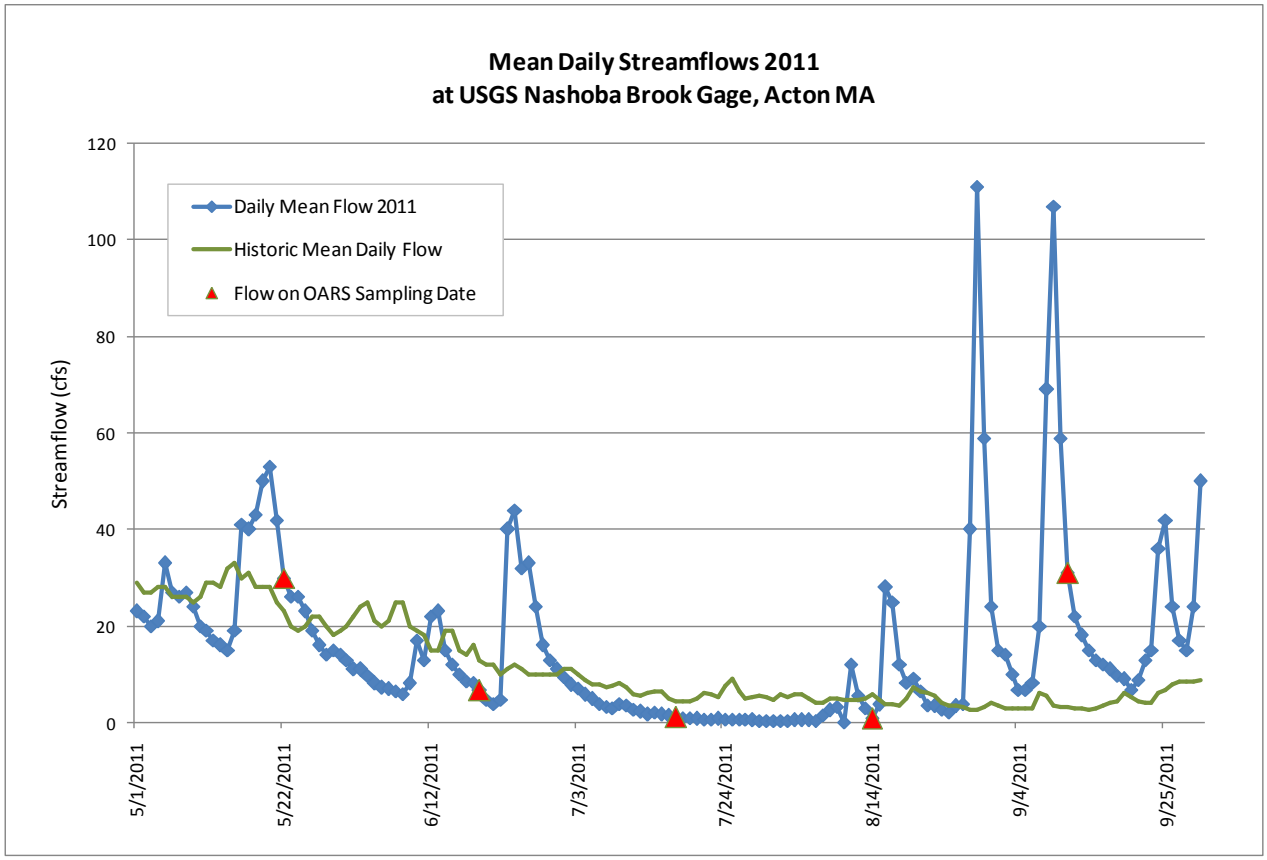
Mean Daily Streamflows: Sudbury River USGS gage, Saxonville, MA



Mean Daily Streamflows: Concord River USGS gage, Lowell, MA



Mean Daily Streamflows: Nashoba Brook USGS gage, Acton, MA



Appendix III: Data Quality Notes

OARS' data quality objectives (Table 12) and data qualifiers are listed below (Table 13). Full QC details are available in OARS' Quality Assurance/Quality Control documents on request.

Qualified data for 2011 includes:

- March 2011: Conductivity readings flagged "Q" for sites: DAN-013, ELZ-004, ABT-077 and ABT-026. Calibration check at 1060 µS/cm for 1000 µS/cm.
- May 2011: NH3 data flagged "Q" for all sites. Two spikes less than 85% recovery (84% and 80%).
- August 2011: NH3 data flagged "Q" for all sites. One spike >115% recovery.
- October 2011: Total Phosphorus data flagged "Q" for all sites. RPD between lab duplicates 22% (0.04 mg/L and 0.05 mg/L) and one spike at 120% recovery.

Data Quality Objectives

Instrument/ Laboratory	Parameter	Data Quality Objectives			
		Accuracy	Field Precision	Lab Precision[a]	Field Blank Cleanliness
YSI 6000-series Thermistor probe	temperature	± 1 °C	< 10% RPD	< 10% RPD	na
YSI 6000-series Glass Electrode	pH	± 0.2 S.U. at pH 7.00	± 0.5 S.U.	± 0.5 S.U.	na
YSI 6000-series Rapid Pulse	DO	± 5% at 100% saturation	< 10% RPD or < 20% RPD if <4.0 mg/L	< 10% RPD	na
YSI 6000-series 4-electrode cell	Conductivity	± 50 µS/cm at 0 and 1000 µS/cm	< 20% RPD or < 30% RPD if <250 µS/cm	< 20% RPD	na
Nashoba Analytical	TSS	85-115% recovery of lab fortified blank	< 30% RPD or < ± 1 mg/L if < 2 mg/L	< 20% RPD	BDL
Nashoba Analytical	TP	85-115% recovery of lab fortified blank	< 20% RPD or ± 0.01 mg/L if <0.030 mg/L	< 20% RPD	BDL
Nashoba Analytical	ortho – P	85-115% recovery of lab fortified blank	< 20% RPD or ± 0.01 mg/L if <0.030 mg/L	< 20% RPD	BDL
Nashoba Analytical	NO3	85-115% recovery of lab fortified blank	< 30% RPD	< 20% RPD	BDL
Nashoba Analytical	NH3	85-115% recovery of lab fortified blank	< 30% RPD	< 20% RPD	BDL
Alpha Analytical	Chlorophyll *a*	75 – 125% recovery of lab QC sample (with known Chl *a* content)	< 20% RPD or ± 2.0 if < 15 µg/L	< 20% RPD	BDL

[a] Lab Precision for field parameters is evaluated by comparing side-by-side meter readings in a bucket of river water.

Data Qualifiers

Data qualifiers	Description
NA	not sampled
P	provisional data (QA/QC not yet performed)
Q	data met most but not all QA/QC requirements
---	data censored

Appendix IV: Water Quality Data