LAWRENCE HYDROELECTRIC PROJECT

LIHI APPLICATION

ATTACHMENT B

WATER QUALITY

40M-1-77-129302

402.2

THE COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION

DIVISION OF WATER POLLUTION CONTROL
110 TREMONT STREET, BOSTON 02108

OFFICE OF THE DIRECTOR

July 5, 1978

Dr. Kenneth Plumb, Secretary
Federal Energy Regulatory Commission
825 North Capitol Street
Washington, D.C. 20426

Re: Water Quality Certification
Lawrence Hydroelectric Project
FERC License Application P-2800
Lawrence, Mass.

Dear Dr. Plumb:

This letter is written at the request of Lawrence Hydroelectric Associates, developers of a proposed 14.1 Megawatt generating station on the Merrimack River at Lawrence, Mass. The Associates have requested a letter from this Division as to the effect of the operation of the proposed facility on the water quality of the Merrimack River below the project.

The proposed development will be located at the existing Essex Dam in Lawrence, approximately two miles upstream of the outfall from the recently-completed Greater Lawrence Sanitary District Wastewater Treatment Plant. This plant was designed to produce an effluent of such quality and characteristics that, with a 7-day, 10-year low flow on the Merrimack River at the outfall, the assigned "B" classification of the river would be attained. The Division was concerned lest the regimen of the river would be so changed through the operation of the proposed facility that the Class B standard would be violated.

Staff of this Division have had numerous meetings and correspondence with staff of the developers. As a result, this Division has now received reasonable assurances from the applicant that the proposed project will be operated in a manner which will not cause a violation of applicable water quality standards adopted by this Division under authority of Section 27 (5) of Chapter 21 of the Massachusetts General Laws.

Therefore, based on these assurances and our own investigations, this Division hereby issues this Water Quality Certification relative to this project, in accordance with the provisions of Section 401 of the Federal Water Pollution Control Act as amended (Public Law 95-217), subject to the following conditions:

1. A minimum flow of 951 c.f.s. (equivalent to approximately 1,000 c.f.s. at the Greater Lawrence Sanitary District Wastewater Treatment Plant outfall) shall be continuously released from the impoundment behind the Essex Dam by whatever means or combination of means necessary to accomplish this release, unless or until the pool elevation behind the dam is so drawn down that it reaches the crest of the dam.

2. At such times, outflow released from the dam shall be equal to inflow as recorded at the U.S.G.S. Lowell, gage, during the period the flow is less than 951 c.f.s. When the flow exceeds 951 c.f.s., the excess flow over 951 c.f.s. may be utilized to refill the impoundment to the top of flashboards, whereupon Condition 1 above will again go into effect.

Should any violation of the water quality standards or the terms of this Certification occur as a result of the proposed activity, the Division will direct that the condition be corrected. Non-compliance on the part of the permittee will be cause for this Division to recommend the revocation of the permit(s) issued therefor or to take such other action as is authorized by the General Laws of the Commonwealth.

Very truly yours,

Thomas C. MaMahon
Director

TCM/WAS/rew

cc: Gordon A. Marker, Lawrence Hydroelectric Associates, 8 Arlington Street, Boston 02116
David Standley, Commissioner, Department of Environmental Quality Engineering, 100 Cambridge Street, Boston 02202
Barbara Ingle, Deputy Commissioner, Department of Environmental Quality Engineering, 100 Cambridge Street, Boston 02202
Morgan Rees, Chief, Permits Branch, Corps of Engineers, 424 Trapelo Road, Waltham 02154
John J. Hannon, Director, Division of Land & Water Use, Department of Environmental Quality Engineering, 100 Nashua Street, Boston 02114
Matthew Connolly, Director, Division of Fisheries & Wildlife, 100 Cambridge Street, Boston 02202

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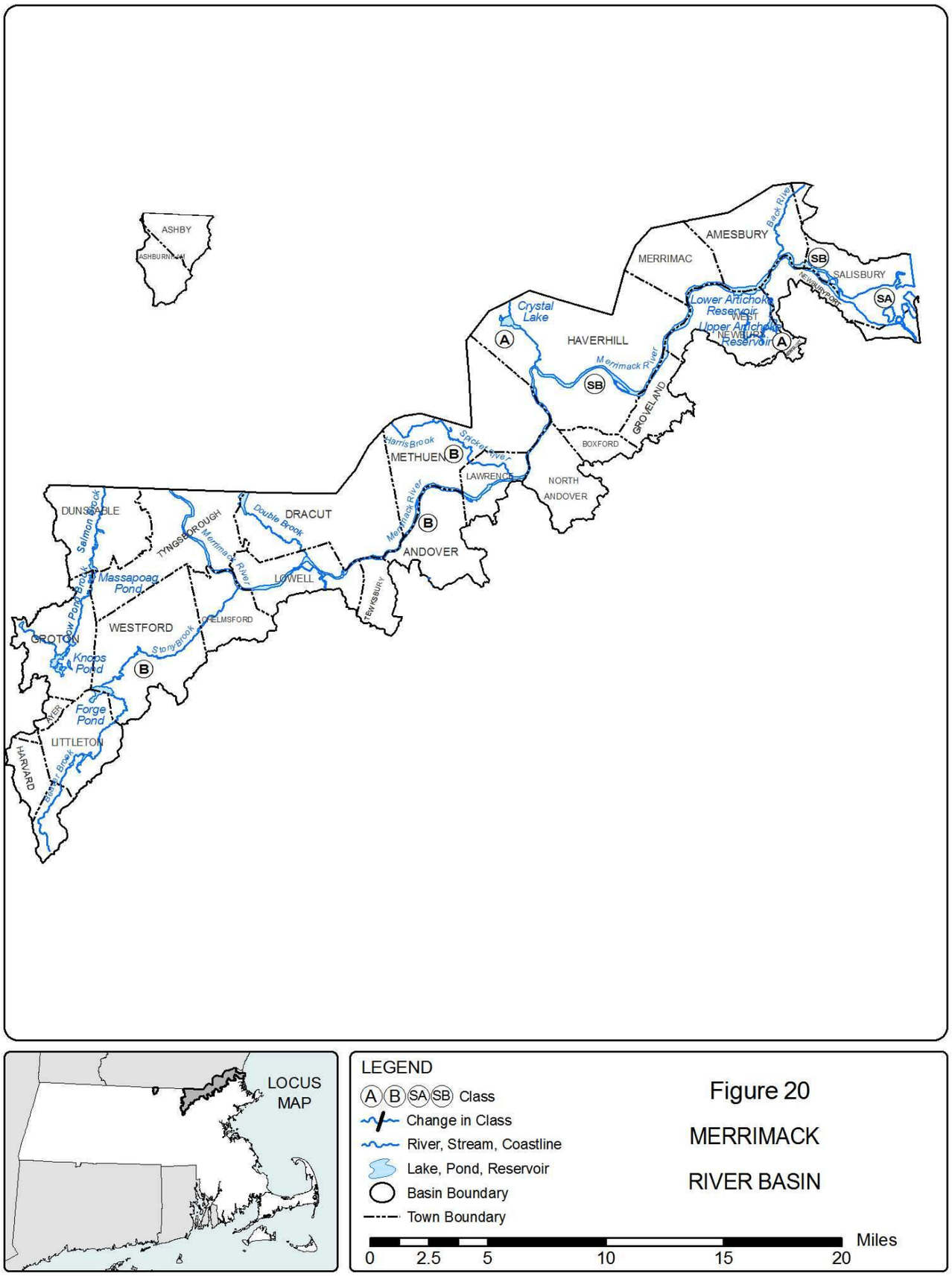

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TABLE 20
MERRIMACK RIVER BASIN

BOUNDARY	MILE POINT	CLASS	QUALIFIERS
Merrimack River			
State line to Pawtucket Dam	49.8 - 40.6	B	Warm Water Treated Water Supply CSO
Pawtucket Dam to Essex Dam, Lawrence	40.6 - 29.0	B	Warm Water Treated Water Supply CSO
Essex Dam, Lawrence to Little River, Haverhill	29.0 - 21.9	B	Warm Water CSO
Little River, Haverhill to Atlantic Ocean	21.9 - 0.0	SB	Shellfishing CSO
The Basin in the Merrimack River Estuary, Newbury and Newburyport	-	SA	Shellfishing
Stony Brook			
Entire Length	10.3 - 0.0	B	Warm Water
Beaver Brook			
State line to confluence with Merrimack River	4.2 - 0.0	B	Cold Water
Spicket River			
State line to confluence with Merrimack River	6.4 -0.0	B	Warm Water
Little River			
State line to confluence with Merrimack River	4.3 - 0.0	B	Warm Water
Cobbler Brook			
Entire Length	3.7 - 0.0	B	Cold Water
Powwow River			
Outlet Lake Gardner to tidal portion	6.4 - 1.3	B	Warm Water
Tidal portion	1.3 - 0.0	SB	Shellfishing
Plum Island River			
North of High Sandy sand bar		SA	Shellfishing Outstanding Resource Water

Water quality standards for Class B and Class SB waters[1]

Designated Use/Standard	Parameter	Support
Inland waters, Class B, warm water fishery Massachusetts waters, MADEP	Dissolved Oxygen	≥ 5.0 mg/l ≥ 60% saturation unless background conditions lower
	Temperature	≤ 28.3ºC (83ºF)
	pH	6.0 to 8.3 S.U.
Coastal/marine waters, Class SB Massachusetts waters, MADEP	Dissolved Oxygen	≥ 5.0 mg/L ≥ 60% saturation unless background conditions lower
	Temperature	< 26.7ºC (80ºF)
	pH	6.5 to 8.5 S.U.
Primary contact recreation (designated swimming area), EPA and MADPH guidelines and, as of 2007, primary contact recreation, Massachusetts MADEP	*Enterococcus*	Single sample limit 61colonies/100 ml (freshwater), 104 colonies/100 ml (marine); geometric mean 33 colonies/100 ml (freshwater), 35 colonies/100 ml (marine)
Freshwater primary contact recreation (designated swimming area), EPA and MADPH guidelines; and, as of 2007, primary contact recreation, Massachusetts MADEP	*E. coli*	Single sample limit 235 colonies/100 ml (freshwater only); geometric mean 126 colonies/100 ml (freshwater only)
Prior to 2007, primary contact recreation, Massachusetts MADEP	Fecal coliform	Geometric mean ≤ 200 colonies/100 ml, no more than 10% of samples above 400 colonies/100 ml
Restricted shellfishing, Massachusetts MADMF	Fecal coliform	Geometric mean ≤ 88 colonies/100 ml

[1] According to Massachusetts Department of Environmental Protection (MADEP) standards as of January 2007

From MADEP 1996:

Inland Water Class B: These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

Coastal and Marine Class SB: These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting with depuration (Restricted Shellfishing Areas). These waters shall have consistently good aesthetic value.

EXCERPTS FROM THE

Merrimack River Watershed Council, Inc.

The Voice of the Merrimack

Merrimack River Monitoring Program

Formerly known as the Merrimack River Water Quality Monitoring, Analyzing, Protecting and Promoting (MAPP) Program

2009 Annual Report

Prepared by:

Merrimack River Watershed Council, Inc.
600 Suffolk Street, 5th Floor
Lowell, MA 01854
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April 22, 2010

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Executive Summary

The *Merrimack River Monitoring Program* is a volunteer water quality monitoring effort begun in 2007 to collect baseline water quality information in the 50-mile mainstem of the Merrimack River in Massachusetts. Since its inception the program has expanded geographically to include monitoring in southern New Hampshire and programmatically to incorporate additional water quality parameters. In 2009 alone, 40 Merrimack Valley community members volunteered with the Merrimack River Watershed Council (MRWC) to collect water quality data at 41 sites along the length of the river. Volunteer teams monitored seven to nine sites in one of five river sections from Newburyport to Nashua, traveling from one site to another via boat. Over forty monitoring trips occurred throughout the spring, summer and fall of 2009, with bacteria samples collected on 23 of these trips, nutrient data collected on five days, pharmaceutical product samples collected once and physical water quality parameters recorded on all of the days.

Physical water quality data collected includes water temperature, pH, dissolved oxygen, conductivity, total dissolved solids, salinity and Secchi depth. Physical water quality parameters met state standards with the exception of pH. On several days between May and August pH values as low as 3.2 to 4.1, the acidity of vinegar, were found in various parts of the river.

Bacteria samples were collected once per month in each section and analyzed at the Region 1 EPA laboratory. In comparison to the data MRWC collected in prior years, 2009 dry weather bacteria results remained relatively consistent for the number of days the river was safe for swimming (96 percent) and boating (99 percent) according to state water quality standards where the sample was collected. In wet weather, 2009 data indicated an improvement in Merrimack River water quality: the river met state water quality standards 95 percent of the time for swimming and 100 percent of the time for boating. Evaluation of Merrimack River water quality based solely on criteria used by New Hampshire or by other Massachusetts watershed associations would indicate lower water quality, however, with only two thirds of wet weather days safe for swimming.

In 2009 MRWC also had the exciting opportunity to get its new *Safe Drinking Water Project* off to a flying start with a screening for pharmaceutical products. Samples collected at several locations between Lawrence and Haverhill, Massachusetts, an area downstream of several drinking water sources, came back positive for 16 of 20 common drugs.

A few of our 2009 discoveries and successes include:

- *Septic leak in Lawrence fixed* – MRWC identified a pipe discharging polluted effluent into the Merrimack River in Lawrence. By working with Massachusetts Department of Environmental Protection officials in cooperation with the City of Lawrence, the source of the leaking septic system was determined and the leak fixed.

- *Spicket and Shawsheen Rivers contribute pollution to the Merrimack* – 2009 bacteria data, supported by a geometric mean of results over the Massachusetts state water quality limit, suggests that both the Spicket and Shawsheen Rivers frequently contain high levels of bacteria. Both rivers also demonstrate significantly higher conductivity and total dissolved solids than the Merrimack mainstem. Sampling along the length the tributaries will be necessary to pinpoint specific sources.
- *Merrimack River nutrient and metals monitoring begun* – Nutrient and metals monitoring began in 2009 as part of the *Search and Restore Project*. Results collected in 2009 have provided baseline nutrient data for the river and identified critical stations to target for the wet- and dry-weather monitoring planned for 2010. Analysis of metals in the water has also identified aluminum as a potential element of concern.

The first three years of the Merrimack River Monitoring program have reestablished MRWC's Volunteer Environmental Monitoring Network and effectively engaged local community organizations and citizens regarding water quality concerns in the river. Future plans include continuing baseline monitoring and bacteria sampling in Massachusetts and southern New Hampshire, nutrient monitoring and intensive sampling of high-use and problem sites on the river. MRWC will also continue spreading information about the work that yet needs to be done to achieve our vision of a pure Merrimack River, respected and enjoyed.

Introduction

The Merrimack River Watershed Council, Inc. (MRWC) is a non-profit 501(c)(3) organization formed in 1976 by local activists and regional planning commissions to promote citizen involvement in the clean-up of the Merrimack River. Its organizational mission today is to *ensure the sustainable ecological integrity and balanced, managed use of the Merrimack River and its watershed through science, advocacy, partnering and recreation.* Our focus area is the Merrimack River Watershed mainstem and its adjoining communities in Massachusetts and New Hampshire, though we have also accomplished many projects in our eighteen sub-watersheds. We understand that we are the only third-party advocate of the entire length of the Merrimack River in Massachusetts who is independent of commercial or regulatory interests; we are "*The Voice of the Merrimack.*"

Since the mission of the MRWC is to ensure the integrity and balanced use of the watershed and its resources, it is imperative that we focus on the river from which our organization is named. In the past, MRWC has performed extensive projects on tributaries of the Merrimack River, while leaving the health of the Merrimack River itself relatively unchecked. In 2007, the board and staff chose to rectify this past oversight by committing to the *Merrimack River Water Quality Monitoring, Analyzing, Protecting and Promoting (MAPP) Project*, now renamed the *Merrimack River Baseline Monitoring Project*. The *Baseline Monitoring Project* is a three phase program designed to: (1) quantify the baseline water quality of the Merrimack River, (2) discover sources of pollution to the river, address and reduce pollution to the Merrimack River through both traditional and creative methods, and (3) educate watershed constituents on how to protect this important resource. Since 2007 MRWC's water quality monitoring efforts have grown to become the Merrimack River Monitoring Program, encompassing the original *Baseline Monitoring (MAPP) Project*, the *Merrimack River Search and Restore Project* (formerly known as the *Impairment Quantification* or *IQ Project*), and the *Safe Drinking Water Project*. The main body of this report summarizes the results of the 2009 *Baseline Monitoring Project*, which includes recent expansion of baseline water quality monitoring into southern New Hampshire. Additional sections review the initial nutrient and metal sampling results of the first year of the two-year *Search and Restore Project* as well as the results of the pharmaceutical screening conducted in June 2009 as the first phase of the *Safe Drinking Water Project*.

Characteristics of the Merrimack River

The Merrimack River is 115 miles long, beginning at the confluence of the Pemigewasset and Winnipesaukee Rivers in Franklin, New Hampshire and flowing approximately 65 miles in New Hampshire and another 50 miles in Massachusetts to its mouth in Newburyport, Massachusetts. There are a total of six dams on the mainstem of the river, though only two in the stretch of river monitored by MRWC: the Essex Dam in Lawrence, Massachusetts and the Pawtucket Dam in Lowell, Massachusetts. There are two USGS gauging stations on the Merrimack River in Massachusetts, one in downtown Haverhill that measures only water height due to the influence of the tides, and one in Lowell at the confluence with the Concord River that measures stream flow. A new

gauging station was installed during the summer of 2009 on the Merrimack in downtown Nashua, New Hampshire.

Between Newburyport and the Essex Dam in Lawrence, the river is affected by ocean tides. Salt water intrudes up the river five to ten miles depending on the tide and river volume, and the river current can reverse, depending on the height of the tide and the level of flow in the river, up to the Mitchell's Falls area in Haverhill when the tide comes in. Water levels in the river can be tidally affected for the entire 29 miles from the estuary in Newburyport up to the Essex Dam during periods of low flow, such as during a typical August and September (M. Vets, Haverhill Harbormaster, anecdotal). In general, high tide in Haverhill lags high tide in Newburyport by approximately 1¼ hours, while low tide in Haverhill lags low tide in Newburyport by approximately 3 hours.

Baseline Monitoring Project

Project Location

The 2009 Baseline Monitoring Project collected water quality information in the mainstem of the Merrimack River in Massachusetts and southern New Hampshire. Figure 1 illustrates the 41 monitoring stations, each near an outfall, tributary or at a historical monitoring site. Monitoring occurred regularly between May and October at most of the identified sites, though data was only collected in Section 2 between June and October. Two stations in Massachusetts, 38.9 and 40.0, and five stations in New Hampshire, 51.8 through 55.9, were only monitored once due to access and boat availability difficulties. Monitoring was conducted in five river sections, with 7 to 9 sites located in each section. The river sections are: 1) the estuary in Newburyport to the Haverhill/Groveland town line, 2) Haverhill to the Essex Dam in Lawrence, 3) the Essex Dam to the Pawtucket Dam in Lowell, 4) the Pawtucket Dam to the Massachusetts/New Hampshire state border, and 5) the state border to Greeley Park in Nashua.

Stations in section 5 were monitored for the first time in 2009 as the program was expanded to encompass the Nashua and Hudson area of southern New Hampshire. Two new stations were also added in section 3 in Lowell between the Pawtucket Dam and Duck Island. Because of shallow water, this area is usually inaccessible via motor boat, but can be reached by paddlers. In section 4, the station located at the Lowell water intake, only 0.2 miles upstream of the Stony Brook station, was removed and replaced with station 44.6 at the Vesper Country Club. In Section 2, station 27.8 was added at the mouth of the Shawsheen River as a result of high levels of bacteria found in hotspot (areas of known or suspected high pollution) samples collected in the tributary. Finally, station 3.8 in Newburyport was eliminated for its proximity to station 4.4 and a new station called Kimball Farm was created upstream at mile 11.8 near Rocks Village, an area that was not being tested. Table 1 lists the stations monitored in 2009.

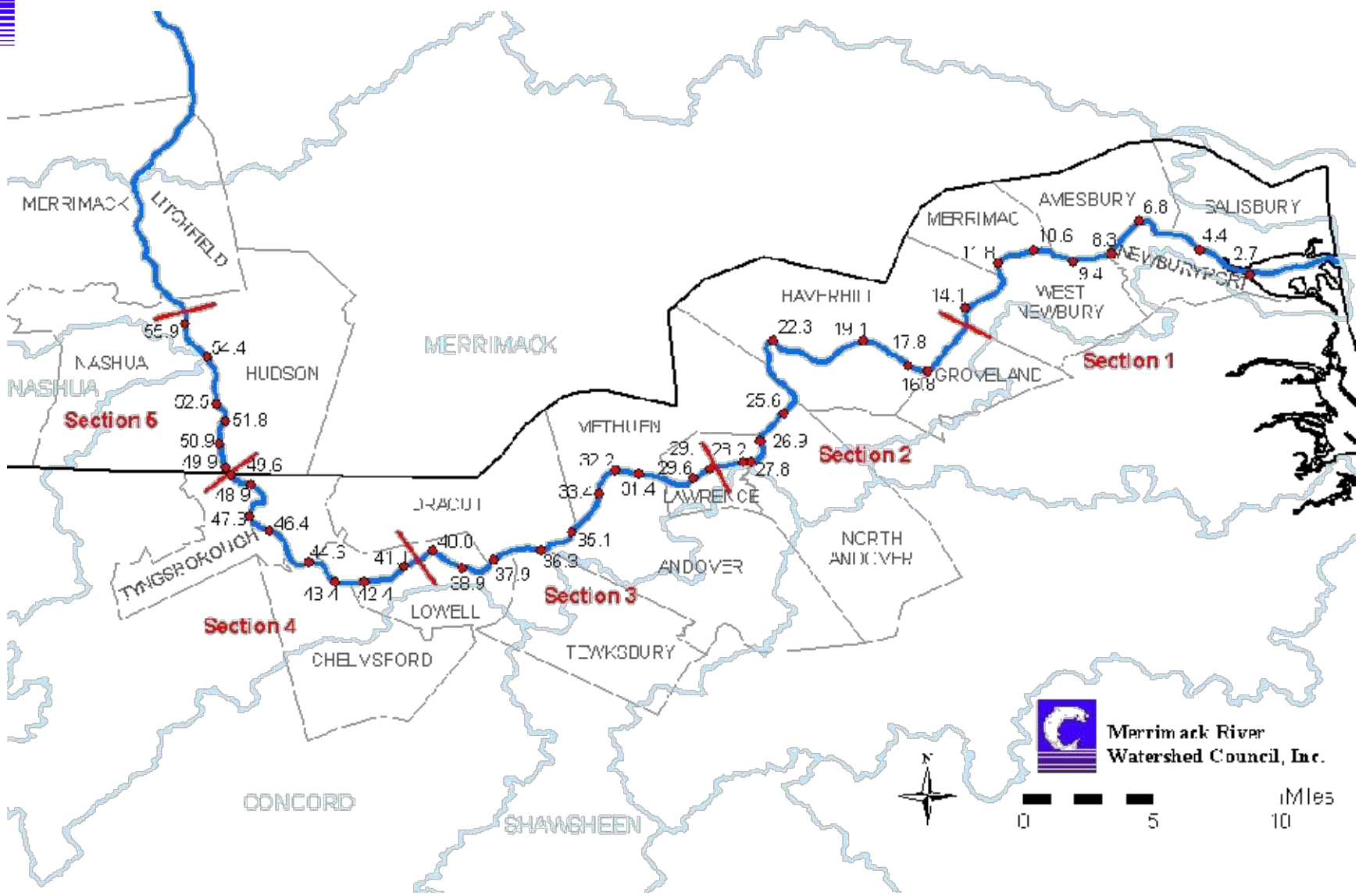

Figure 1. Map of 2009 Baseline monitoring stations on the Merrimack River.

Table 1. List of 2009 Baseline monitoring stations in the Merrimack River.

Section	Station	Description	Town
1	2.7	Newburyport Waste Water Treatment Plant	Newburyport
	4.4	Yankee Marina	Newburyport
	6.8	Powow River	Amesbury
	8.3	Artichoke River	Newburyport
	9.4	Indian River	West Newbury
	10.6	Cobbler Brook	Merrimac
	11.8	Kimball Farm	Merrimac
	14.1	Old North Canal	Haverhill
2	16.8	Johnson Creek	Groveland
	17.8	Haverhill Waste Water Treatment Plant	Haverhill
	19.1	Little River	Haverhill
	22.3	Creek Brook	Haverhill
	25.6	Lucent Technologies	North Andover
	26.9	Greater Lawrence Wastewater Treatment Plant	North Andover
	27.8	Shawsheen River	Lawrence
	28.2	Spickett River	Lawrence
	29.1	Below Essex Dam	Lawrence
3	29.6	Above Essex Dam	Lawrence
	31.4	Methuen Water Intake	Methuen
	32.2	Bartlett Brook	Methuen
	33.4	Fish Brook	Andover
	35.1	Gravel Pit	Dracut
	36.3	Trull Brook	Tewksbury
	37.9	Duck Island	Lowell
	38.9	Concord River	Lowell
	40.0	Oulette Bridge	Lowell
4	41.1	Pawtucket Dam	Lowell
	42.4	Rourke Bridge	Lowell
	43.4	Stony Brook	Chelmsford
	44.6	Vesper Country Club	Lowell
	46.4	Lawrence Brook	Tyngsborough
	47.3	Tyngsborough (Rte. 113) Bridge	Tyngsborough
	48.9	Limit Brook	Tyngsborough
	49.6	Massachusetts/New Hampshire Border	Tyngsborough
5	49.9	Pheasant Lane Mall	Nashua
	50.9	Spit Brook	Nashua
	51.8	Unnamed Stream	Hudson
	52.5	Nashua Country Club	Nashua
	53.1	Nashua WWTP	Nashua
	54.4	Nashua River	Nashua
	55.9	Greeley Park	Nashua

The Merrimack River is designated as a Class B (freshwater) warm water fishery in New Hampshire and in Massachusetts from the New Hampshire state border to Haverhill and a Class SB (tidally affected) water body from Haverhill to the estuary in Newburyport. This means that the river is expected to support fish, aquatic life and other wildlife as well as be suitable for primary (swimming) and secondary (boating) contact. Class B waters should also be suitable as a drinking water supply with adequate treatment, while Class SB waters should support conditional shellfish harvesting (MA DEP 2007). For this type of water body, each state has set limits for the amount of bacteria the water can safely contain, the maximum water temperature, the amount of dissolved oxygen in the water and the pH. These limits are listed in Table 4.

Table 4. Massachusetts (MA DEP 2007) and New Hampshire (NH 1998) water quality standards.

Parameter	MA Limit	NH Limit
E. coli (fresh water bacteria, cfu/100 mL)	235 (swim) single sample 126 (swim) geometric mean	88 (swim) single sample 47 (swim) geometric mean
	1260 (boat)* 10% samples 630 (boat)* geometric mean	406 single sample 126 geometric mean
Enterococcus (salt water bacteria, cfu/100 mL)	104 (swim) single sample 35 (swim) geometric mean	N/A
	350 (boat)* 10% samples 175 (boat)* geometric mean	
Water Temperature	≤ 28.3°C Class B warm ≤ 29.4°C Class SB	Supportive of Class B uses
Dissolved Oxygen	≥ 5.0 mg/l	≥ 75% saturation ≥ 5.0 mg/l during CSOs
pH	6.5 ≤ pH ≤ 8.3 Class B 6.5 ≤ pH ≤ 8.5 Class SB	6.5 ≤ pH ≤ 8.0 Class B N/A

* Bacteria safety limits for secondary contact/boating are based on Massachusetts Class C waters.

Bacteria

FIELD STUDY ANALYSIS

Measurements of *Escherichia coli* (*E. coli)* and *Enterococcus* bacteria are used by the states of Massachusetts and New Hampshire to determine human health risks from primary (swimming) and secondary (boating) contact in fresh and salt waters, with *E. coli* used in fresh water and *Enterococcus* used in salt water. Both *E. coli* and *Enterococcus* are bacterium commonly found in the waste of warm-blooded animals. While these strains of bacteria have not been identified as directly causing adverse health effects, they do indicate that other, more harmful, strains of bacteria are likely present. The states use two different standards to evaluate bacterial water quality, and also use different standards depending on the number of samples collected at the site. For class B (fresh) waters in Massachusetts "the geometric mean of all *E. coli* samples taken within the most

recent six months shall not exceed 126 colonies per 100 ml typically based on a minimum of five samples and no single sample shall exceed 235 colonies per 100 ml…" (MA DEP 2007). For Massachusetts class SB (salt) waters "no single *Enterococci* sample taken during the bathing season shall exceed 104 colonies per 100ml and the geometric mean of the five most recent samples taken within the same bathing season shall not exceed 35 *Enterococci* colonies per 100ml" (MA DEP 2007). New Hampshire standards are more strict for fresh water where "designated beach areas shall contain not more than a geometric mean based on at least 3 samples obtained over a 60-day period of 47 *Escherichia coli* per 100 milliliters, or 88 *Escherichia coli* per 100 milliliters in any one sample" (NH 1998), but are the same for salt water, though the Merrimack watershed is entirely fresh water in New Hampshire.

Of the samples MRWC collected during dry weather in 2009, the Merrimack River met single sample bacteria water quality standards for swimming 96 percent of the time and 99 percent of the time for boating. According to the samples MRWC gathered during wet weather, the river met single sample water quality standards 95 percent of the time for swimming and 100 percent of the time for boating. Figures 3 and 4 illustrate the 2009 single sample bacteria counts at each station for *Enterococcus* in Section 1 and for *E. coli* in Sections 2, 3, 4 and 5, respectively. In these calculations, Massachusetts water quality standards were used for those samples collected in Massachusetts while New Hampshire standards were used for samples gathered in that state. Table 5 summarizes the 2009 bacteria water quality results under these state standards as well as under the two more protective standards described below.

Table 5. Summary of 2009 Merrimack River Baseline Water Quality Monitoring Project bacteria water quality results – percent of time the Merrimack River meets water quality standards under various criteria.

	State Single Sample		**NH Standards**		**CRWA Standards**	
Weather	*Swim*	*Boat*	*Swim*	*Boat*	*Swim*	*Boat*
Dry	96%	99%	85%	99%	74%	99%
Wet	95%	100%	68%	98%	61%	98%

If New Hampshire's water quality standards were used for bacteria results in both Massachusetts and New Hampshire, water quality in the Merrimack would appear to be lower. Using the *E. coli* 88 cfu/100ml standard for swimming and 406 cfu/100ml standard for boating in both states, while maintaining the *Enterococcus* 104 cfu/100ml (swimming) and 350 cfu/100ml (boating) standards, the 2009 data MRWC collected during dry weather indicates that the Merrimack River met bacteria water quality standards for swimming only 85 percent of the time but still met standards for boating 99 percent of the time. Similarly, MRWC wet weather samples under the New Hampshire criteria suggest that the river met water quality standards just 68 percent of the time for swimming but 98 percent of the time for boating.

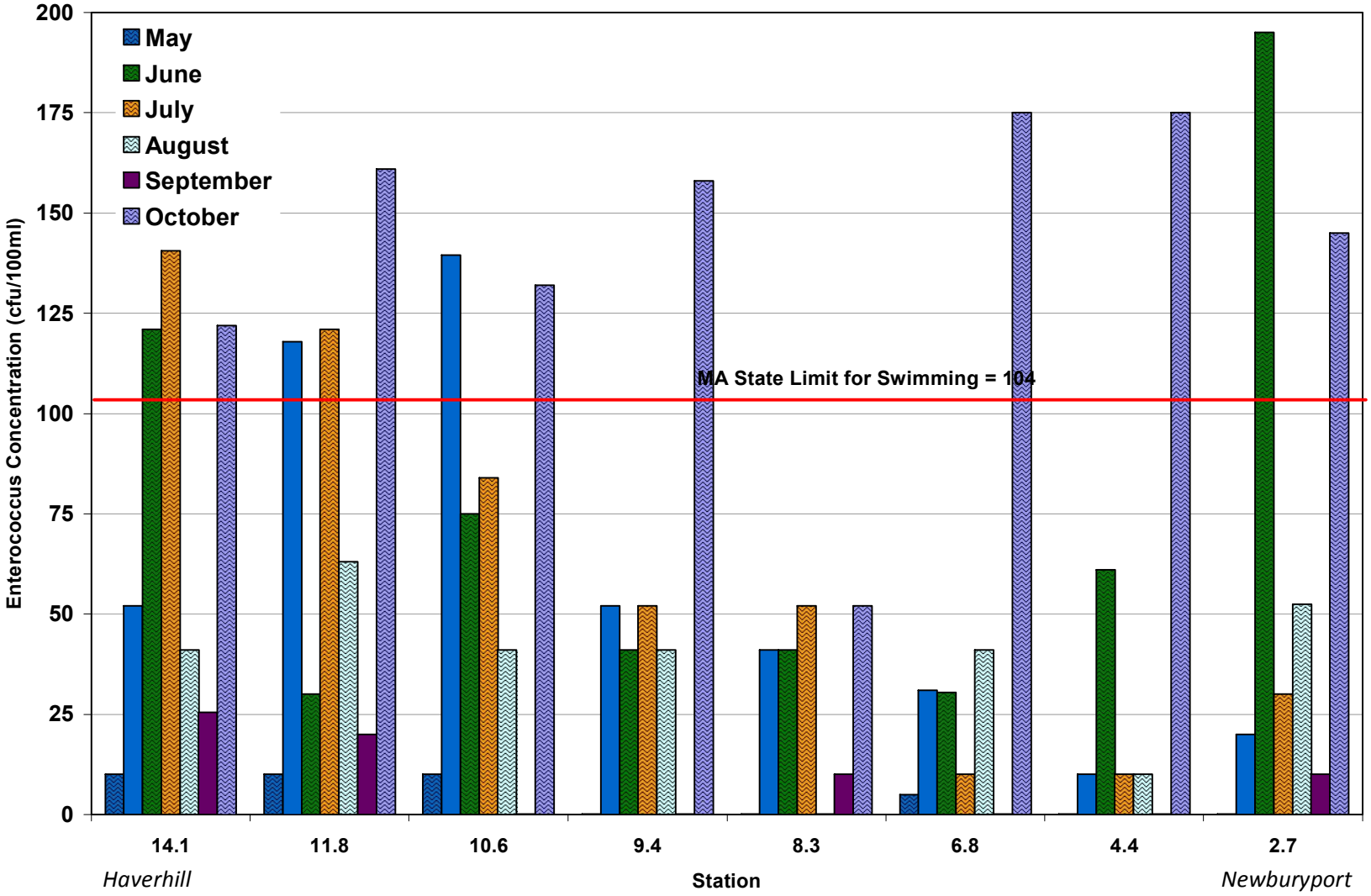

Figure 3. *Enterococcus* bacteria concentrations May through October 2009 in the Merrimack River in Section 1 between Haverhill and Newburyport, Massachusetts. Hatch pattern indicates wet weather event. Values greater than 104 cfu/100ml indicate unsafe swimming conditions.

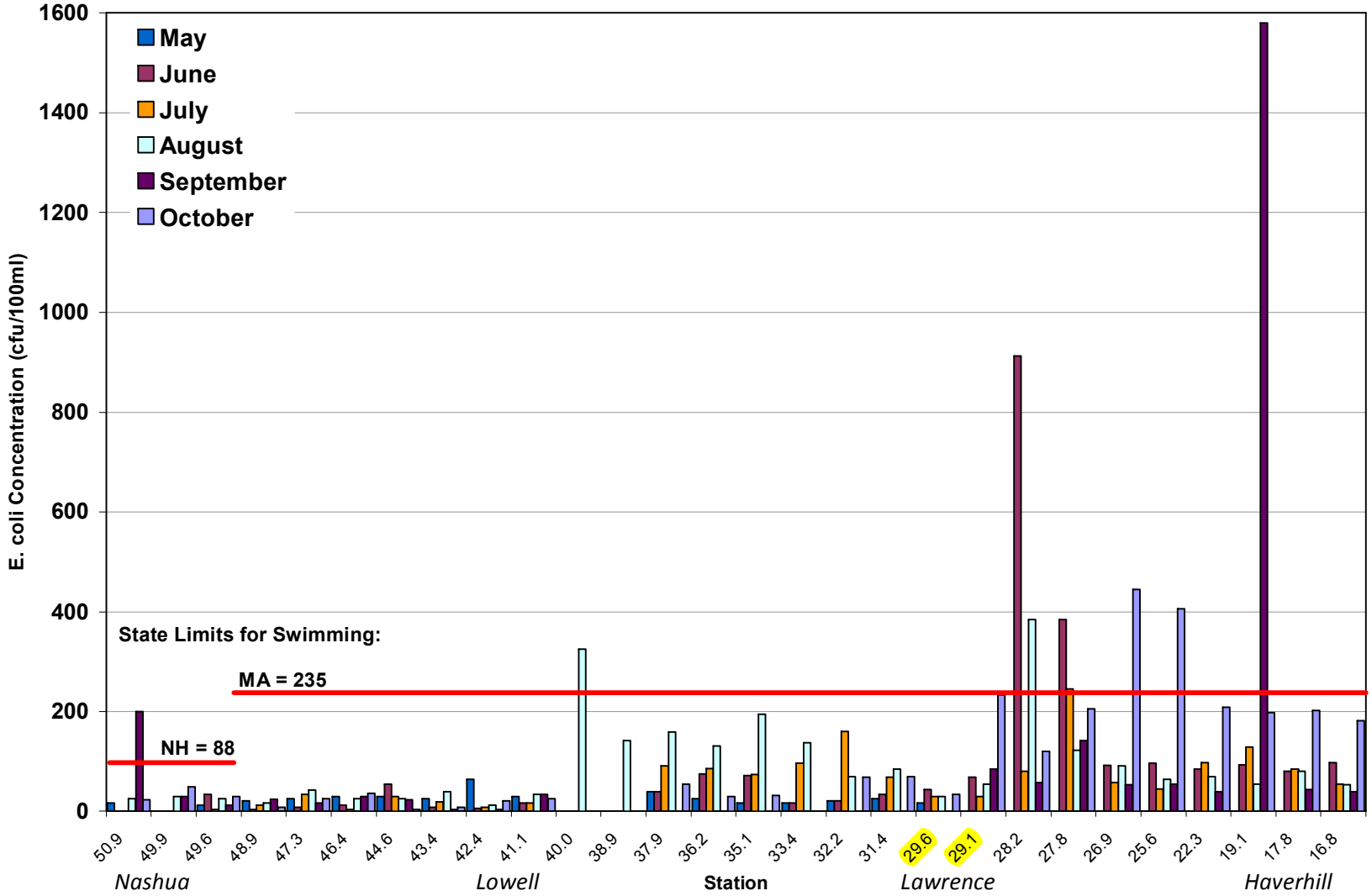

Figure 4. *E. coli* bacteria concentrations in the Merrimack River between May and October 2009 in Section 2 (Haverhill to Lawrence), Section 3 (Lawrence to Lowell), Section 4 (Lowell to Tyngsborough), and Section 5 (Nashua/Hudson). See Table 3 for wet versus dry weather events. Values over the red line indicate unsafe swimming conditions according to respective state water quality standards.

The Charles River Watershed Association (CRWA) uses the Massachusetts geometric mean bacteria limits, 126 cfu/100ml for *E. coli*, on single sample bacteria results rather than the single sample criteria, 235 cfu/100ml for *E. coli*, to determine whether or not the Charles River is safe for swimming or boating, arguing that these lower limits are more protective of human and river health (CRWA 2009). Under these criteria, assuming a similar use of the geometric mean limit of 35 cfu/100ml for single *Enterococcus* samples, the 2009 data MRWC collected during dry weather indicates that the Merrimack River met bacteria water quality standards for swimming only 74 percent of the time but still met standards for boating 99 percent of the time. Similarly, MRWC wet weather samples under the CRWA criteria suggest that the river met water quality standards just 61 percent of the time for swimming but 98 percent of the time for boating.

Because MRWC was able to collect at least five samples at most Massachusetts stations in 2009, we were also able to calculate the geometric mean of bacteria counts for each station. Based on the 2009 geometric mean calculations, water quality at six stations exceeded Massachusetts state standards. As shown in Figure 5, three of these stations are located in Section 2, all of them at the mouth a major tributary (Spicket, Shawsheen and Little Rivers). Both the Spicket and Shawsheen Rivers have demonstrated water quality problems in the past and need to be monitored more intensely to track pollution sources within them. The Little River has not traditionally shown significant water quality problems, and the geometric mean exceedance may be the result of just one very dirty sample. Three additional stations in Section 1 exceeded Massachusetts state water quality standards for Enterococcus levels. Each of these stations is located in the upstream, fresh water portion of the section just downstream of Haverhill. New Hampshire bacteria standards for geometric mean calculations require at least three samples collected within a 60 day period. Since MRWC collected bacteria data only once per month in 2009, data frequency is insufficient for geometric means at the New Hampshire stations.

In comparison to the sample data MRWC collected in 2007 and 2008, water quality in the Merrimack River seems to be generally improving during wet weather but diminishing, at least according to the more protective New Hampshire and CRWA standards, during dry weather. In general, the amount of bacteria in our samples has decreased. For example, the highest bacteria count MRWC collected in 2007 was 191,800 cfu/100 ml, but the highest collected in 2009 was only 1580 cfu/100 ml. The improvement during wet weather is probably the result of fewer combined sewer overflows (CSOs) throughout the river as cities such as Nashua, Lowell and Lawrence add stormwater treatment facilities, increase overall treatment capacity, and separate stormwater and septic sewer systems. The cause of the increase in dry weather bacteria amounts is currently unknown, but possibilities include an increasing number of failing septic systems and sewer pipes, more illicit connections whose discharges are no longer masked by CSOs, increased contamination from wildlife feces or a host of other potential causes. Additional data is required to determine if this trend is statistically significant.

Appendix A summarizes the bacteria results from 2007 through 2009.

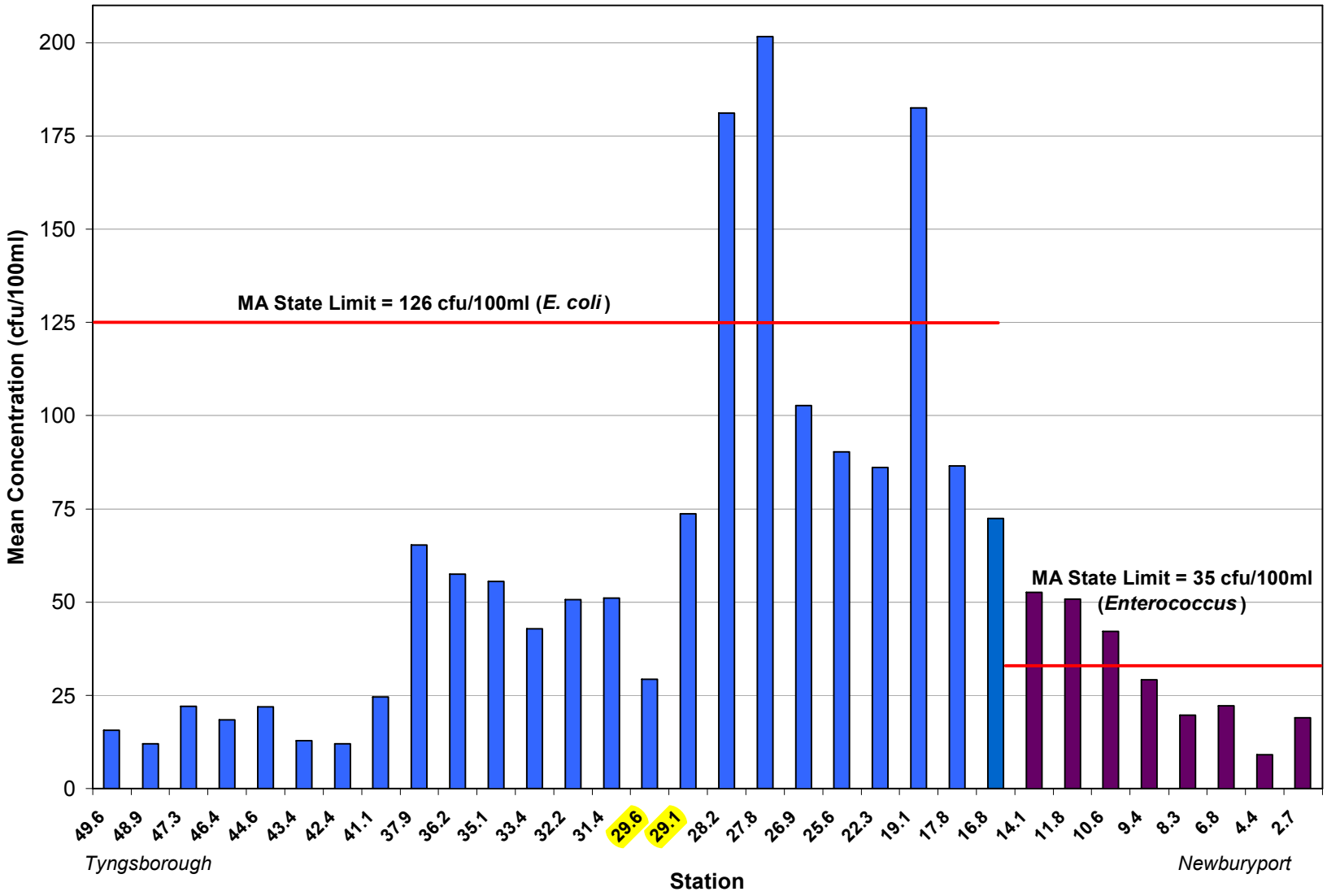

Figure 5. Geometric mean of *E. coli* and *Enterococcus* bacteria concentrations May through October 2009 in the Merrimack River. Stations with less than five samples, including all those in Section 5, were not included in the geometric mean calculation.

Temperature

None of the water temperature readings collected in 2009 exceeded the Massachusetts state maximum temperature limit for Class B warm (28.3°C) or Class SB (29.4°C) waters. Frequent rain storms, especially during the first half of the 2009 monitoring season, resulted in higher average flows in 2009 (9,110 cu. ft./sec.) than during the same months in 2007 (5,251 cu. ft./sec.) or 2008 (8,479 cu. ft./sec.), reducing the amount of time water remained in the river exposed to sunlight and heating. Mean discharge May to October is approximately 5,448 cu. ft./sec. at the Merrimack River gauge in Lowell, Massachusetts, based on data collected from 1923 through 2009 (USGS undated).

Water temperature in the Merrimack River followed the expected trend of heating during the warm summer months and cooling as the days shortened and the average air temperature cooled through the fall (Figure 9). The graph demonstrates the influence that warmer air temperatures have on the river, which is of concern as a result of the expected trend of temperature increases as a result of global warming. While the Merrimack is considered a warm water fishery, historically it has provided access to cold water streams and spawning habitat for anadromous fish and must remain cool enough for both the resident and transient fish and wildlife who depend on it for survival.

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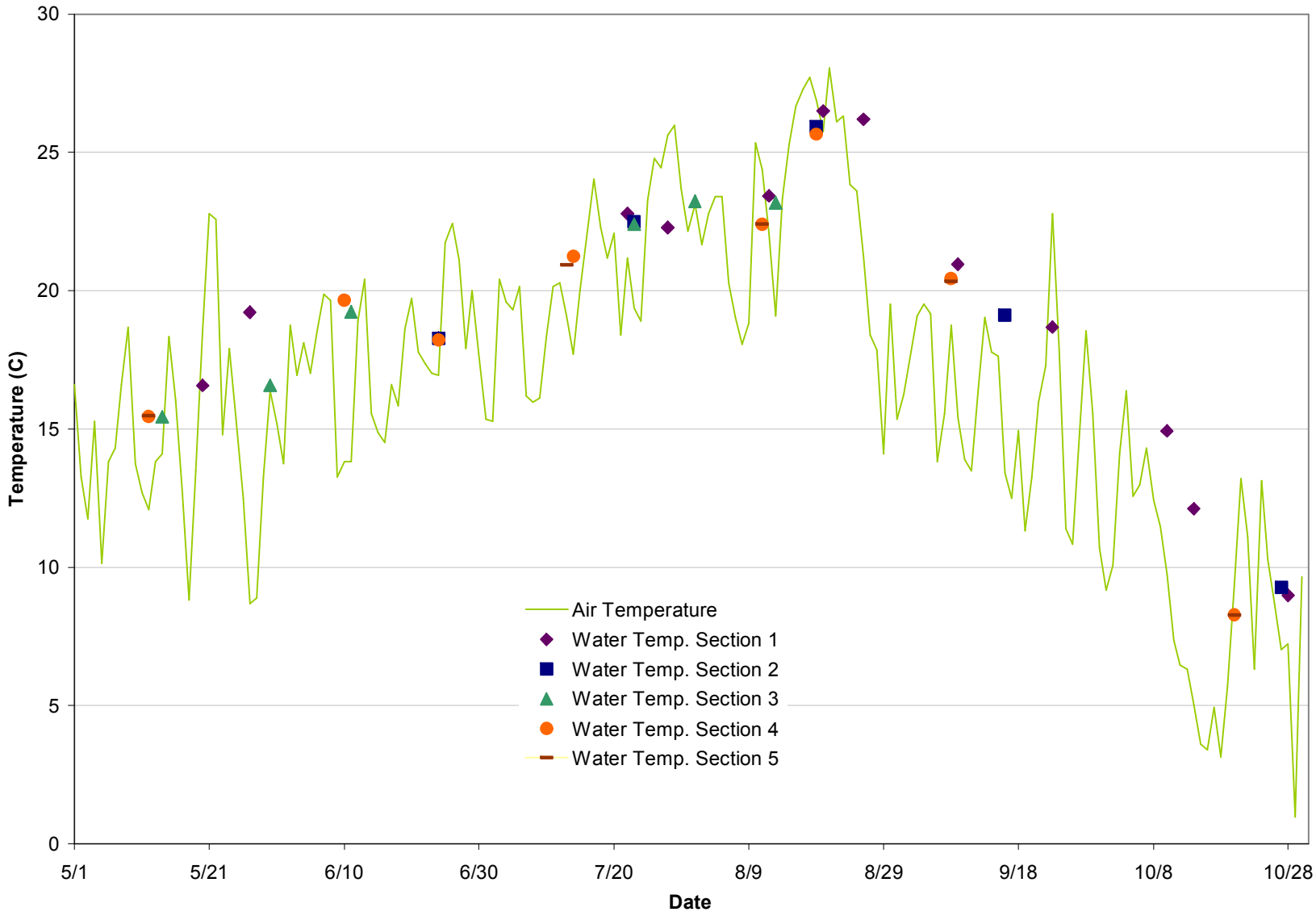

Figure 9. Median daily water temperature in the Merrimack River between May and October 2009 combined with the average of the mean daily air temperature for the lower Merrimack Valley (Nashua, NH and Lowell, Lawrence, Haverhill and Groveland, MA).

Dissolved Oxygen

No 2009 dissolved oxygen (DO) readings were under the water quality limit of 5 mg/l for warm water fisheries. In addition, Figure 10 shows that DO followed the expected seasonal trend of decreasing as the water increased and increasing again in the fall as water temperatures decreased. DO values collected on August 1, 2009 in Section 3 of the Merrimack River did not follow this trend, but this data was collected the day after a heavy storm, when increased river flow can add oxygen to the water.

On August 26, 2009, dissolved oxygen readings throughout the monitoring trip in Section 1 were below normal for the Merrimack River. Many of the measurements were below 6.5 mg/l, and two taken at the Newburyport Wastewater Treatment Facility were slightly below 6.0 mg/l. Measurements of other water quality parameters that day were normal for fresh water at that time of year, though water temperatures that day were among the highest recorded during the 2009 monitoring season.

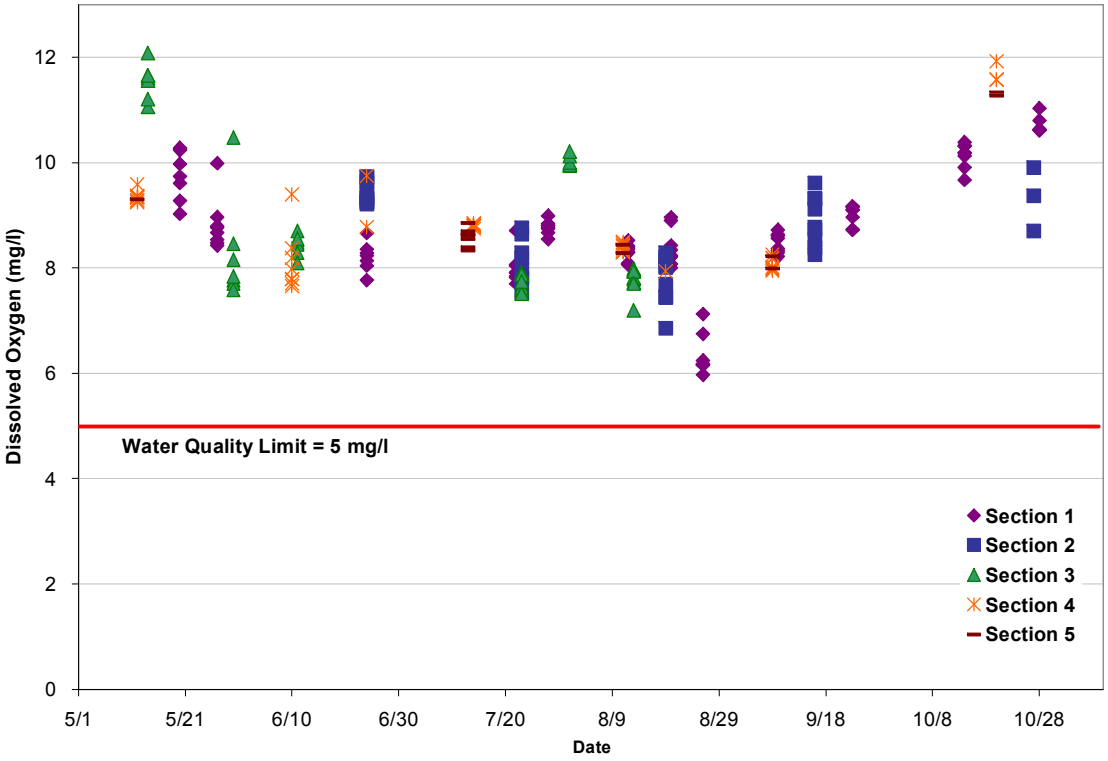

Figure 10. Median dissolved oxygen results by station in the Merrimack River between May and October 2009.

pH

During the summer of 2009, MRWC water quality monitors measured unusually low pH values in the Merrimack River in Massachusetts. As apparent in Figure 11, pH values on four separate days, May 20 in Section 1, May 30 in Section 3, August 1 in Section 3, and August 19 in Section 4, were found to be well below the lower limit of 6.5 standard units set by the state for conditions acceptable in Class B waters. The pH of the Merrimack River water measured on these four days is equivalent to the pH of vinegar. The data has been reviewed for potential equipment malfunction and while it does not appear that the observed readings were in error, the possibility cannot be completely eliminated. On two occasions the low pH readings were confirmed using pH test strips.

MRWC has consulted with MA DEP, EPA, U.S. Fish and Wildlife Service, and municipal water treatment plant officials regarding the pH results we recorded. None of the water quality experts contacted has been able to offer an explanation for the extremely low measurements found.

On May 20, 2009, MRWC staff and volunteers monitored in Section 1 from Old North Canal in Haverhill to the Newburyport Wastewater Treatment Plant. At the Old North Canal site (station 14.1), pH values around 3.0 to 3.5 were observed and thought to be erroneous; therefore, they were not recorded. Calibration of the pH probe was checked and found to be within tolerance. Values observed at the next station downstream ranged from 3.3 to 3.5. From that point, pH values gradually increased at each station as the team headed downstream, rising from 5.2 at Cobbler Brook (station 10.6); to 7.0 at the Newburyport Wastewater Treatment Plant (station 2.7). During the return trip upstream, the team collected another pH reading as well as a sample of water at a point between stations 11.8 and 10.6. The pH at this site was 5.8, and the water sample, evaluated with a volunteer's swimming pool test strips, confirmed the low pH readings.

On May 30, 2009, MRWC staff and volunteers monitored in Section 3 from above the Essex Dam in Lawrence to Duck Island in Lowell. pH in this section of the Merrimack River ranged from 4.1 to 6.2 with the lowest values found at Fish Brook (station 33.4) and Trull Brook (station 36.3) and the highest values found at Bartlett Brook (station 32.2) and the Methuen Water Intake (station 31.4). Changes in pH from one site to another did not demonstrate any particular trend, unlike the data collected on May 20th where pH consistently increased as the team moved downstream.

On August 1, 2009, MRWC volunteers again monitored in Section 3 from above Essex Dam to Trull Brook. On this day pH ranged from 3.3 at five meters depth to 6.4 at the surface at the Methuen Water Intake (station 31.4). Low pH values were recorded at several other sites as well, but none demonstrated the extreme range of station 31.4.

On August 19, 2009, MRWC interns and volunteers monitored at the Lowell Motor Boat Club near station 41.1 and in the Pawtucket Canal. During this monitoring event, pH ranged from 3.2 in the Merrimack River at the Lowell Motor Boat Club to 6.5 at the Swamp Locks in the canal, though pH varied significantly by depth at most sites.

The monitoring equipment was checked with pH 4.0 buffer solution after the first station and found to be properly calibrated. A few hours later, MRWC interns returned to the Lowell Motor Boat Club to check pH values, monitoring from the shore with a seven meter extension pole. Here pH ranged from 6.5 at the surface to 3.6 at one meter depth to 4.8 at two meters depth. pH test strips confirmed the results found using the YSI 556 water quality meters. Eight days later, EPA sampled in the same area and found that pH had returned to normal levels.

All of the pH results over the neutral value of 7 shown in Figure 12 were recorded in Section 1 and are due to the influence of salt water, which has a higher pH than fresh water, at Stations 2.7 through 8.3. Salt water rarely extends as far upstream as Station 8.3 at the mouth of the Artichoke River, but tides were unusually high the night of August 19, 2009 and salt water was still draining out of the tributary and tidal wetlands surrounding Station 8.3 on the morning of August 20th, resulting in higher salinity and pH values at that station than typical.

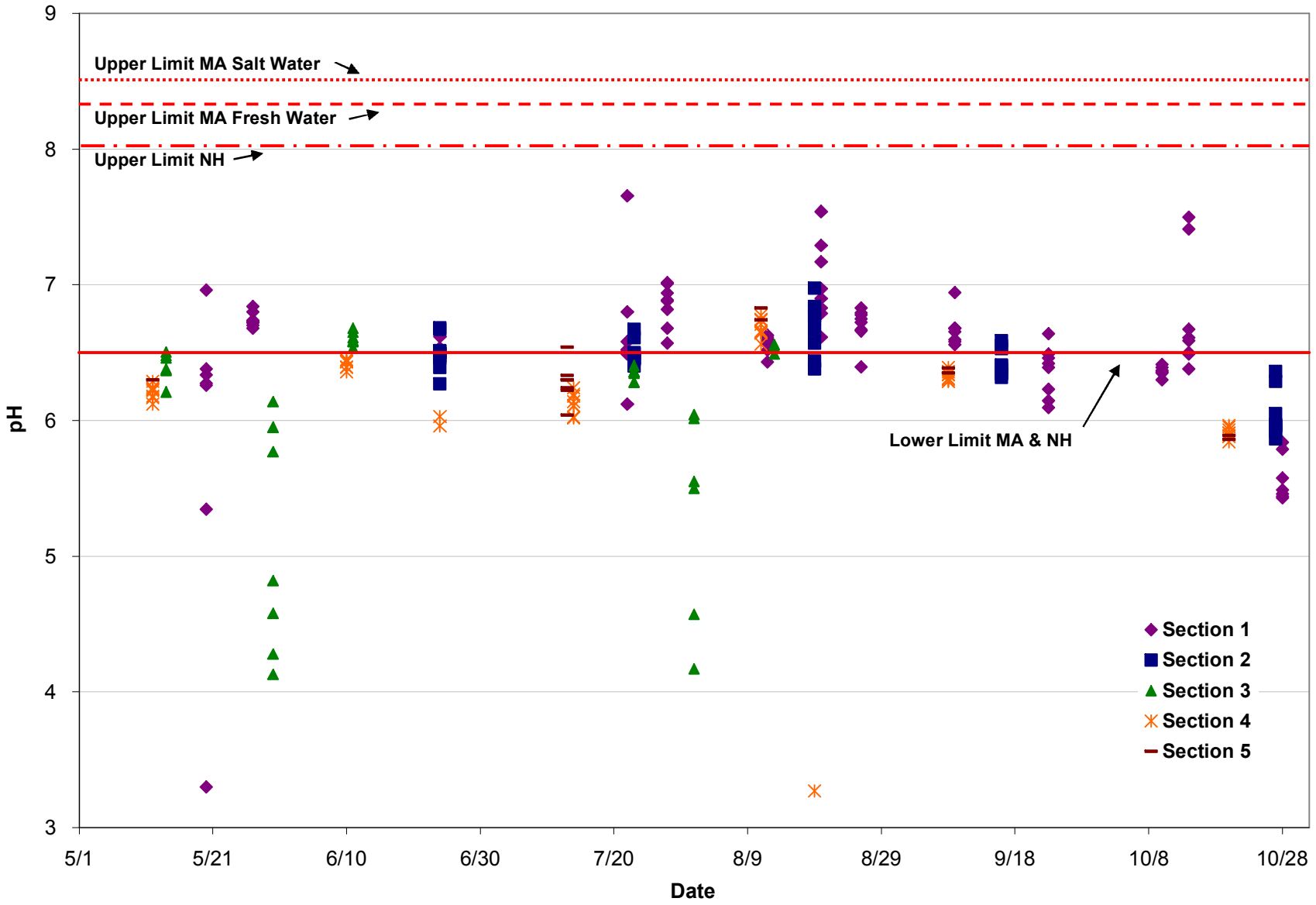

Figure 11. Median pH at each monitoring station in the Merrimack River between May and October 2009.

Continuous Water Quality Monitoring

In order to obtain a better understanding of the daily changes in dissolved oxygen and other parameters occurring in the Merrimack River, MRWC conducted continuous water quality monitoring over the course of two weeks in 2009. A YSI 556 meter was installed on a Lowell Motor Boat Club dock located in the impoundment of the Pawtucket Dam in Lowell, Massachusetts. Sensors were positioned at one-meter depth off the end of the floating dock such that the depth would remain at one meter despite changes in the river height. The handheld display unit was hidden to prevent tampering or theft. Water temperature, dissolved oxygen, total dissolved solids, conductivity, pH and barometric pressure were recorded every ten minutes beginning the afternoon of September 22, 2009 and ending the morning of October 5th. River flow at the site was deemed sufficient, despite its location in the dam impoundment, to provide a continuous supply of fresh water, eliminating the problem of oxygen depletion at the DO probe interface.

As expected, water temperature, dissolved oxygen and pH exhibited diurnal fluctuations, with highest values just before sunset and lowest values before sunrise. In contrast, specific conductance and total dissolved solids remained relatively constant throughout the day.

Figure 13 illustrates the diurnal change in dissolved oxygen saturation as well as a trend toward reduced oxygen saturation over the course of the continuous monitoring period. The average daily fluctuation in DO was 0.6 mg/l, or 8% saturation. The average difference between the nighttime low DO reading to the 9:30 AM measurement was 0.3 mg/l (3%). In prior years, MRWC has recorded DO levels below 6 mg/l at station 41.1, only a few meters away from the Lowell Motor Boat Club docks. Measurements of DO collected at station 41.1 are typically made around 9:30 AM. Low past measurements combined with the knowledge that the lowest daily DO levels were likely 0.3 mg/l or more lower leads to concerns that the Merrimack River may not be fully supportive of aquatic life during some parts of the year.

While the downward trend in percent saturation is consistent during dry weather, the trend is interrupted each time it rains. Dissolved oxygen and DO saturation both increased slightly following rain events. Presumably the rain water itself combined with higher flows resulting from the rain increases the amount of dissolved oxygen in the water.

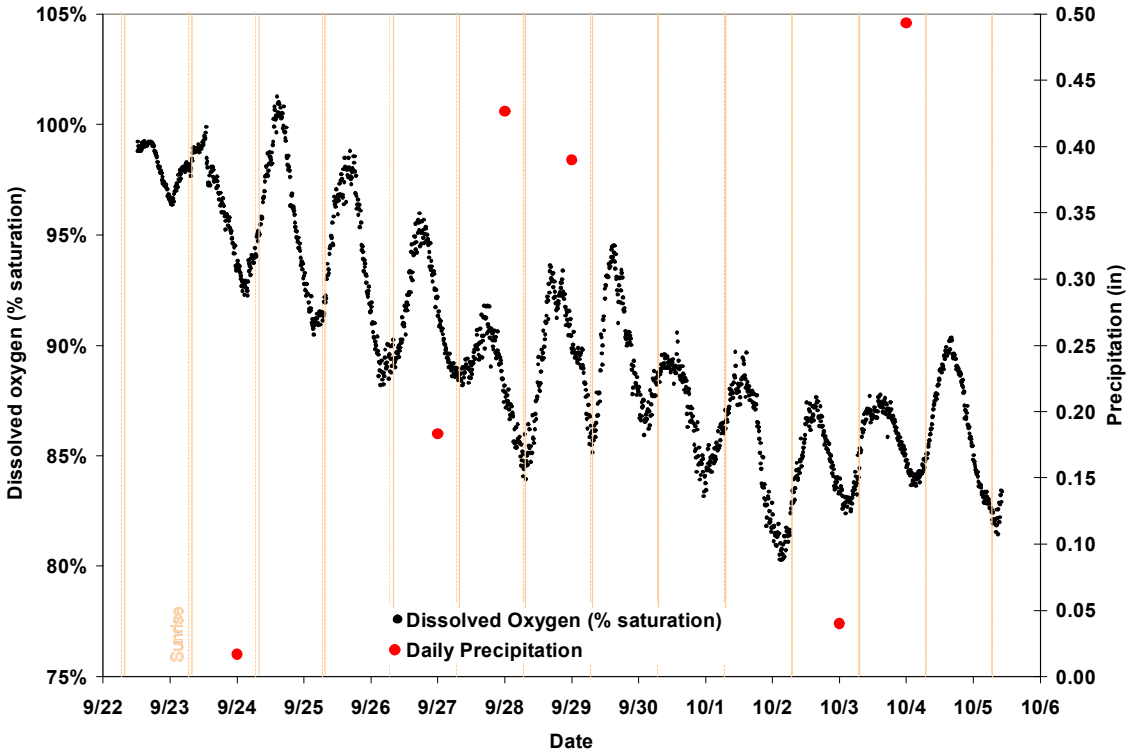

Figure 13. Percent dissolved oxygen saturation and daily precipitation in the Merrimack River's Pawtucket Dam impoundment in Lowell, Massachusetts from September 22 through October 6, 2009.

Appendix B:

Water Quality Tables

Bacteria Results

Section	Station	Test	May		June	July	August	September	October	Geometric Mean
1	2.7	Enterococcus	ND	20	195	30*	53*	10	145	33
	4.4	Enterococcus	ND	10	61	10	10	ND	175	16
	6.8	Enterococcus	8*	31	31	10	41	ND	175*	22
	8.3	Enterococcus	ND	41	41	52	ND	10	52	20
	9.4	Enterococcus	ND	52	41	52	41	ND	158	29
	10.6	Enterococcus	10	140*	75	84	41	ND	132	42
	11.8	Enterococcus	10	118	30	121	63	20	161	51
	14.1	Enterococcus	10	52	121	141*	41	26*	122	53
2	16.8	E. Coli			98	54	53	39	182*	72
	17.8	E. Coli			81*	85	80	44	202	87
	19.1	E. Coli			93	129	54*	1,580	198	183
	22.3	E. Coli			85	98	70	39	208	86
	25.6	E. Coli			96	45*	64	54	406	90
	26.9	E. Coli			92	58	91	53	445	103
	27.8	E. Coli			384	245	122	142*	205	202
	28.2	E. Coli			913	80	384	58	120	181
	29.1	E. Coli			68	30	54	85	233	74
3	29.6	E. Coli		16	44	30	30		34	29
	31.4	E. Coli		25	34	69	85		70	51
	32.2	E. Coli		21	21	160	70		68	51
	33.4	E. Coli		16	16	96	137*			43
	35.1	E. Coli		16	72*	75*	195		32*	56
	36.2	E. Coli		25	75	86	131		30	58
	37.9	E. Coli		39	39	91	159		54	65
	38.9	E. Coli					142			
	40.0	E. Coli					325			
4	41.1	E. Coli		30	16	16	34	34	25	25
	42.4	E. Coli		64	6*	8	12	4	21	12
	43.4	E. Coli		25*	8	19*	39	4	8	13
	44.6	E. Coli		30	54	30	25*	23*	4	22
	46.4	E. Coli		30	12	4	25	30	37*	18
	47.3	E. Coli		25	8	34	43	16	25	22
	48.9	E. Coli		21	4	12	16	24	8	12
	49.6	E. Coli		12	34	4	25	12	30	16
5	49.9	E. Coli					30	30	49	
	50.9	E. Coli		16			25	200	23*	

Wet weather event (>= 0.25 in. precip over prior 72 hours)

* Average of station samples

Bacteria concentrations in number of colony forming units per 100 milliliters (cfu/100 mL) collected in the Merrimack River, Massachusetts and New Hampshire during 2009. Analysis performed at EPA Region I laboratory in North Chelmsford, Massachusetts.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Water Temperature Results

Section	Station	5/12	5/14	5/20	5/27	5/30	6/10	6/11	6/24	7/13	7/14	7/22	7/23	7/28	8/1
1	2.7			15.3	19.2				18.3			19.1		22.3	
	4.4			16.6	19.2				18.3			22.8		22.3	
	6.8			16.9	19.0				18.3			22.9		22.3	
	8.3			16.9	19.0				18.3			22.8		22.2	
	9.4			17.0	19.1				18.3			22.8		22.3	
	10.6			16.5	19.4				18.3			22.8		22.3	
	11.8			16.3	19.5				18.3			22.8		22.3	
	14.1			15.8	19.3				18.3			22.7		22.2	
2	16.8								17.8				22.4		
	17.8								18.3				22.5		
	19.1								18.3				22.5		
	22.3								18.3				22.6		
	25.6								18.3				22.5		
	26.9								18.3				22.5		
	27.8								17.3				20.5		
	28.2								17.5				22.5		
	29.1								18.3				22.5		
3	29.6		15.6			16.6		19.2					22.5		23.3
	31.4		15.4			16.6		19.4					22.3		23.3
	32.2		15.4			16.5		19.3					22.4		23.3
	33.4		15.6			16.5		19.2					22.4		23.2
	35.1		15.6			16.7		19.1					22.4		23.1
	36.3		15.4			16.9		19.2					22.5		23.0
	37.9		15.4			16.8		19.2					22.4		
	38.9														
	40.0														
4	41.1	15.7					19.9		18.3		21.3				
	42.4	15.6					19.8				21.4				
	43.4	15.6					19.7				21.4				
	44.6	15.5					19.7				21.4				
	46.4	15.4					19.7				21.2				
	47.3	15.3					19.6				21.2				
	48.9	15.3					19.3				21.1				
	49.6	15.3					19.2		18.2		21.1				
5	49.9									21.0					
	50.9	15.5								21.1					
	51.8									20.9					
	52.5									20.9					
	53.1									20.9					
	54.4									20.8					
	55.9									21.2					

Median water temperature in degrees Celsius (°C) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Water Temperature Results (continued)

Section	Station	8/11	8/12	8/13	8/19	8/20	8/26	9/8	9/9	9/16	9/23	10/10	10/14	10/20	10/27	10/28
1	2.7		23.5			17.0	26.6		20.6		18.6		11.5			
	4.4		23.6			25.0	26.6		21.0		18.7		11.9			9.1
	6.8		23.6			26.5	26.4		20.7		18.8	14.9	12.4			9.0
	8.3		23.5			26.7	26.3		20.6		18.9	15.0	12.2			9.0
	9.4		23.3			26.8	26.1		20.9		18.9	15.0	12.5			9.0
	10.6		23.3			26.8	25.9		21.2		18.7	14.9	12.2			8.9
	11.8		23.0			26.5	25.7		21.1		18.5	14.9	12.0			8.9
	14.1		22.8			26.1	25.7		21.1		18.6	14.8	12.0			8.8
2	16.8				25.5					19.3					9.3	
	17.8				25.5					19.1					9.3	
	19.1				25.7					18.7					9.3	
	22.3				25.9					19.0					9.2	
	25.6				26.2					18.9					9.2	
	26.9				26.0					19.4					9.1	
	27.8				24.7					17.5					10.2	
	28.2				26.5					19.8					9.7	
	29.1				26.3					19.9					9.0	
3	29.6			23.4												
	31.4			23.2												
	32.2			23.1												
	33.4			23.2												
	35.1			23.0												
	36.3			23.2												
	37.9			23.1												
	38.9			23.3												
	40.0			23.2												
4	41.1	22.3			25.7			20.8						8.4		
	42.4	22.3						20.5						8.1		
	43.4	22.4						20.4						8.1		
	44.6	22.4						20.2						8.2		
	46.4	22.4						20.4						8.3		
	47.3	22.4						20.5						8.3		
	48.9	22.5						20.5						8.3		
	49.6	22.4						20.4						8.3		
5	49.9	22.4						20.3						8.3		
	50.9	22.4						20.3						8.3		
	51.8															
	52.5															
	53.1															
	54.4															
	55.9															

Median water temperature in degrees Celsius (°C) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Dissolved Oxygen Results

Section	Station	5/12	5/14	5/20	5/27	5/30	6/10	6/11	6/24	7/13	7/14	7/22	7/23	7/28	8/1
1	2.7			9.0	10.0				7.8			8.7		8.8	
	4.4			9.7	8.7				8.3			8.0		8.7	
	6.8			9.6	8.5				8.0			8.1		8.8	
	8.3			10.0	8.4				8.1			7.9		8.6	
	9.4			10.3	8.5				8.2			7.8		8.8	
	10.6			10.2	8.8				8.4			7.7		8.8	
	11.8			9.3	8.8				8.7			7.8		8.8	
	14.1				9.0				9.7			7.9		9.0	
2	16.8								9.2						
	17.8								9.3				8.6		
	19.1								9.5				8.3		
	22.3								9.7				8.2		
	25.6								9.3				8.0		
	26.9								9.7				7.8		
	27.8								9.3				7.5		
	28.2								9.3				8.8		
	29.1								9.6				7.8		
3	29.6		11.1			10.5		8.5					7.9		9.9
	31.4		11.2			8.5		8.5					7.6		10.0
	32.2		11.6			8.2		8.5					7.6		10.0
	33.4		12.1			7.8		8.3					7.5		10.0
	35.1		11.7			7.7		8.1					7.5		10.1
	36.3		11.6			7.8		8.7					7.9		10.2
	37.9		11.7			7.6		8.6					7.7		
	38.9														
	40.0														
4	41.1	9.6					9.4		8.8		8.8				
	42.4	9.4					8.4				8.8				
	43.4	9.4					8.2				8.8				
	44.6	9.3					8.0				8.8				
	46.4	9.3					7.8				8.8				
	47.3	9.3					7.8				8.8				
	48.9	9.3					7.7				8.7				
	49.6	9.4					7.7		9.8		8.8				
5	49.9									8.3					
	50.9	9.3								8.4					
	51.8									8.7					
	52.5									8.6					
	53.1									8.6					
	54.4									8.6					
	55.9									8.9					

Median dissolved oxygen in milligrams per liter (mg/L) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Dissolved Oxygen Results (continued)

Section	Station	8/11	8/12	8/13	8/19	8/20	8/26	9/8	9/9	9/16	9/23	10/10	10/14	10/20	10/27	10/28
1	2.7		8.3			8.9	6.0		8.4		9.0		9.7			
	4.4		8.5			8.1	6.2		8.6		9.1		9.9			
	6.8		8.4			8.2	6.6		8.2		9.2		10.3			11.0
	8.3		8.4			8.4	6.2		8.3		9.2		10.2			10.6
	9.4		8.3			9.0	6.2		8.6		9.1		10.3			10.6
	10.6		8.4			8.3	6.2		8.7		8.7		10.1			10.6
	11.8		8.1			8.0	6.2		8.6		8.7		10.2			10.6
	14.1		8.1			8.2	7.1		8.3		9.2		10.4			10.8
2	16.8				7.4					8.8						
	17.8				7.4					8.4						
	19.1				7.7					8.3						
	22.3				8.0					8.7						
	25.6				8.0					8.5						
	26.9				8.2					9.1						
	27.8				6.9					9.6					8.7	
	28.2				8.3					9.3					9.4	
	29.1				8.2					9.3					9.9	
3	29.6			8.0												
	31.4			7.8												
	32.2			7.8												
	33.4			7.7												
	35.1			8.0												
	36.3			7.9												
	37.9			7.9												
	38.9			7.2												
	40.0			7.7												
4	41.1	8.4			7.9			8.0								
	42.4	8.4						8.0								
	43.4	8.5						8.0								
	44.6	8.3						8.0								
	46.4	8.4						8.2								
	47.3	8.3						8.2						11.9		
	48.9	8.5						8.3						11.6		
	49.6	8.3						8.0						11.6		
5	49.9	8.4						8.0						11.3		
	50.9	8.3						8.2						11.3		
	51.8															
	52.5															
	53.1															
	54.4															
	55.9															

Median dissolved oxygen in milligrams per liter (mg/L) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

pH Results

Section	Station	5/12	5/14	5/20	5/27	5/30	6/10	6/11	6/24	7/13	7/14	7/22	7/23	7/28	8/1
1	2.7			7.0	6.8				6.6			7.7		6.7	
	4.4			6.4	6.7				6.5			6.6		6.6	
	6.8			6.3	6.7				6.5			6.8		7.0	
	8.3			6.3	6.7				6.5			6.5		6.9	
	9.4			6.3	6.7				6.5			6.5		7.0	
	10.6			5.3	6.7				6.5			6.5		6.9	
	11.8			3.3	6.7				6.5			6.5		6.9	
	14.1				6.8				6.5			6.1		6.8	
2	16.8								6.3				6.5		
	17.8								6.5				6.5		
	19.1								6.5				6.5		
	22.3								6.5				6.5		
	25.6								6.5				6.5		
	26.9								6.5				6.5		
	27.8								6.7				6.7		
	28.2								6.7				6.6		
	29.1								6.4				6.4		
3	29.6		6.5			4.8		6.6					6.3		4.2
	31.4		6.4			6.0		6.7					6.4		5.6
	32.2		6.4			6.1		6.6					6.4		4.6
	33.4		6.5			4.1		6.6					6.4		5.5
	35.1		6.5			4.6		6.5					6.4		6.0
	36.3		6.4			4.3		6.7					6.4		6.0
	37.9		6.2			5.8		6.6					6.3		
	38.9														
	40.0														
4	41.1	6.1					6.4		6.0		6.0				
	42.4	6.2					6.4				6.1				
	43.4	6.2					6.4				6.1				
	44.6	6.2					6.5				6.2				
	46.4	6.2					6.4				6.2				
	47.3	6.2					6.4				6.2				
	48.9	6.2					6.4				6.1				
	49.6	6.3					6.4		6.0		6.0				
5	49.9									6.3					
	50.9	6.3								6.3					
	51.8									6.0					
	52.5									6.3					
	53.1									6.5					
	54.4									6.2					
	55.9									6.2					

Median pH by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

pH Results (continued)

Section	Station	8/11	8/12	8/13	8/19	8/20	8/26	9/8	9/9	9/16	9/23	10/10	10/14	10/20	10/27	10/28
1	2.7		6.6			7.5	6.8		6.9		6.6		7.5			
	4.4		6.6			7.2	6.8		6.7		6.5		7.4			5.8
	6.8		6.6			6.8	6.8		6.6		6.4	6.4	6.7			5.6
	8.3		6.6			7.3	6.8		6.6		6.5	6.4	6.6			5.5
	9.4		6.6			7.0	6.7		6.7		6.4	6.4	6.6			5.4
	10.6		6.6			6.9	6.7		6.7		6.2	6.4	6.5			5.5
	11.8		6.5			6.8	6.7		6.7		6.1	6.4	6.5			5.4
	14.1		6.4			6.6	6.4		6.6		6.1	6.3	6.4			5.8
2	16.8				6.4					6.4					5.9	
	17.8				6.4					6.3					6.1	
	19.1				6.6					6.4					5.9	
	22.3				6.7					6.4					6.0	
	25.6				6.8					6.4					6.0	
	26.9				6.8					6.6					6.0	
	27.8				6.8					6.3					6.3	
	28.2				7.0					6.6					6.4	
	29.1				6.8					6.5					6.0	
3	29.6															
	31.4															
	32.2															
	33.4															
	35.1															
	36.3															
	37.9			6.5												
	38.9			6.6												
	40.0			6.5												
4	41.1	6.6			3.3			6.3						6.0		
	42.4	6.7						6.3						5.9		
	43.4	6.7						6.3						5.8		
	44.6	6.6						6.3						5.9		
	46.4	6.7						6.4						6.0		
	47.3	6.7						6.4						5.9		
	48.9	6.7						6.3						5.9		
	49.6	6.8						6.3						5.9		
5	49.9	6.7						6.4						5.9		
	50.9	6.8						6.4						5.9		
	51.8															
	52.5															
	53.1															
	54.4															
	55.9															

Median pH by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Specific Conductance Results

Section	Station	5/12	5/14	5/20	5/27	5/30	6/10	6/11	6/24	7/13	7/14	7/22	7/23	7/28	8/1
		Data from stations 2.7 and 4.4 were too disparate to calculate meaningful specific conductance medians due to the influence of ocean water.													
1	6.8			213	211				138					127	
	8.3			188	207				138			196		127	
	9.4			187	206				138			196		125	
	10.6			187	203				139			195		125	
	11.8			185	202				137			195		126	
	14.1			182	202				137			194		125	
2	16.8								154				194		
	17.8								137				193		
	19.1								134				189		
	22.3								132				186		
	25.6								169				186		
	26.9								161				200		
	27.8								411				491		
	28.2								303				174		
	29.1								125				180		
3	29.6		117			169		189					178		109
	31.4		119			159		190					169		106
	32.2		118			157		194					169		103
	33.4		124			161		195					187		119
	35.1		122			152		176					155		104
	36.3		111			170		211					177		99
	37.9		106			135		176					151		
	38.9														
	40.0														
4	41.1	108					143		102		119				
	42.4	104					145				118				
	43.4	103					143				114				
	44.6	103					141				114				
	46.4	102					145				113				
	47.3	100					144				113				
	48.9	102					144				112				
	49.6	99					142		99		114				
5	49.9									117					
	50.9	103								128					
	51.8									97					
	52.5									139					
	53.1									199					
	54.4									164					
	55.9									96					

Median specific conductance in micro-Siemens per cm (µS/cm) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Specific Conductance Results (continued)

Section	Station	8/11	8/12	8/13	8/19	8/20	8/26	9/8	9/9	9/16	9/23	10/10	10/14	10/20	10/27	10/28
		Data from stations 2.7 and 4.4 were too disparate to calculate meaningful specific conductance medians due to the influence of ocean water.														
1	6.8		164			253	161		182		228	185				
	8.3		163			563	158		182		219	184	203			
	9.4		166			188	156		179		219	183	248			
	10.6		176			188	154		178		220	177	171			
	11.8		166			187	154		178		220	177	165			
	14.1		169			187	156		179		218	177	169			
2	16.8				191					218					119	
	17.8				189					226					113	
	19.1				180					235					110	
	22.3				175					208					107	
	25.6				201					258					115	
	26.9				246					253					111	
	27.8				592					412					441	
	28.2				178					197					254	
	29.1				176					195					99	
3	29.6			160												
	31.4			147												
	32.2			144												
	33.4			170												
	35.1			142												
	36.3			166												
	37.9			133												
	38.9			196												
	40.0			122												
4	41.1	121			130			132						128		
	42.4	120						132						121		
	43.4	118						129						118		
	44.6	119						127						120		
	46.4	116						135						138		
	47.3	116						133						131		
	48.9	111						128						123		
	49.6	114						129						129		
5	49.9	121						132						127		
	50.9	116						133						126		
	51.8															
	52.5															
	53.1															
	54.4															
	55.9															

Median specific conductance in micro-Siemens per cm (µS/cm) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Total Dissolved Solids Results

Section	Station	5/12	5/14	5/20	5/27	5/30	6/10	6/11	6/24	7/13	7/14	7/22	7/23	7/28	8/1
		Data from stations 2.7 and 4.4 were too disparate to calculate meaningful TDS medians due to the influence of ocean water.													
1	6.8			0.14	0.14				0.09					0.08	
	8.3			0.12	0.13				0.09			0.13		0.08	
	9.4			0.12	0.13				0.09			0.13		0.08	
	10.6			0.12	0.13				0.09			0.13		0.08	
	11.8			0.12	0.13				0.09			0.13		0.08	
	14.1			0.12	0.13				0.09			0.13		0.08	
2	16.8								0.10				0.13		
	17.8								0.09				0.13		
	19.1								0.09				0.12		
	22.3								0.09				0.12		
	25.6								0.11				0.12		
	26.9								0.11				0.13		
	27.8								0.27				0.32		
	28.2								0.20				0.11		
	29.1								0.08				0.12		
3	29.6		0.08			0.11		0.12					0.12		0.07
	31.4		0.08			0.10		0.12					0.11		0.07
	32.2		0.08			0.10		0.13					0.11		0.07
	33.4		0.08			0.10		0.13					0.12		0.08
	35.1		0.08			0.10		0.12					0.10		0.07
	36.3		0.07			0.11		0.14					0.12		0.06
	37.9		0.07			0.09		0.11					0.10		
	38.9														
	40.0														
4	41.1	0.07					0.09		0.07		0.08				
	42.4	0.07					0.09				0.08				
	43.4	0.07					0.09				0.07				
	44.6	0.07					0.09				0.07				
	46.4	0.07					0.09				0.07				
	47.3	0.07					0.09				0.07				
	48.9	0.07					0.09				0.07				
	49.6	0.06					0.09		0.06		0.07				
5	49.9									0.08					
	50.9	0.07								0.08					
	51.8									0.06					
	52.5									0.09					
	53.1									0.13					
	54.4									0.11					
	55.9									0.06					

Median total dissolved solids in grams per liter as NaCl (g/L) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Total Dissolved Solids Results (continued)

Section	Station	8/11	8/12	8/13	8/19	8/20	8/26	9/8	9/9	9/16	9/23	10/10	10/14	10/20	10/27	10/28
		Data from stations 2.7 and 4.4 were too disparate to calculate meaningful TDS medians due to the influence of ocean water.														
1	6.8		0.11			0.16	0.10		0.12		0.15	0.12				
	8.3		0.11			0.37	0.10		0.12		0.14	0.12	0.13			
	9.4		0.11			0.12	0.10		0.12		0.14	0.12	0.16			
	10.6		0.11			0.12	0.10		0.12		0.14	0.12	0.11			
	11.8		0.11			0.12	0.10		0.12		0.14	0.12	0.11			
	14.1		0.11			0.12	0.10		0.12		0.14	0.12	0.11			
2	16.8				0.12					0.14					0.08	
	17.8				0.12					0.15					0.07	
	19.1				0.12					0.15					0.07	
	22.3				0.11					0.14					0.07	
	25.6				0.13					0.17					0.08	
	26.9				0.16					0.16					0.07	
	27.8				0.39					0.27					0.29	
	28.2				0.12					0.13					0.17	
	29.1				0.12					0.13					0.07	
3	29.6			0.10												
	31.4			0.10												
	32.2			0.09												
	33.4			0.11												
	35.1			0.09												
	36.3			0.11												
	37.9			0.09												
	38.9			0.13												
	40.0			0.08												
4	41.1	0.08			0.08			0.09						0.08		
	42.4	0.08						0.09						0.08		
	43.4	0.08						0.08						0.08		
	44.6	0.08						0.08						0.08		
	46.4	0.08						0.09						0.09		
	47.3	0.08						0.09						0.09		
	48.9	0.07						0.08						0.08		
	49.6	0.07						0.08						0.08		
5	49.9	0.08						0.09						0.08		
	50.9	0.08						0.09						0.08		
	51.8															
	52.5															
	53.1															
	54.4															
	55.9															

Median total dissolved solids in grams per liter as NaCl (g/L) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Salinity Results

Section	Station	5/12	5/14	5/20	5/27	5/30	6/10	6/11	6/24	7/13	7/14	7/22	7/23	7/28	8/1
1	2.7	Data from stations 2.7 and 4.4 were too disparate to calculate meaningful salinity medians due to the influence of ocean water.													
	4.4														
	6.8			0.10	0.10				0.06					0.06	
	8.3			0.09	0.10				0.06			0.09		0.06	
	9.4			0.09	0.10				0.06			0.09		0.06	
	10.6			0.09	0.10				0.06			0.09		0.06	
	11.8			0.09	0.10				0.06			0.09		0.06	
	14.1			0.09	0.10				0.06			0.09		0.06	
2	16.8								0.07				0.09		
	17.8								0.06				0.09		
	19.1								0.06				0.09		
	22.3								0.06				0.09		
	25.6								0.08				0.09		
	26.9								0.08				0.09		
	27.8								0.20				0.24		
	28.2								0.15				0.08		
	29.1								0.06				0.08		
3	29.6		0.06			0.08		0.09					0.08		0.05
	31.4		0.06			0.08		0.09					0.08		0.05
	32.2		0.06			0.07		0.09					0.08		0.05
	33.4		0.06			0.08		0.09					0.09		0.05
	35.1		0.06			0.07		0.08					0.07		0.05
	36.3		0.05			0.08		0.10					0.08		0.05
	37.9		0.05			0.06		0.08					0.07		
	38.9														
	40.0														
4	41.1	0.05					0.07		0.05		0.06				
	42.4	0.05					0.07				0.05				
	43.4	0.05					0.07				0.05				
	44.6	0.05					0.07				0.05				
	46.4	0.05					0.07				0.05				
	47.3	0.05					0.07				0.05				
	48.9	0.05					0.07				0.05				
	49.6	0.05					0.07		0.05		0.05				
5	49.9									0.05					
	50.9	0.05								0.06					
	51.8									0.04					
	52.5									0.07					
	53.1									0.10					
	54.4									0.08					
	55.9									0.04					

Median salinity in parts per thousand (ppt) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project

Salinity Results (continued)

Section	Station	8/11	8/12	8/13	8/19	8/20	8/26	9/8	9/9	9/16	9/23	10/10	10/14	10/20	10/27	10/28
1	2.7	Data from stations 2.7 and 4.4 were too disparate to calculate meaningful salinity medians due to the influence of ocean water.														
	4.4															
	6.8		0.08			0.12	0.07		0.09		0.11	0.09				
	8.3		0.08			0.27	0.07		0.09		0.10	0.09	0.10			
	9.4		0.08			0.09	0.07		0.08		0.10	0.09	0.12			
	10.6		0.08			0.09	0.07		0.08		0.10	0.08	0.08			
	11.8		0.08			0.09	0.07		0.08		0.10	0.08	0.08			
	14.1		0.08			0.09	0.07		0.08		0.10	0.08	0.08			
2	16.8				0.09					0.10					0.06	
	17.8				0.09					0.11					0.05	
	19.1				0.08					0.11					0.05	
	22.3				0.08					0.10					0.05	
	25.6				0.09					0.13					0.05	
	26.9				0.11					0.12					0.05	
	27.8				0.29					0.20					0.21	
	28.2				0.08					0.09					0.12	
	29.1				0.08					0.09					0.05	
3	29.6			0.07												
	31.4			0.07												
	32.2			0.07												
	33.4			0.08												
	35.1			0.07												
	36.3			0.08												
	37.9			0.06												
	38.9			0.09												
	40.0			0.06												
4	41.1	0.06			0.06			0.06						0.06		
	42.4	0.06						0.06						0.06		
	43.4	0.05						0.06						0.06		
	44.6	0.06						0.06						0.06		
	46.4	0.05						0.06						0.07		
	47.3	0.05						0.06						0.06		
	48.9	0.05						0.06						0.06		
	49.6	0.05						0.06						0.06		
5	49.9	0.06						0.06						0.06		
	50.9	0.05						0.06						0.06		
	51.8															
	52.5															
	53.1															
	54.4															
	55.9															

Median salinity in parts per thousand (ppt) by station in the Merrimack River, Massachusetts and New Hampshire during 2009.

Highlighted cells indicate stations upstream and downstream of the Lawrence Project