Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2011

Massachusetts Water Resources Authority

Environmental Quality Department

Report ENQUAD 2012-07

Citation

Coughlin, Kelly. 2012**. Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2011.** Boston: Massachusetts Water Resources Authority. Report 2012-07. 46 pp.

Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2011

Prepared by:

Kelly Coughlin
Environmental Quality Department, Operations Division
Massachusetts Water Resources Authority
100 First Avenue, Boston, MA 02129

July 2012

Environmental Quality Department Technical Report 2012-07

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

This report summarizes data collected as part of Massachusetts Water Resources Authority's (MWRA's) combined sewer overflow (CSO) receiving water monitoring program, and is produced in accordance with the variance for CSO discharges to Lower Charles River/Charles Basin and Variance for CSO discharges to the Alewife Brook/Upper Mystic River. The goal of this monitoring is to identify the water quality impacts of CSO flows on water bodies.

During the 2011 calendar year, MWRA continued to implement its Long Term CSO Control Plan, which was developed to address CSO discharges from all CSOs hydraulically connected to the MWRA sewer system and its member communities. This monitoring summary provides an assessment of water quality in the Charles and Mystic Rivers, which are affected by CSO projects implemented as part of this plan.

In 2010, the Massachusetts Department of Environmental Protection (MADEP) extended the Variance for CSO discharges to the Lower Charles River/Charles Basin issued to MWRA, Boston Water and Sewer Commission (BWSC) and the City of Cambridge respectively by three years, to October 1, 2013. MADEP also extended the Variance for CSO discharges to the Alewife Brook/Upper Mystic River issued to MWRA, the City of Cambridge and the City of Somerville respectively by three years, to September 1, 2013.

Under the agreement on the Long Term Control Plan (the "Plan") reached by EPA, MADEP and MWRA in March 2006, MADEP agreed to issue a series of three-year variance extensions until 2020, and MWRA agreed to implement the revised Plan by 2015 and verify the predicted performance at all CSO outfalls by 2020. At that time, DEP will consider issuing long-term water quality standards determinations, based on the verified performance of the Plan and other conditions affecting the water quality and uses of these water bodies.

Conditions in the recent variance extensions require MWRA to implement the Plan and require MWRA and the municipalities to continue to implement the Nine Minimum Controls of EPA's National CSO Control Policy, and all of the CSO permittees are required to report estimated CSO discharge frequency and volume from their respective outfalls to these receiving waters on an annual basis. MWRA is also required to continue receiving water quality monitoring to assess impacts of CSO discharges.

2011 CSO progress as it relates to the Charles River and Alewife Brook/Mystic River includes the following:

- The Town of Brookline has commenced its $16.6 million construction contract, which is the final contract of the Brookline sewer separation project. Nearly 60% complete, this project involves sewer separation in several areas of Brookline totaling 72 acres where there are remaining combined sewers tributary to MWRA's Charles River Valley Sewer. The project is intended to reduce discharges to the Charles River at MWRA's Cottage Farm facility. The contract involves the installation of large sanitary sewers in Beacon, St. Mary's, and Monmouth Streets and the conversion of existing combined sewers to storm drains. The Brookline Sewer

Separation Project includes MWRA's plan to rehabilitate outfall MWR010, which will convey the separated stormwater to the Charles River. All of Brookline and MWRA's work is scheduled to be complete by the end of 2012, and the CSO benefit of the project should be realized then.

- On March 30, 2011 the City of Cambridge completed construction of $5.4 million CAM400 Common Manhole Separation project. This project closed the CAM400 outfall—eliminating 600,000 gallons of CSO per year—and reduced stormwater flows to its combined sewer system and MWRA interceptors.

- Cambridge is 40% complete with its construction of the CAM004 stormwater outfall and wetland basin project, which commenced in spring 2011. This project will provide detention and wetlands treatment to stormwater flows that will be removed from the Cambridge combined sewer system in the Huron Avenue/Concord Avenue area with construction contracts scheduled in 2012-15 (see "CAM004 Sewer Separation project"), to mitigate water quality and flooding impacts to Alewife Brook.

- Cambridge also plans to issue a Notice to Proceed with final design of the CAM004 Sewer Separation project by September 2012. This project is intended to close Outfall CAM004 and lower discharges at other outfalls and is the centerpiece of MWRA's Alewife Brook CSO control plan.

- On March 30, 2012 MWRA issued a notice to proceed with a contract for design of the last two CSO projects in the Long-Term Control Plan, both benefitting Alewife Brook: the Control Gate/Floatables Control at Outfall MWR003 and MWRA Rindge Avenue Siphon Relief project and the Interceptor Connection Relief and Floatables Control at Outfall SOM01A project.

As of the end of 2011, 37 CSOs have been closed or effectively closed in Boston Harbor and its tributaries; 47 CSOs remained active.[1] In the Charles, nine CSOs remained active and ten have been closed. In the Alewife Brook, seven CSOs remained active, six have been closed. In the Mystic River, one treated CSO (Somerville Marginal) remains active, discharging at two locations depending on tide (MWR205A upstream of the Amelia Earhart dam and MWR205 in the marine river mouth). BOS17 also discharges at the river mouth.

System-wide, average annual CSO discharge has been reduced from 3.3 billion gallons in 1988 to 527 million gallons as of the end of 2011, an 84% reduction, with 83% of current discharge volume receiving treatment at MWRA's four CSO treatment facilities. Other system improvements since the 1990s have also reduced the frequency and volume of CSO flows over the period of the monitoring program and has resulted in increased treatment of remaining flows. Figure 1-1 shows the estimated CSO flow reduction system-wide

[1] SOM002 and SOM006 were closed prior to the approval of the Long Term Control Plan and are included in this total. SOM009 discharges to the system upstream of other outfalls and is not included in the overall count. CAM009 and 011 are also included, which are temporarily closed, pending the results of a long-term hydraulic assessment by the City of Cambridge. Discharges at BOS-081, -082, -084, -085 and -086 are effectively eliminated, with a 25-year storm level of control.

since 1987, and Figure 1-2 shows the CSO flow reduction by receiving water. For purposes of this report, receiving water quality data from 2006 to the present is considered representative of current conditions.

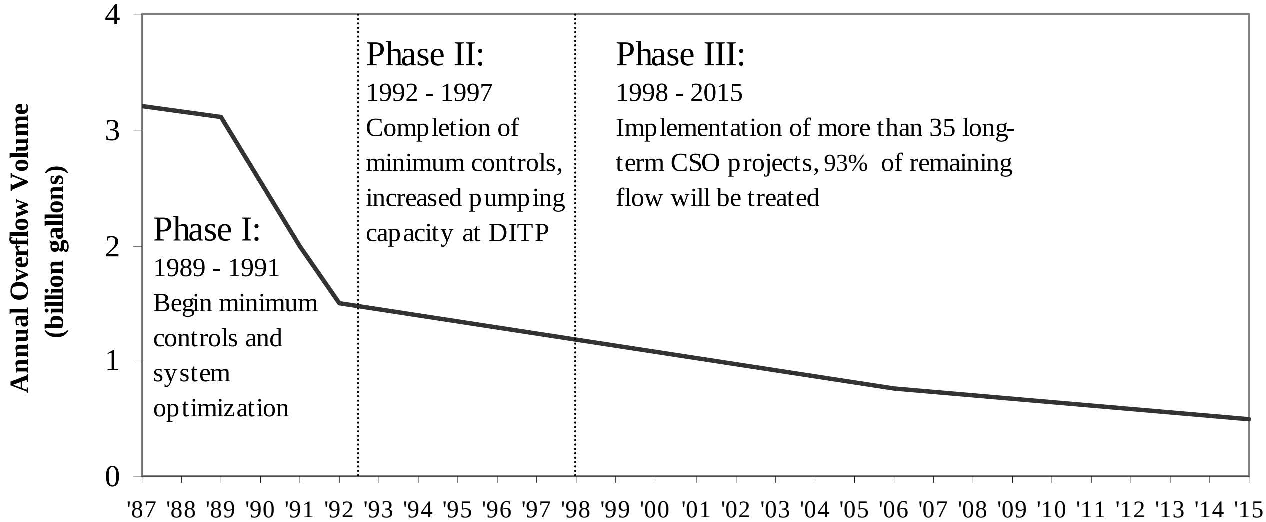

Figure 1-1. Estimated CSO flow reductions, 1987 – 2015.
Source: MWRA CSO Annual Progress Report 2011 (March 2012)

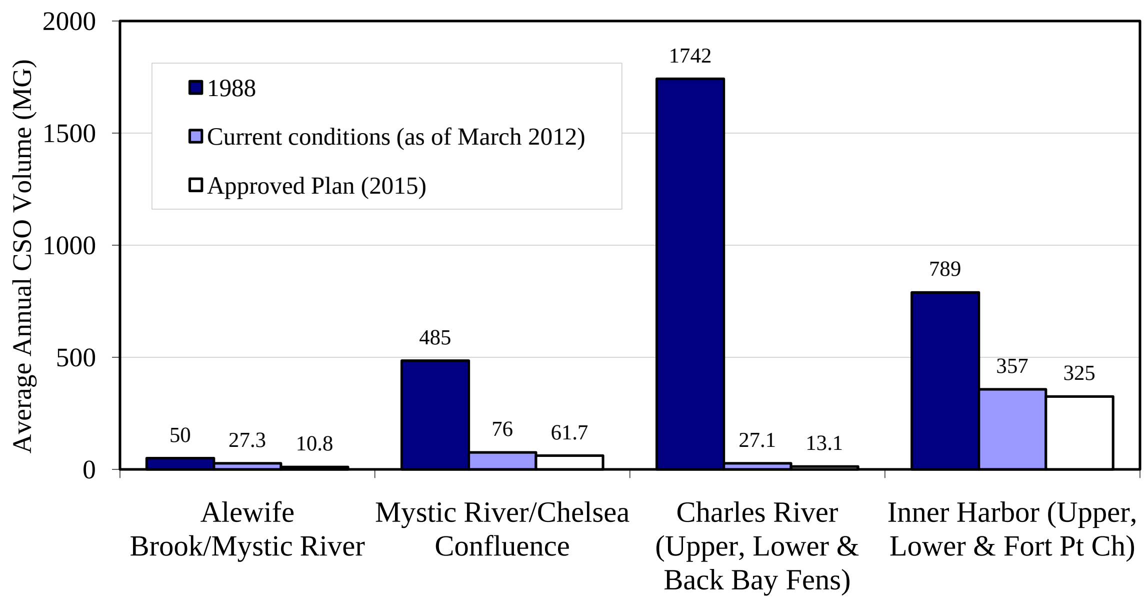

Figure 1-2. CSO Typical Year Discharge Volumes for 1988, Current, and Approved Long Term Control Plan model estimates
Source: MWRA CSO Control Plan Annual Progress Report 2011 (March 2012)

Rainfall volumes at various locations in the MWRA service area appear in Table 1-1. The table summarizes the frequency of rain events within selected ranges of total rainfall for 2011. There were fewer storms less than 1.0 inch rainfall depth and more storms greater than 1.0 inch rainfall depth, storms that typically cause CSOs to discharge. There were no extreme storms like those that occurred in 2010, though localized, short duration heavy downpours that can overwhelm combined sewers in affected areas did occur. Total rainfall for the year was as much as 20% higher than the average (data not shown). CSO discharge estimates overall are higher than the Typical Year predictions because 2011 was a wetter year (refer to Tables 3-3 and Table 4-3- for CSO discharge estimates for the Charles and Mystic, respectively).

Table 1-1. Comparison of rain event frequency by rainfall volume, 2011 rainfall vs. typical year.

	Total Rainfall (in.)	**Total Number of Storms**	**Number of storms, by rainfall volume**				
			<0.25 inches	**0.25 – 0.5 inches**	**0.5 – 1.0 inches**	**1.0 – 2.0 inches**	**≥2.0 inches**
Typical Year	46.8	93	49	14	16	8	6
2011 Ward St. Headworks	60.85	84	34	9	14	20	7
2011 Columbus Park Headworks	54.93	80	33	9	15	16	7
2011 Chelsea Creek Headworks	53.57	79	30	12	13	21	3
2011 Fresh Pond (USGS)	52.12	93	43	11	21	15	3

Source: MWRA CSO Discharge Estimates and Rainfall Analyses for Calendar Year 2011, Table 1.

1.1 Overview of the monitoring program

MWRA's CSO receiving water quality monitoring program has been ongoing since 1989, with most sampling locations continuously monitored since 1991. All harbor and tributary areas impacted by CSOs in Boston, Chelsea, Cambridge, and Somerville are included in the monitoring program. For most sampling locations included in this report, at least 20 samples have been collected each year.

1.2 Organization and purpose of the report

Chapter 2 presents the materials and methods used in monitoring. Chapters 3 and 4 of this report discuss the results of the CSO receiving water quality monitoring program in the Charles River and Mystic River/Alewife Brook. Water quality parameters examined for each region include: bacterial indicators (*E. coli*, *Enterococcus* and fecal coliform), dissolved oxygen, water clarity (Secchi depth, total suspended solids), nutrients (phosphate, ammonium, nitrate/nitrite) and chlorophyll.

The purpose of the report is to summarize 2011 water quality in the Charles and Alewife Brook/Mystic River. The report compares sampling results to water quality standards, and shows spatial and temporal variations in water quality, and differences between wet and dry weather. Data from the previous five monitoring years are analyzed together for representativeness, and data for 2011 for bacterial and physical parameters are also shown separately.

2 Materials and Methods

2.1 Field and laboratory methods

2.1.1 Selection of sampling locations

Some sampling locations were chosen for their proximity to CSO discharges and others were chosen to provide representative water quality measurements for a given area. Complete lists of stations including descriptions for the Charles and Mystic River/Alewife Brook appear in Section 3.1 and 4.1, respectively.

2.1.2 Sampling schedules

Approximately 20 station visits or more were made to each location each year, within two separate monitoring projects. Eutrophication monitoring is conducted once monthly year-round at a subset of river locations, and includes nutrient, chlorophyll, TSS, bacteria, and physical measurements. CSO receiving monitoring includes bacteria sampling and physical measurements that are collected between April and December of each year, in weekly rotations for each region. Sampling is random with respect to weather; however efforts were made to collect additional samples during wet weather, if an inadequate number of station visits occurred following rainfall events by mid-year.

2.1.3 Sample collection

At all locations, water samples and water quality measurements were collected near-surface (approximately 0.1 meters below surface).   Surface samples were collected by grab into rinsed sample containers. Bottom samples were collected at locations with a water depth greater than 3 meters, using a Kemmerer sampler or alpha bottle at 0.5 meters above the sediment surface. Bottom water quality measurements (physical measurements such as dissolved oxygen, temperature, and salinity) were made at most locations regardless of depth, but some upstream locations are too shallow for separate bottom readings. Separate sampling containers were used for bacteria, nutrient, and TSS analyses.

2.1.4 Field measurements

Field measurements were made with different instruments over the course of the monitoring program. Table 2-1 lists the instruments used and the variables measured.

Table 2-1. Field measurements.

Variable	Instruments used
Temperature, conductivity/salinity, dissolved oxygen, turbidity, pH	Hydrolab Datasonde 4 (1997 - 2008) Hydrolab Datasonde 5 (2006 - 2011) YSI6600, YSI6820 (2009 - 2011) YSI 600XL for temperature, conductivity, dissolved oxygen (1999 – 2011)
Secchi Depth	Wildco 8-inch limnological Secchi disk (upstream of dams) Wildco 8-inch oceanographic Secchi disk (marine waters)

2.1.5 Rainfall measurements

Rainfall measurements were taken from the National Weather Service (NWS) rain gauge located at Logan Airport in East Boston, as this was considered the most representative location for the entire monitoring area. Results from the gauge are reported in one-day intervals. Data are downloaded from the NWS website and stored in MWRA's Environmental Monitoring & Measurement System (EM&MS) database.

2.1.6 Laboratory analyses

Samples were analyzed at the MWRA Central Laboratory. For enumeration of bacteria, nutrients, and TSS, MWRA Department of Laboratory Services Standard Operating Procedures is followed.

Detailed laboratory methods with quality assurance and quality control procedures are described in the Central Laboratory Standard Operating Procedure (MWRA 2009).

Table 2-2 lists the analytes measured and methods used in the monitoring program. MWRA discontinued *E. coli* monitoring at marine locations due to methodological concerns with the use of the Colilert method for marine samples, replacing *E. coli* with fecal coliform. Fecal coliform monitoring was resumed in Alewife Brook in 2010 to supplement long term historical data and to validate *E. coli* results.

Table 2-2. Laboratory measurements.

Analyte	Method
Enterococcus	Standard Methods 9230C 2c, membrane filtration (for samples collected 1996 – 2003) EPA Method 1600 (for samples collected 1999 – 2006, some 2008) Enterolert (for samples collected 2008 - 2011)
E. coli	Modified EPA 1103.1, membrane filtration (for samples collected 2000 – 2006) Colilert (for samples collected 2009 - 2011)
Fecal coliform	Standard Methods 9222D, membrane filtration
Total suspended solids	Clesceri et al. (1998, Method 2540D), using nucleopore filters
Total phosphorus	TP and/or TDP: Solarzano and Sharp (1980a); PP: Solarzano and Sharp (1980a), Whatman GF/F
Phosphate	Murphy and Riley (1962), modified as in Clesceri et al (1998, Method 4500-P F) Skalar SAN^{plus} autoanalyzer, Whatman GF/F filters
Total Nitrogen	TN and/or TDN: Solarzano and Sharp (1980b), Whatman G/F filters; PN: Perkin Elmer CHN analyzer, Whatman GF/F
Ammonium	Fiore and O'Brien (1962), modified as in Clesceri et al (1998, Method 4500-NH3 H), Skalar SAN^{plus} autoanalyzer, Whatman GF/F filters
Nitrate+nitrite	Bendshneider and Robinson (1952), modified as in Clesceri et al (1998, Method 4500-NO3 F), Skalar SAN^{plus} autoanalyzer, Whatman GF/F filters
Chlorophyll *a*	Acid-corrected (Holm Hansen 1965) as described in EPA (1992). Sequoia Turner Model 450 fluorometer, GF/F filters

2.2 Data analysis

Descriptive Analyses. Indicator bacteria counts are typically log-normally distributed, and therefore a proper measure of central tendency for these data is the geometric mean. Geometric means and their associated 95% confidence intervals were calculated for the measurements made at each station over the sampling period.

Many results are plotted as percentile plots, as shown in Figure 2-1. These plots present a frequency distribution of a group of measurements. Each box comprises measurements from a single beach or sampling location. Values are shown in Figure 2-1 for the 10th, 25th, 50th, 75th, and 90th percentiles. Single measurements beyond these ranges (outliers) are displayed as dots.

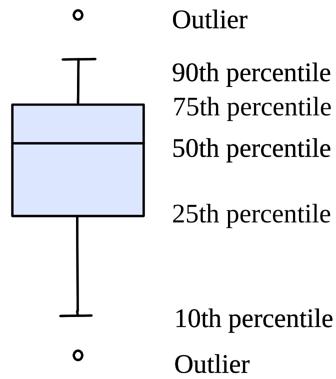

Figure 2-1. Percentile distributions indicated on percentile plots

Box plots display the range and central tendencies of the data allow for easy comparison of the results among stations. The 50th percentile (median) is equivalent to the geometric mean, assuming the data are log-normally distributed.

2.3 Water Quality Standards used in this report

Standards are shown in Table 2-6, and include standards and guidelines from the Massachusetts Department of Environmental Protection (MADEP), Environmental Protection Agency (EPA), Massachusetts Department of Public Health (MADPH), and the Massachusetts Division of Marine Fisheries (MADMF). The MADEP standard for Class SB waters (fishable swimmable) are based on *E. coli* and/or *Enterococcus* counts for freshwater, and *Enterococcus* counts for marine waters, following a USEPA recommendation for *Enterococcus* in marine waters (USEPA 1986). The Massachusetts Department of Public Health issued regulations for beach management based on the USEPA criteria. MADMF uses fecal coliform to monitor shellfish growing waters.

Table 2-3. 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	6.5 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 MADPH, 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, MADEP	*E. coli*	Single sample limit 235 colonies/100 ml (freshwater only); geometric mean 126 colonies/100 ml (freshwater only)
Pre-2007, primary contact recreation, MADEP	Fecal coliform	Geometric mean ≤ 200 colonies/100 ml, no more than 10% of samples above 400 colonies/100 ml
Restricted shellfishing, MADMF	Fecal coliform	Geometric mean ≤ 88 colonies/100 ml
Primary contact recreation, MADEP, aesthetics -- transparency	Secchi disk depth	≥ 1.2 meters (4 feet) at public bathing beaches and lakes

[1] All receiving water areas discussed in this report are either Class B or SB according to MADEP standards current as of January 2007 (except for Mystic River mouth, which is SB_{CSO}. SB_{CSO} has the same water quality standards as SB except CSOs are present).

From MADEP 2007:

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.

3 Results: Charles River

3.1 Sampling area

MWRA's sampling area in the Charles River includes the river segment from the Watertown Dam in Watertown downstream to the New Charles River Dam in Boston, near the river mouth. This area, for purposes of this report called the Charles Basin, is freshwater and designated Class B with a variance for Combined Sewer Overflows by MADEP (the variance was extended in 2010). The river segment is approximately 10.3 km (8.6 mi) long. The New Charles River Dam and locks limit river flow and tidal exchange at the river mouth.

MWRA monitoring locations are primarily located midstream, bracketing CSO outfalls. Locations were also selected near to or downstream of outfalls where accessible by boat: at the Stony Brook outlet and CSO (MWR023), Faneuil Brook outlet and CSO that has since been closed (BOS032, closed in 1997), and downstream of the Cottage Farm CSO outfall diffusers (MWR201).

For purposes of this report, MWRA's monitoring area in the lower Charles is divided into three smaller reaches. Table 3-1 describes the reaches, sampling locations and CSOs within each reach. Sampling locations and CSOs appear in Figure 3-1.

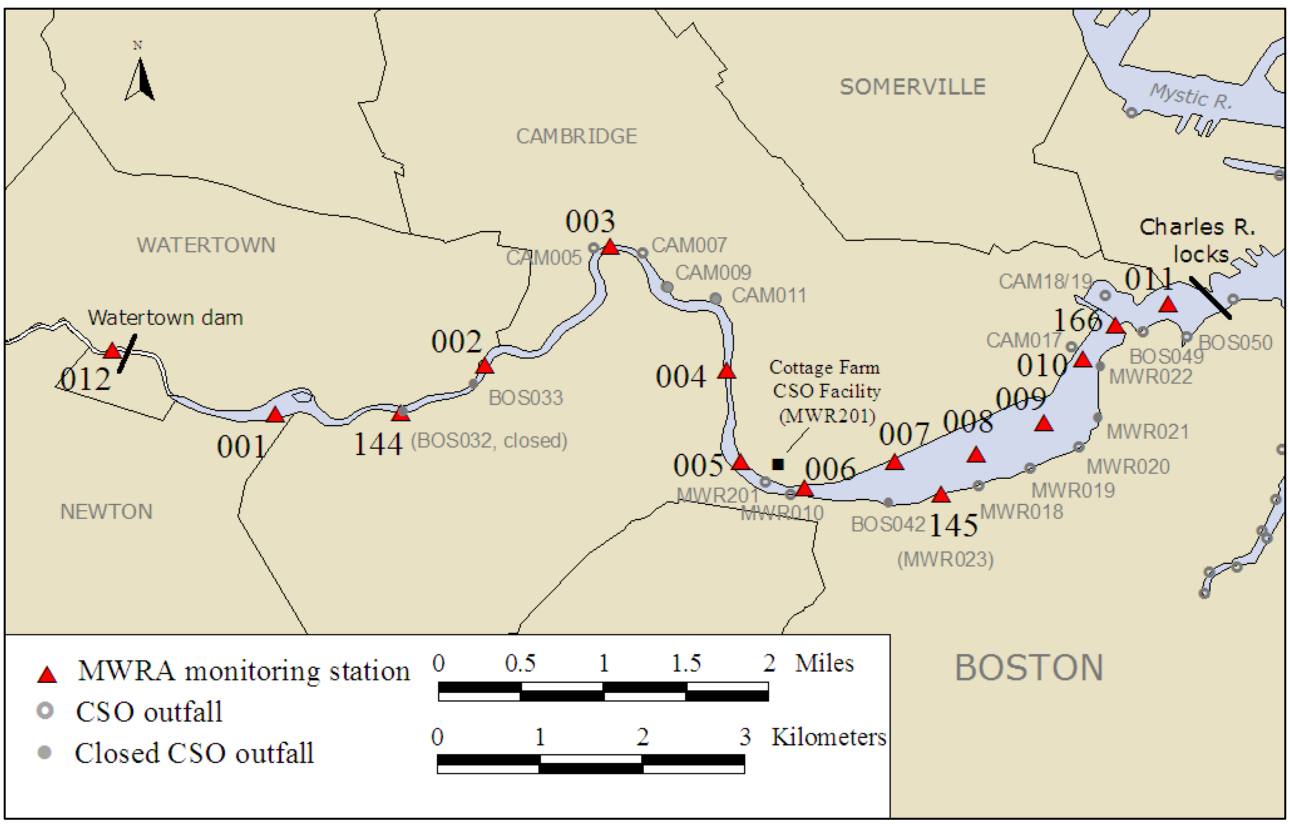

Figure 3-1. Map of MWRA Charles River sampling locations

Table 3-1. MWRA monitoring locations, Charles River Basin.

Reach	Description of Reach	Sampling location	Location Description
Upper Basin (Class B/Variance, warm water fishery)	Watertown Dam in Watertown, downstream to Magazine Beach (near BU Bridge) in Cambridge	012, Watertown	Watertown Dam at footbridge (upstream of all CSOs)
		001, Newton	Downstream of Newton Yacht Club (upstream of all CSOs)
		144, Allston	Faneuil Brook outlet (at BOS032, closed 11/97)
		002, Allston	Downstream of Beacon St. Bridge (downstream of BOS033, closed 10/96)
		003, Cambridge	Downstream of Eliot Bridge, Cambridge side (at CAM005)
		004, Cambridge/Allston	Between River St. and Western Ave. bridges
		005, Cambridge	10 m off of Magazine Beach
Mid-Basin (Class B/Variance, warm water fishery)	BU Bridge on Boston/Cambridge line to downstream of Longfellow Bridge	006, Cambridge/Boston	BU Bridge, downstream side (downstream of MWR201)
		007, Cambridge	MIT Boathouse, Cambridge side
		145, Boston	Stony Brook outlet, Boston side (at MWR203)
		008, Cambridge/Boston	Mass. Ave Bridge, downstream side (downstream of MWR203, MWR018)
		009, Cambridge/Boston	Longfellow Bridge, upstream side (downstream of MWR021, closed 3/00)
		010, Boston	Longfellow Bridge, downstream side (downstream of MWR022, closed 3/00)
Lower Basin (Class B/Variance, warm water fishery)	Science Museum to North Station railroad bridge, near Charlestown.	166, Boston	Science Museum, upstream of old dam (downstream of all lower basin CSOs)
		011, Boston	Between Science Museum and New Charles Dam/locks (downstream of all Charles CSOs)

Sampling locations are midstream unless otherwise noted.

3.2 Pollution sources

Known pollution sources to the Charles River are shown in Table 3-2, which include nine active CSOs. MWRA's Cottage Farm CSO treatment facility, located upstream of the BU Bridge, screens, chlorinates and dechlorinates CSO flow before discharge and is the only source of treated CSO discharge to the river. (MWRA's Prison Point CSO facility, located near the Charles River mouth, has its discharge point on the Boston Harbor side of the New Charles Dam.) With increases in sewer system capacity, the number of activations at Cottage Farm has decreased since the late 1990's – from 24 activations in 1999 to 10 activations in 2011. The Stony Brook/Muddy River outlet near Kenmore Square is a source of contaminated brook flow and stormwater flows to the basin area, however CSO discharge volumes to the Stony Brook have been reduced in recent years due to sewer separation by Boston Water and Sewer Commission (BWSC) in the mid-2000s.

Table 3-3 shows the MWRA model simulation results for CSOs affecting the Charles River Basin in calendar year 2011. Actual CSO volumes and activation frequency are available for the Cottage Farm CSO facility, while the remaining results are estimated using model data. According to the simulation in 2011 conditions, only one untreated CSO--CAM017--discharged in 2011, with two activations.

The receiving water program is designed to capture water quality in all weather conditions. Table 3-4 summarizes the proportion of samples collected in dry, damp, and wet weather, which indicate a slightly higher proportion of samples collected in rainy conditions than prior years.

Table 3-2. Charles River Basin pollution sources.

Source	Upper Basin	Mid-Basin	Lower Basin
CSOs (untreated)	2 active, 4 closed CAM005, CAM007 CAM009 closed 11/07 CAM011 closed 11/07 BOS032 closed 11/97 BOS033 closed 10/96	6 active, 3 closed MWR010, MWR023, MWR018, MWR019, MWR20, CAM017 BOS042 closed 5/96 MWR021 closed 3/00 MWR022 closed 3/00	3 closed BOS049 closed 7/10 BOS028 closed SOM010 closed
CSO treatment facility (settling and detention; screened, chlorinated and dechlorinated CSO discharge)	No	Yes Cottage Farm (MWR201) Activated 10 times in 2011	No
Storm drains	Yes	Yes	Yes
Upstream inputs (elevated bacteria counts upstream)	Yes	Yes	Yes
Dry weather inputs (elevated bacteria counts in dry weather)	Yes	Yes	Yes
Tributary brook or stream flow	Yes	Yes	Yes

Table 3-3. Charles River Basin CSO activations, results of MWRA model simulations and facility records for 2011 system conditions and 2011 rainfall.[1]

CSO Outfall	Activation Frequency	Total Discharge Duration (hr)	Total Discharge Volume (million gallons)
Upper Charles			
CAM005	3	4.68	1.77
CAM007	2	3.48	2.15
TOTAL		8.17	3.92
Back Bay Fens (Muddy River)			
BOS046	0	0	0.00
TOTAL		0	0.00
Lower Charles			
CAM017	2	2.24	2.04
MWR010	0	0	0.00
MWR018	0	0	0.00
MWR019	0	0	0.00
MWR020	0	0	0.00
MWR201 (Cottage Farm Facility) [2,3]	6	18.2	47.30
MWR023 (Stony Brook)	0	0	0.00
TOTAL		20.44	49.34

[1]Activation frequency and volume are from MWRA model results, except where noted.
[2]Activation frequency and volume are from MWRA facility records (measurements).
[3]47.3 million gallons of 49.3 million gallons – or 96% – of total annual CSO discharge to the Lower Charles is treated.

Table 3-4. Charles River sample collection by rainfall condition.

Sampling period	Dry[1]	Damp[1]	Wet[1]	Total
2006 - 2010	31% 1037 samples	32% 1059 samples	37% 1208 samples	100% 3304 samples
2011	22% 148 samples	37% 245 samples	41% 274 samples	100% 667 samples

[1] Dry: no rainfall for previous 3 days; Wet: at least 0.5 inches in previous 2 days; damp is everything in between. Sampling is random with respect to weather, though if needed wet weather sampling is added late in the year to maintain a representative annual sample.

3.3 Summary of water quality, 2007-2011

A detailed summary of water quality results collected during the last five years is shown in Table 3-5.

Table 3-5. Summary of water quality, Charles River Basin 2007 - 2011.

Parameter		MA DEP Water Quality Guideline or Standard	Upper Basin				Mid-Basin				Lower Basin			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Surface Temperature (°C)[1]	Summer	<28.3	20.8 ± 4.9	98.3	6.3 - 30.3	998	20.3 ± 4.6	97.6	6.8 - 29.6	936	21.9 ± 4.5	88.6	8.4 - 29.9	272
	Winter		2.5 ± 2.7	100.0	-0.1 - 9.1	52	ND	ND	ND	0	3.7 ± 2.3	100.0	0.7 - 10.4	56
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	7.8 ± 1.8	95.0	0.6 - 14.5	986	6 ± 3.3	69.0	0 - 12.7	925	6.9 ± 2.4	80.8	0.3 - 13.8	271
	Winter	5.0	14.2 ± 1.3	100.0	11.1 - 15.8	48	ND	ND	ND	0	13.2 ± 1.1	100.0	10.2 - 15.8	54
pH[6] (S.U.)		6.5-8.3	6.5-8.3	7.3 ± 0.4	98.7	6.7 - 8.9	1438	7.2 ± 0.7	91.5	6.2 - 9.5	1235	7.4 ± 0.6	92.1	6.4 - 9.4
Water clarity	Total Suspended Solids (mg/L)	NS	4.5 ± 5.5	-	0.5 - 37.5	128	ND	-	ND	0	5 ± 6.3	-	0.3 - 51.7	119
	Secchi depth (m)	NS	1.1 ± 0.3	-	0.5 - 2	456	1.1 ± 0.3	-	0.3 - 1.7	618	1.2 ± 0.3	-	0.4 - 1.8	121
	Turbidity (NTU)	NS	6.5 ± 3.7	-	0.2 - 32.5	1095	7.2 ± 4.1	-	0 - 52.5	1031	5.2 ± 3.4	-	0.6 - 22.5	298

Table 3-5. Summary of water quality, Charles River Basin 2007 - 2011, continued.

Parameter		MA DEP Water Quality Guideline or Standard	Upper Basin				Mid- Basin				Lower Basin			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Bacteria (col/100mL)[2]	*E. coli*	126 / 235[3,4]	155 (140-171)	73.3	0 - 13000	804	85 (76-96)	67.5	0 - 17300	1029	61 (51-73)	70.3	0 - 8660	344
	Enterococcus	33 / 61[3]	13 (11-16)	84.1	0 - 5480	806	6 (5-7)	81.6	0 - 15500	1030	5 (4-6)	79.7	0 - 1290	344
Nutrients (µmol/L)	Phosphate	NS	0.72 ± 0.42	-	0.01 - 2.67	130	ND	-	ND	0	0.61 ± 0.42	-	0.02 - 1.97	120
	Ammonium	NS	4.4 ± 3.4	-	0.2 - 25.5	130	ND	-	ND	0	5.7 ± 5.3	-	0 - 30.2	120
	Nitrate+nitrite	NS	42.3 ± 19.9	-	7.9 - 116	130	ND	-	ND	0	39.3 ± 26.1	-	0 - 202	120
Algae (µg/L)	Chlorophyll	25[5]	3.9 ± 3.8	100.0	0.5 - 19.6	130	ND	ND	ND	0	14.6 ± 17.8	84.2	0.6 - 108	120

NS: no standard or guideline. ND: No data.

[1]Summer (June-September), Winter (December-March).

[2]For bacterial data, 95% confidence intervals are provided in lieu of standard deviations. "Mean" = geometric mean for bacteria data.

[3]First number is the all samples geometric mean limit - compare to the "Mean±SD" column; the second number is the single sample limit - compare to the "% meeting guideline" column.

[4]*E. coli* or *Enterococcus* is an acceptable indicator for Massachusetts Department of Public Health, EPA, and MADEP to assess suitability for swimming in freshwater.

[5]NOAA guideline.

[6] Median and standard error of the median are shown for pH, not arithmetic mean and standard deviation.

3.4 Trends in water quality, 2011

This section provides an analysis of trends for water quality parameters measured in the lower Charles in the 2011 monitoring year.

3.4.1 Physical measurements

Temperature. Summer water temperatures for 2011 are shown for each sampling location in the top graph in Figure 3-2. Surface temperatures are relatively consistent upstream to downstream. Bottom-water temperatures are slightly lower in the deeper waters downstream, particularly Station 009 upstream of the Longfellow Bridge, where depths average 6 to 7 meters (20 to 23 feet). Station 166 is collected in a shallow location in the basin near the Science Museum where differences in surface and bottom temperatures are small. Locations upstream of Station 004 (upstream of the Eliot Bridge in Cambridge) are relatively shallow, with depths ranging from 1 to 3 meters.

Dissolved Oxygen. The spatial trend in dissolved oxygen (DO) is shown in the center graph of Figure 3-2. Average surface DO does meet the State standard of 5.0 mg/L at most locations, but mean bottom water DO failed to meet meets the standard at deeper water locations, including stations 007, 009, and 010. Stratification (due to salt water intrusion through the river locks during the summer months, as well as cooler bottom temperatures) results in extremely low bottom-water dissolved oxygen in the lower basin area upstream of the Longfellow Bridge. Bottom water DO concentrations improved compared to 2010 (data not shown) which had unusually low concentrations at all Lower Basin locations. Station 166, downstream of the lower basin, is collected at a relatively shallow near-shore location and does not reflect the low DO levels of deeper water in the lower basin.

Water clarity. Water clarity is indicated by Secchi disk depth. Summer Secchi results (collected June through September) are shown for individual sampling locations in the bottom graph in Figure 3-2. In general, there is a pattern of increasing water clarity from upstream to downstream, though all locations are relatively consistent with Secchi depths at or near the standard of 1.2 meters.

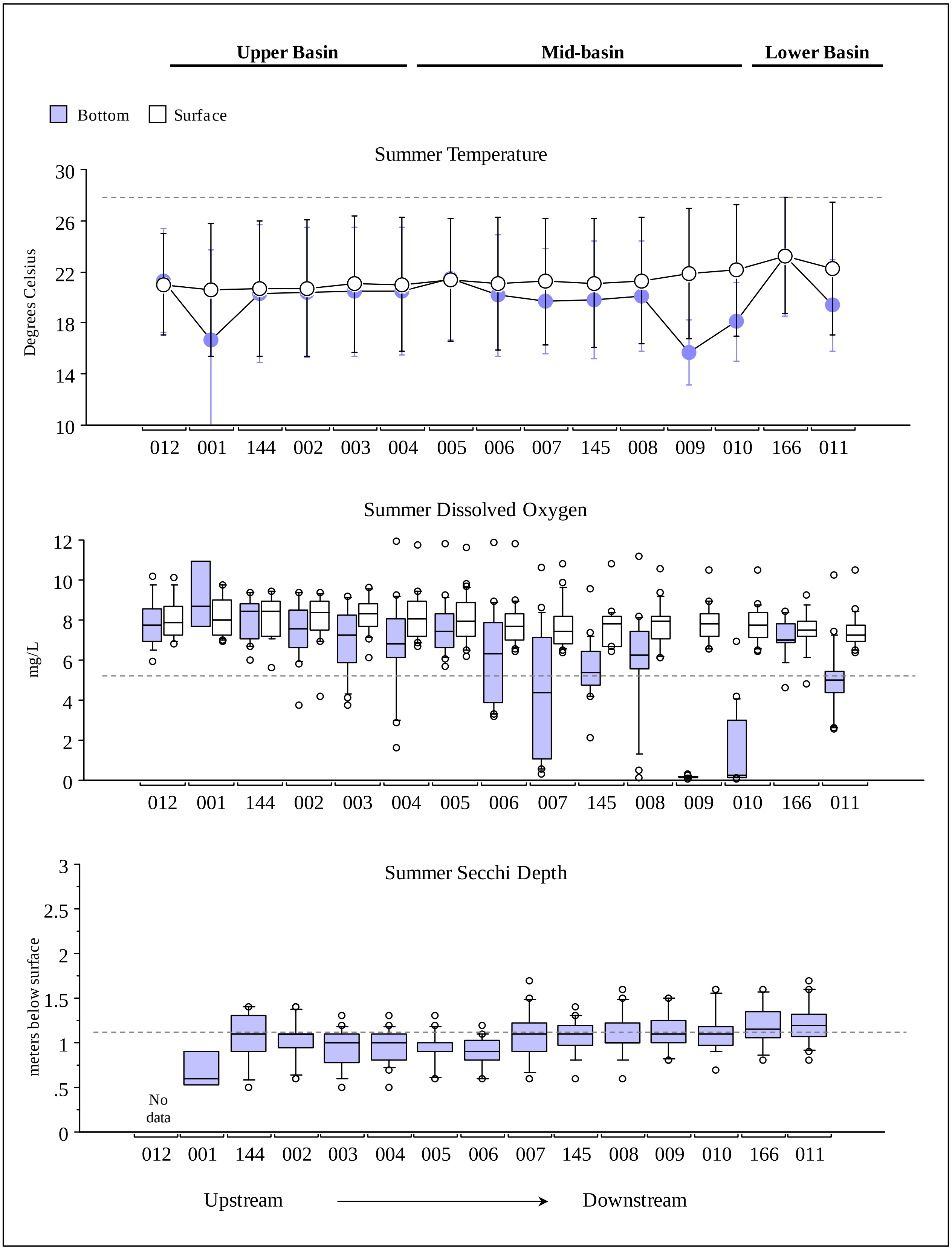

Figure 3-2. Summer temperature, dissolved oxygen and Secchi depth, Charles River Basin, 2011.
Dashed lines are State standards or guideline (maximum for temperature, minima for DO and Secchi).
No Secchi data are available for Station 012 because of shallow depth; the site is typically visible to bottom.

3.4.2 Nutrients, TSS and chlorophyll

Monthly means for total nitrogen, ammonium, nitrate/nitrite, total phosphorus, phosphate, total suspended solids, and chlorophyll *a* at the upstream (012) and downstream (166) locations in the lower Charles are shown in Figure 3-3 and Figure 3-4, respectively. 2011 averages are plotted with the average of the previous five years (2006 – 2010) for comparison.

Seasonal signals are most evident with nitrate+nitrite, total phosphorus/phosphate, and chlorophyll *a*. While the two locations show similar concentrations for most parameters, there are marked differences between the two stations for chlorophyll *a*. Historically, Station 012 has the highest chlorophyll concentrations in spring, where as the Lower Basin has highest concentrations in late summer. However, in 2011 the Lower Basin failed to show a strong late summer signal, with below average chlorophyll concentrations for September and October.

Trends for the 2011 monitoring year are similar to the 2006 – 2010 averages for most parameters, though phosphate, TSS, and chlorophyll showed some differences for 2011. Total suspended solids concentrations increased at both locations following a series of rain storms in August 2011. Phosphate concentrations were consistently below the 5-year average at the Lower Basin location near the Science Museum, but about average upstream at the Watertown dam.

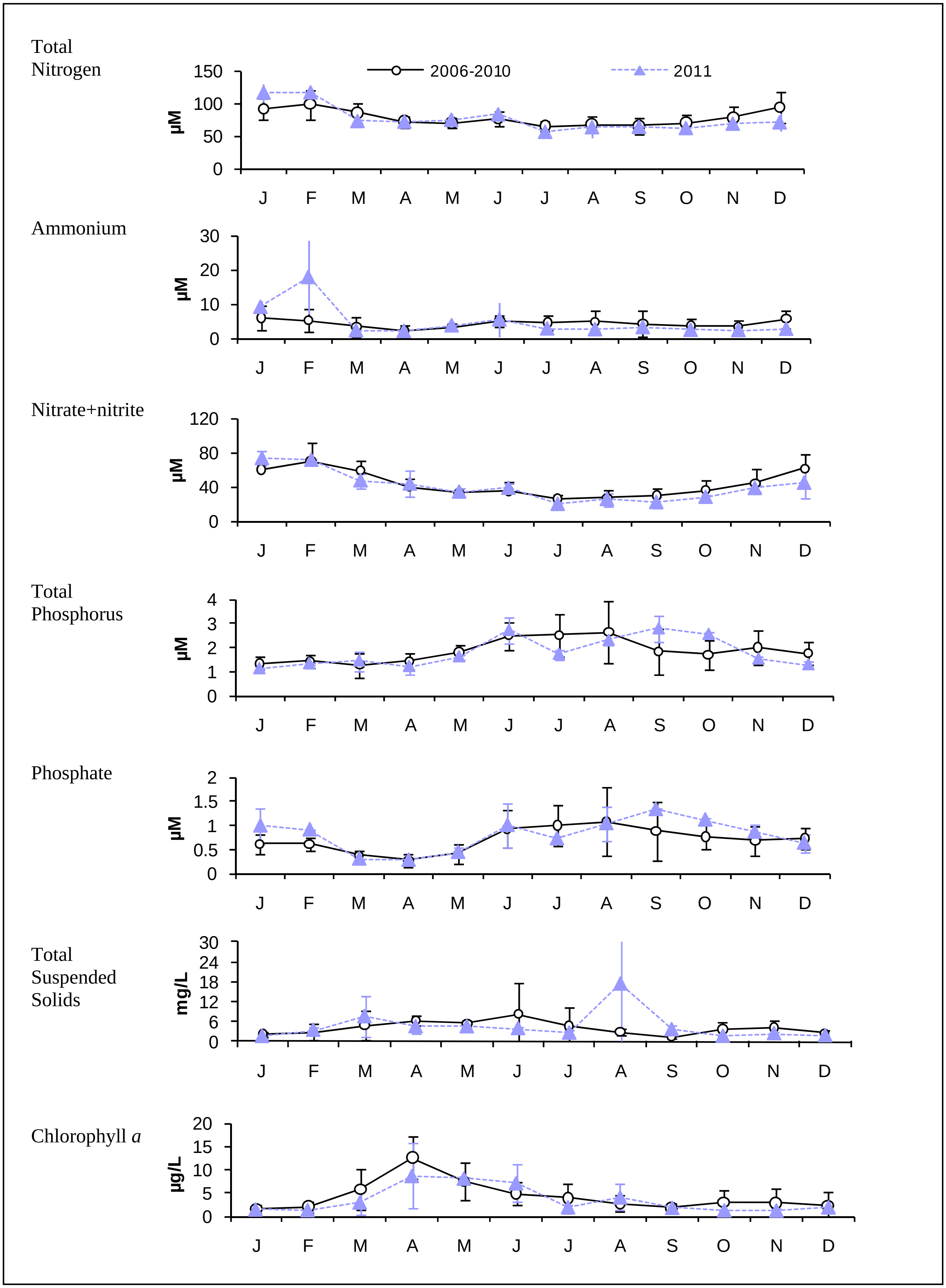

Figure 3-3. Monthly average nutrients, TSS and Chlorophyll 2006 – 2011, Station 012, Watertown Dam.
Error bars are ± 1 SD.

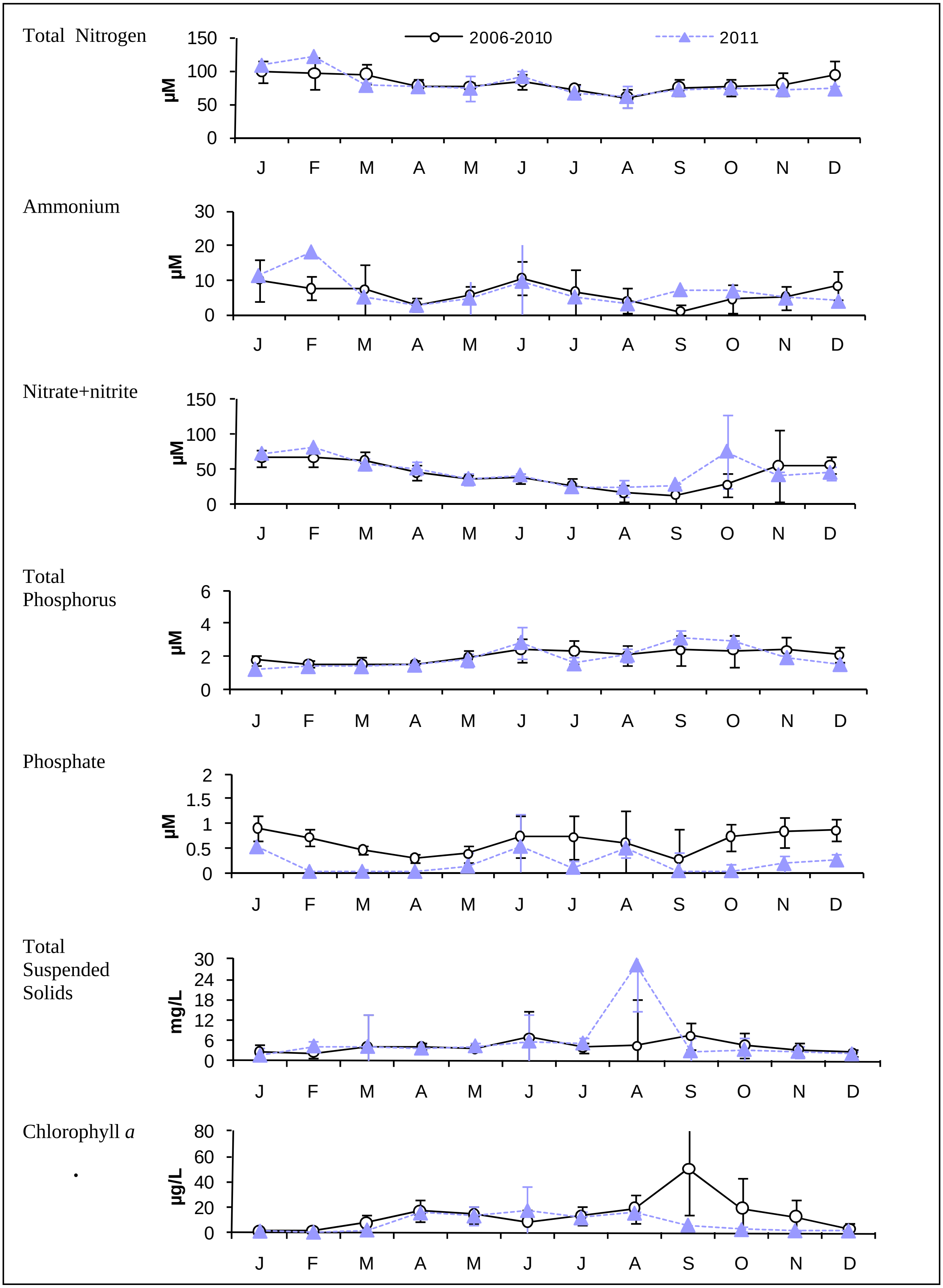

Figure 3-4. Monthly average nutrients, TSS and Chlorophyll 2006 – 2011, Station 166, Science Museum.
Error bars are ± 1 SD.

3.4.3 Bacterial water quality

Figure 3-5 shows the current bacterial water quality at each location sampled in the Charles for 2011, for dry, damp, and wet weather. Upstream reaches generally have more elevated bacteria counts than downstream locations, though this trend is less pronounced in 2011 than in past years, with an improvement in conditions at Watertown Dam.

Annual geometric means for each location for 2006 - 2011 appear in Table 3-6. Geometric means for 2011 are shown in a separate column from the five-year means. If confidence intervals for the two periods overlap, this indicates no statistically significant difference between the two means ($\alpha = 0.95$). With the exception of Watertown Dam, concentrations are higher at all locations relative to the 5-year mean. This may in part be explained by the higher proportion of samples collected in wet weather in 2011 compared to prior years.

The top graph in Figure 3-5 shows percentile plots of *Enterococcus* counts arranged from upstream to downstream locations for 2011 (note log scale). The bottom graph in Figure 3-5 shows percentile plots of *E. coli* counts arranged from upstream to downstream locations for 2011. Generally, *E. coli* shows the same spatial trend as *Enterococcus*, with more elevated bacteria counts upstream relative to downstream locations. However, fewer locations met geometric mean standards for *E. coli* than for *Enterococcus* in dry and wet weather. Locations downstream of the BU Bridge in Cambridge met geometric mean standards for both bacterial indicators in dry weather except for Station 166, at the Science Museum. Upstream locations failed to meet geometric mean standards in any weather condition, with the exception of Watertown Dam, which showed a large improvement. Annual geometric means shown in Table 3-6 met the *E. coli* and *Enterococcus* geometric mean standard, a first since monitoring began there in 1989.

Figure 3-6 shows the impact of rainfall on the three river reaches on *Enterococcus* densities, along with the change at locations near CSO outfalls. All reaches show a similar pattern, with wet weather median counts generally higher than in dry weather.

The change in *Enterococcus* concentrations since 1989 in the Upper Charles Basin (upstream of CSO influences) and the lower Charles (including the Mid- and Lower-Basin locations) appear in Figure 3-7 and Figure 3-8. Results are grouped by phases of the Long Term CSO Plan improvements and include the geometric mean counts in each rainfall condition. These figures show change over time in both regions, with statistically significant improvement in water quality in the latest phase. Upper Basin shows improvement in both dry and wet conditions but does not consistently meet the geometric mean swimming standard in wet weather. The most pronounced change is in the lower Charles, which meets the geometric mean swimming standard in all but heavy rain. The greatest improvement in bacterial water quality since the early 1990s has been in dry weather, followed by heavy rain conditions.

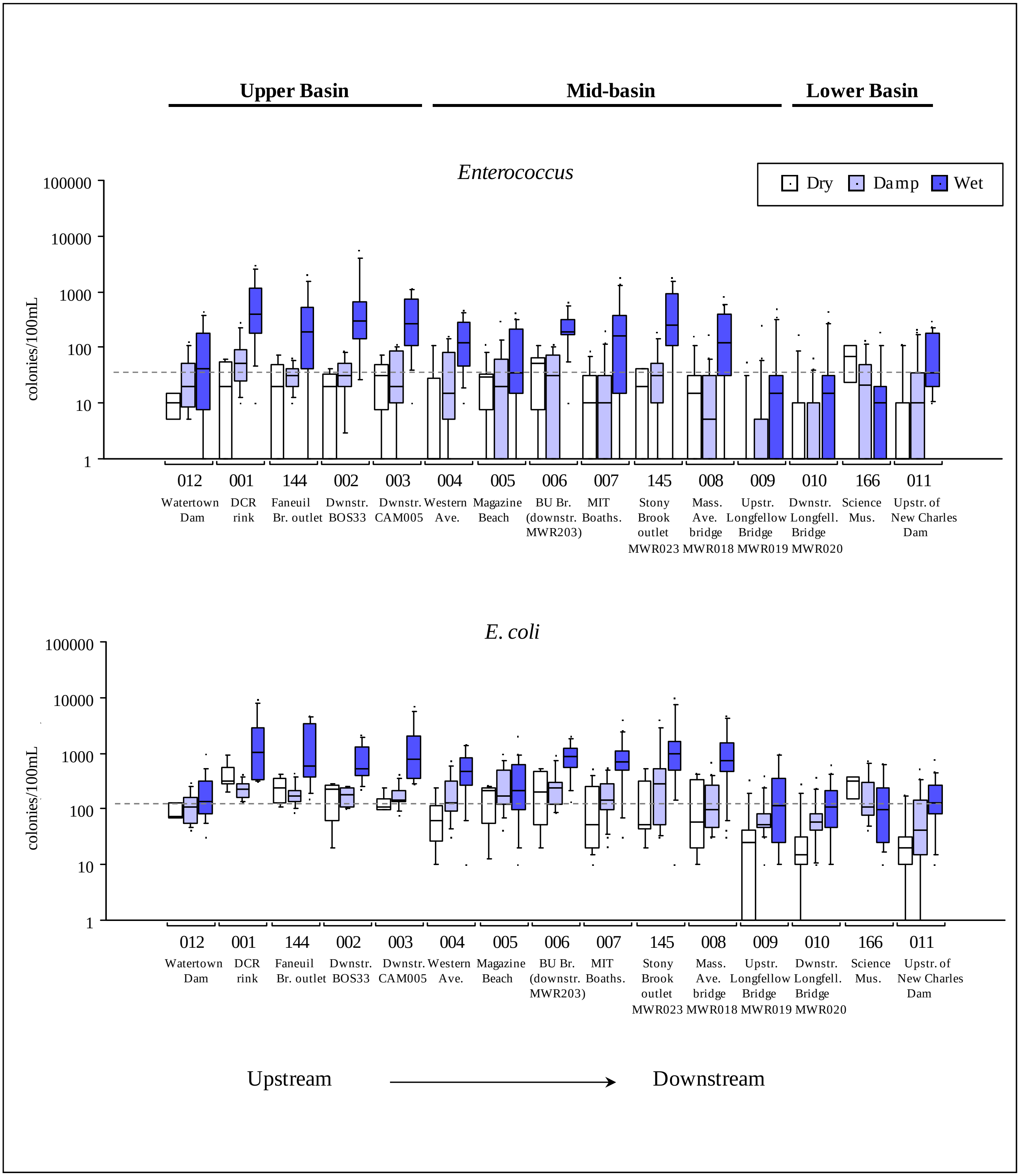

Figure 3-5. Indicator bacteria concentrations, Charles River Basin, 2011.

Dotted lines show MADEP *Enterococcus* and *E. coli* standard. Dry: no rainfall for previous 3 days; Wet: at least 0.5 inches in previous 2 days; damp is everything in between.

Table 3-6. Geometric mean indicator bacteria, Charles River Basin, 2006 – 2011.

Station	Location	Surface or Bottom	Number of samples		*Enterococcus* (95% CI)[1] cfu/100 mL		*E. coli* (95% CI)[1] cfu/100 mL	
			2006–'10	2011	2006 – 2010	2011	2006 – 2010	2011
012	Newtown/Watertown, footbridge upstream of Watertown Dam	S	149	26	38 (26-55)	19 (9-38)	190 (156-232)	126 (91-173)
001	Newton, near Nonantum Rd., rear of DCR skating rink	S	123	21	37 (24-57)	72 (29-179)	242 (193-303)	459 (287-734)
144	Brighton, downstream of N. Beacon St. bridge, Faneuil Brook outlet, BOS-032 (closed 1999)	S	62	21	34 (20-56)	31 (12-77)	340 (232-498)	324 (199-529)
002	Allston, downstream of Arsenal Street bridge, BOS-033	S	108	21	20 (13-31)	39 (14-107)	214 (174-264)	243 (154-383)
003	Allston/Cambridge, midstream, near Mt. Auburn Street, between CAM-005 and CAM-006	S	108	21	15 (10-23)	43 (17-105)	170 (135-213)	296 (178-491)
004	Allston/Cambridge, midstream, between River Street and Western Avenue bridges	S	110	21	8 (5-13)	19 (7-51)	73 (51-103)	156 (85-286)
005	Cambridge, near Magazine Beach, upstream of Cottage Farm	S	185	43	9 (6-13)	21 (11-38)	88 (71-110)	165 (108-251)
006	Cambridge/Boston, midstream, downstream of Cottage Farm, BU bridge	S	108	21	16 (10-23)	36 (14-90)	140 (107-182)	312 (191-511)
007	Cambridge, near Memorial Dr., MIT Boathouse	S	108	21	8 (5-13)	11 (3-32)	104 (75-143)	160 (82-311)
		B	108	21	20 (13-31)	25 (8-71)	184 (142-237)	227 (105-486)
145	Boston (Charlesgate), Muddy River/Stony Brook outlet	S	108	21	22 (15-32)	28 (9-85)	226 (163-315)	282 (129-611)
008	Cambridge/Boston, midstream, downstream of Harvard Bridge	S	108	21	8 (5-12)	13 (4-39)	108 (78-150)	149 (65-340)
		B	108	21	13 (8-20)	17 (6-46)	154 (111-214)	221 (116-421)
009	Cambridge/Boston, midstream, upstream of Longfellow Bridge near Community Sailing	S	108	21	4 (2-6)	9 (3-22)	67 (48-91)	98 (56-173)
		B	108	21	1 (1-2)	1 (0-2)	11 (8-16)	22 (10-50)
010	Boston, downstream of Longfellow Bridge, MWR-022	S	108	21	3 (2-5)	5 (1-15)	45 (31-64)	70 (36-137)
		B	108	21	3 (2-5)	3 (1-7)	23 (15-34)	30 (15-58)
166	Boston, old Charles River dam, rear of Science Museum	S	149	24	6 (4-8)	9 (4-21)	103 (77-138)	106 (61-182)
011	Boston, upstream of river locks (New Charles River Dam) and I-93, near Nashua St.	S	108	21	3 (2-5)	11 (4-26)	45 (35-58)	34 (13-87)
		B	108	21	9 (6-12)	15 (6-36)	41 (30-54)	65 (40-108)

[1]Geometric mean limit for *Enterococcus* is 35 cfu/100 mL in marine water, 33 cfu/100 mL in freshwater. The *E. coli* limit is 126 cfu/100 mL.

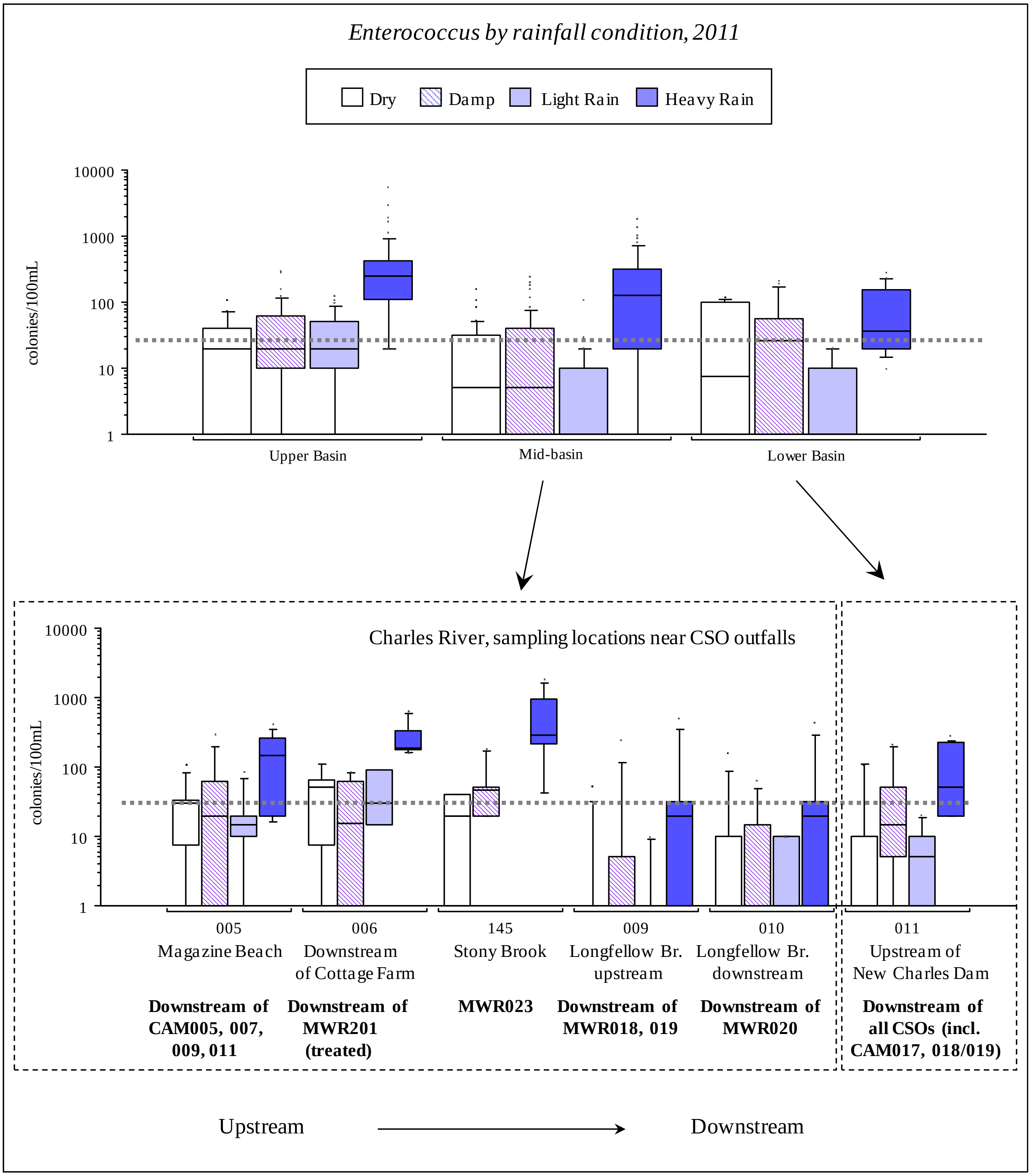

Figure 3-6. *Enterococcus* by rainfall condition, Charles Basin, 2011.

Dotted line shows MADEP standard of 33 colonies/100 mL. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

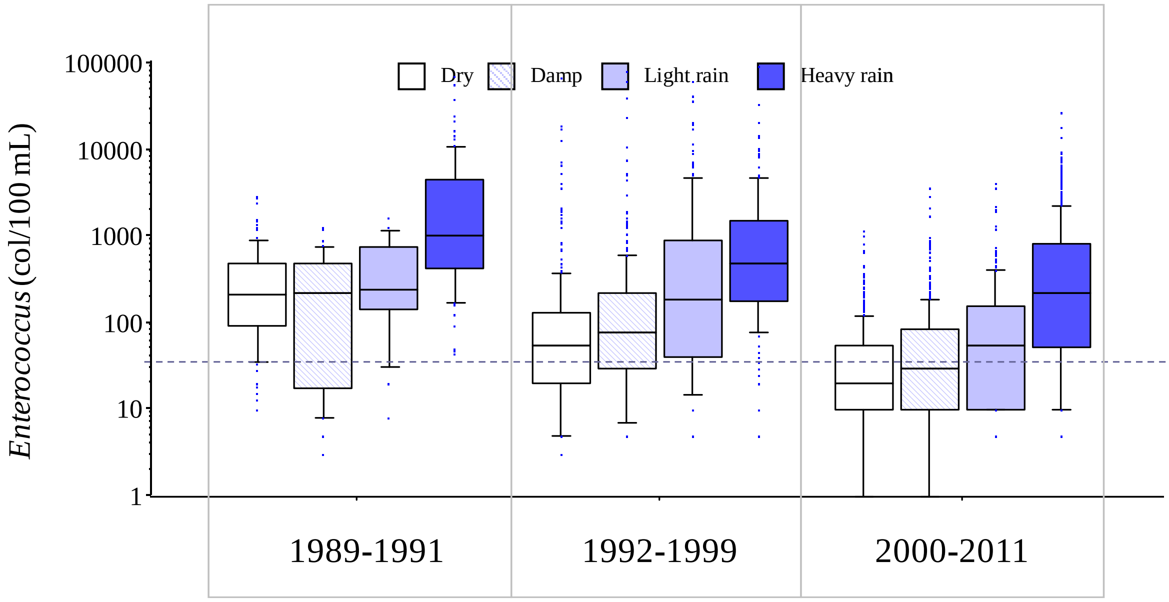

Figure 3-7. *Enterococcus* over time, Upper Charles Basin (upstream of CSOs) by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for stations 012, 001, 002, 003. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

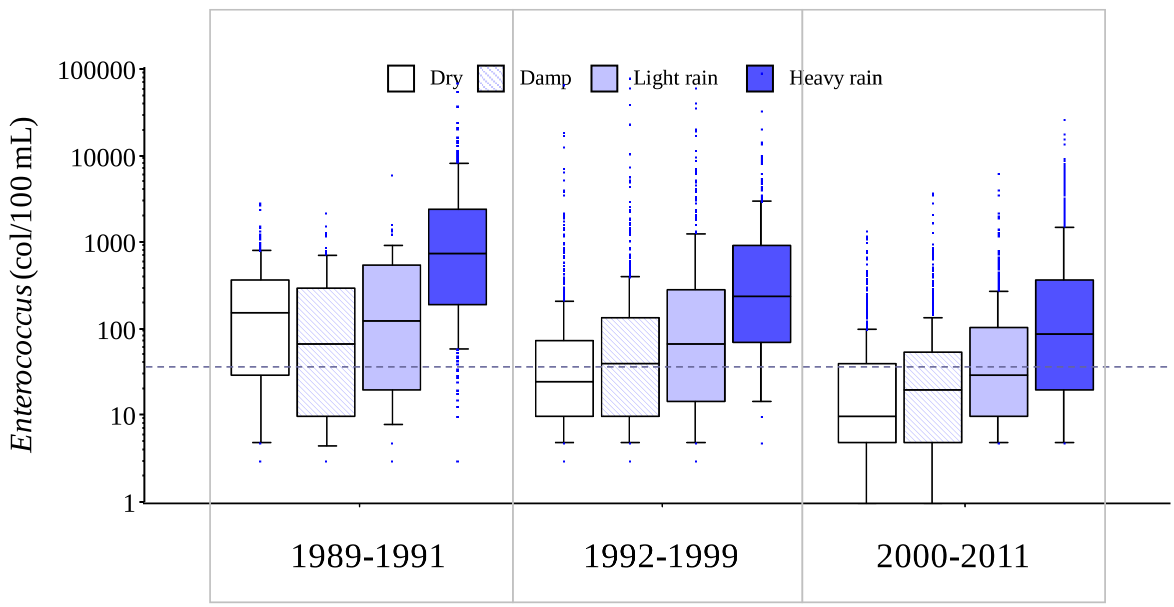

Figure 3-8. *Enterococcus* over time, Lower Charles Basin by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for all stations downstream of Western Ave (Station 004). Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

3.5 Summary of Charles River Water Quality

Bacterial water quality in the Charles in 2011 was affected by the wetter weather of 2011 compared to previous years, despite a lower number of estimated CSO activations. Water quality was for the most part spatially consistent with prior years, with more elevated concentrations at upstream locations (upstream of most CSOs), improving as the river widens and slows in the Lower Basin and approaches the New Charles Dam. The exception was Watertown Dam, which showed a marked improvement in 2011, despite a year with proportionally more wet weather samples. Except for the dam, geometric mean counts overall were above the five year average for *E. coli* and *Enterococcus*.

As in past years, bottom-water dissolved oxygen met standards in the Upper Charles Basin, but worsened in the lower Charles Basin. 2011 showed some improvement in the Lower Basin, with more locations meeting the dissolved oxygen standard of 5 mg/L in bottom waters than in 2010. Seawater entering through the Charles locks in summer contributes to stratification of the basin, limiting exchange with surface waters and at least partially explains the lower bottom DO.

Nutrients and chlorophyll exhibited seasonal signals but matched long term averages closely. The exceptions were above-average winter ammonium following February rain events, and an increase in TSS following storms in August 2011. Monthly Chlorophyll *a* concentrations were below average at the Lower Basin location in late summer, whereas Watertown Dam was about average.

4 Results: Mystic River and Alewife Brook

4.1 *Sampling area*

Monitoring results of the Mystic River are divided into four reaches. Table 4-1 describes the reaches and the sampling locations within each reach. Locations are shown on the map in Figure 4-1.

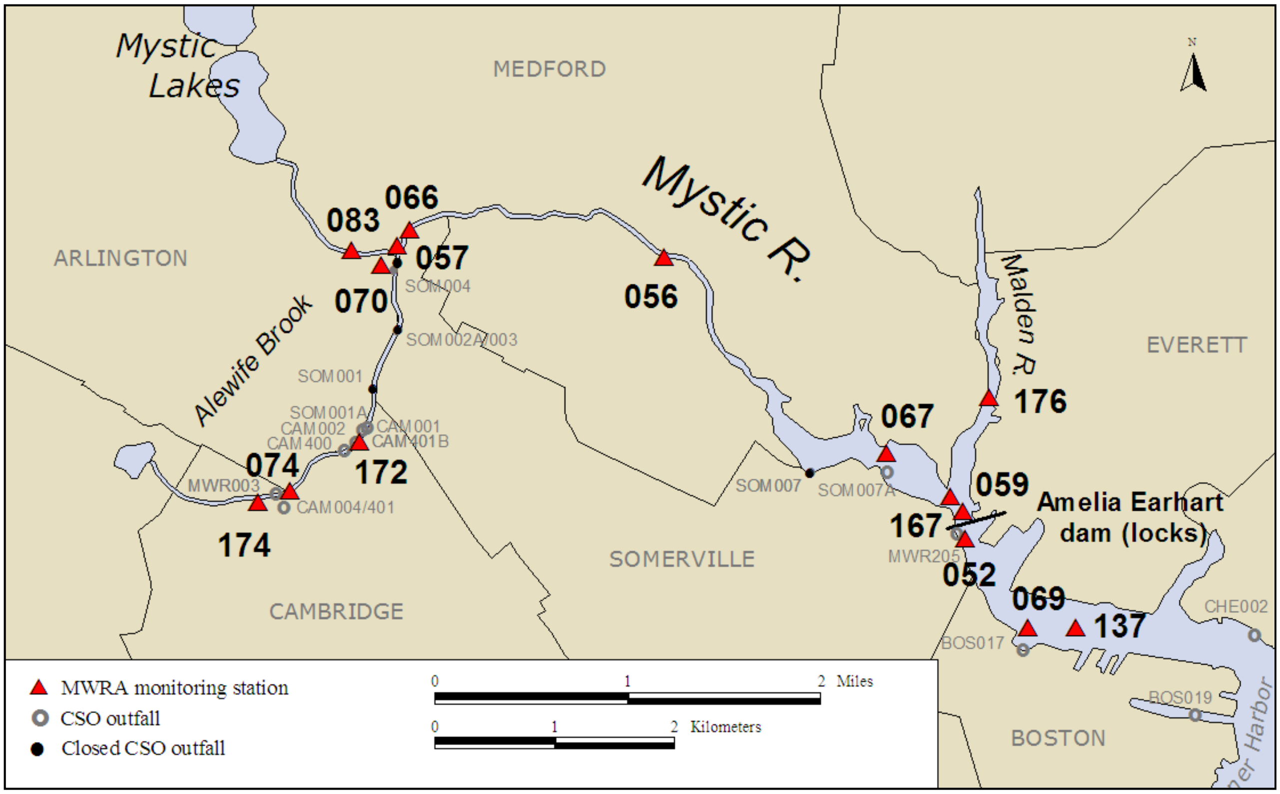

Figure 4-1. Map of Mystic River sampling locations.

4.2 *Pollution sources*

Known pollution sources to the Mystic River/Alewife Brook are shown in Table 4-2 and consist of stormwater, upstream inputs and CSOs. Nine CSOs are located in Cambridge and Somerville, including seven active CSOs in Alewife Brook, and one treated CSO in the Lower Mystic basin (Somerville Marginal CSO, MWR205A/SOM007A), which discharges screened and dechlorinated flow only during an activation occurring at high tide. At low tide, the Somerville Marginal CSO (MWR205) discharges downstream of the Amelia Earhart dam, screening and chlorinating CSO flow before discharge. It is the only source of treated CSO discharge to the Mystic River. For calendar year 2011, Somerville Marginal 205A/SOM007A had six discharge events, and Somerville Marginal 205 had 36 activations resulting in discharge below the dam.

Table 4-3 shows the MWRA model simulation results for CSOs affecting the Mystic River and Alewife Brook in calendar year 2011. Metered CSO volumes and activation frequency are available for the Somerville Marginal CSO facility, while the remaining results are estimated using model results.

Table 4-4 summarizes the proportion of samples collected in dry, damp, and wet weather between 2006 and 2011.

Table 4-1. MWRA monitoring locations, Mystic River and Alewife Brook.

Reach	Description of Reach	Sampling location	Location Description
Alewife Brook (Class B/Variance, warm water fishery)	Tributary to Mystic River. From confluence at Little River in Cambridge/Arlington to confluence with Mystic River in Arlington/Somerville	174, Cambridge/Arlington	Little River, upstream of Rt. 2 and off ramp to Alewife T station. Upstream of all CSOs.
		074, Cambridge/Arlington	Downstream of CAM001A, CAM004, MWR003
		172, Cambridge/Arlington	Downstream of CAM001, CAM002, CAM400, CAM401B, SOM001A
		070, Arlington/Somerville	Mystic Valley Parkway bridge. Downstream of all Alewife CSOs
Upper Mystic River (Class B/Variance, warm water fishery)	Downstream of Lower Mystic Lake in Arlington/Medford to Route 28 bridge in Medford	083, Arlington/Medford	Upstream of confluence of Mystic River and Alewife Brook
		057, Medford	Confluence of Mystic River and Alewife Brook
		066, Medford	Boston Ave bridge, downstream side
		056, Medford	Upstream of I-93 bridge, near Medford Square off ramp
Lower Mystic River basin (Class B/Variance, warm water fishery)	Route 28 bridge in Medford to Amelia Earhart Dam in Somerville/Everett	177, Medford	Downstream of Rt. 16 bridge
		067, Medford	Rt. 28 bridge, downstream side, near Somerville Marginal MWR205A outfall
		176, Medford/Everett	Malden River, upstream of Rt. 16 bridge
		059, Somerville/Everett	Confluence of Mystic and Malden Rivers
		167, Somerville/Everett	Amelia Earhart Dam, upstream side
Mystic River mouth (Class SB/CSO, marine)	Downstream of Amelia Earhart Dam in Somerville/Everett to Tobin Bridge, Chelsea R. confluence in Chelsea/East Boston	052, Somerville	Downstream of Amelia Earhart dam, near Somerville Marginal CSO facility outfall (MWR205)
		069, Charlestown	Rear of Schrafft's Center at BOS-017 outfall
		137, Charlestown/Everett	Upstream of Tobin Bridge near confluence of Mystic, Chelsea Rivers and upper inner harbor

Sampling locations are midstream unless otherwise noted.

Table 4-2. Mystic River/Alewife Brook pollution sources.

Source	Alewife Brook	Upper Mystic River	Lower Mystic Basin	Mystic River mouth
CSOs (untreated)	4 active, 5 closed CAM401A, MWR003, CAM001, CAM002, CAM401B, SOM001A *CAM400 to be closed* CAM004 closed 3/11 SOM001 closed 12/96 SOM002 closed 1994 SOM002A closed 8/95 SOM003 closed 8/95 SOM004 closed 12/95	2 closed SOM006 closed 12/96 SOM007 closed 12/96	None	1 active BOS017
CSO treatment facility (screened, chlorinated and dechlorinated CSO discharge)	No	No	Yes Somerville Marginal (MWR205A/SOM007A, high tide only) Activated 6 times in 2011	Yes Somerville Marginal (MWR205) Activated 36 times in 2011
Storm drains	Yes	Yes	Yes	Yes
Upstream inputs (elevated bacteria counts upstream)	Yes	Yes	Yes	Yes
Dry weather inputs (elevated bacteria counts in dry weather)	Yes	Yes	Yes	Yes
Tributary brook or stream flow	Yes	Yes	Yes	Yes

Table 4-3. Mystic River/Alewife Brook CSO activations, results of MWRA model simulations and facility records for 2011 system conditions and 2011 rainfall.[1]

CSO Outfall	Activation Frequency	Total Discharge Duration (hr)	Total Discharge Volume (Million Gallons)
Alewife Brook			
CAM001	0	0.0	0.0
CAM002	2	1.43	0.13
MWR003	2	1.96	0.28
CAM004	10	20.45	5.33
CAM401A	3	4.16	1.14
CAM401B	27	123.12	14.39
SOM001A	6	9.89	6.52
TOTAL		161.01	27.78
Mystic River (upstream of dam)			
SOM007A/MWR205A (Somerville Marginal, high tide discharge only)[2]	10	2.40	9.24[4]
TOTAL		2.40	9.24[4]
Mystic River mouth (downstream of dam, marine outfalls)			
MWR205 (Somerville Marginal Facility)[3]	36	125.63	105.16[4]
BOS017	0	0.0	0.0
TOTAL		125.63	105.16[4]

[1]Activation frequency and volume are from MWRA model results, except where noted.
[2]Activation frequency and volume are from MWRA depth sensor measurement and MWRA model results, respectively.
[3]Activation frequency and volume are from MWRA facility records (measurements).
[4]Treated discharge.

Table 4-4. Mystic River/Alewife Brook sample collection by rainfall condition.

Sampling period	Dry[1]	Damp[1]	Wet[1]	Total
2006-2010	33% 1092 samples	33% 1075 samples	34% 1111 samples	100% 3256 samples
2011	24% 235 samples	25% 251 samples	51% 514 samples	100% 1000 samples

[1] Dry: no rainfall for previous 3 days; Wet: at least 0.5 inches in previous 2 days; Damp is everything in between. Sampling is random with respect to weather, though if needed wet weather sampling is added late in the year to maintain a representative annual sample of wet weather.

4.3 Summary of water quality, 2006-2011

A detailed summary of water quality results collected from the last five years is shown in Table 4-5.

Table 4-5. Summary of water quality, Mystic River/Alewife Brook 2007 - 2011.

Parameter		Water Quality Guideline or Standard	Alewife Brook				Upper Mystic				Lower Mystic Basin				Malden River				Mystic Mouth			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Surface Temperature (°C)[1]	Summer	<28.3	18.1 ± 4	100.0	7.3 - 27	477	20.5 ± 3.9	100.0	9.3 - 27.1	645	20.2 ± 4	99.8	8.8 - 28.4	611	19.8 ± 3.9	100.0	9.2 - 26.9	121	16.8 ± 2.6	100.0	9.3 - 23.3	366
	Winter		3.5 ± 1.7	100.0	0.8 - 6.9	23	2.9 ± 1.9	100.0	0.4 - 8.1	60	3.5 ± 1.9	100.0	0.3 - 9	81	ND	ND	ND	0	2.7 ± 1.6	100.0	0.5 - 7.2	57
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	4.7 ± 2.3	43.9	0 - 15.1	472	6.9 ± 1.6	89.4	0.4 - 10.9	643	7.2 ± 2.4	82.6	0.4 - 13.8	610	5.9 ± 3.4	66.4	0.3 - 13.3	119	7.2 ± 1.6	93.7	3.5 - 15.4	364
	Winter	5.0	11.3 ± 1.5	100.0	8.2 - 13.9	23	12.1 ± 0.8	100.0	10 - 14.6	58	11.9 ± 1.2	100.0	8.7 - 15	77	ND	ND	ND	0	10.2 ± 0.7	100.0	8.8 - 12.6	57
pH[6] (S.U.)		6.5-8.3 (8.5 marine)	7.2 ± 0.3	99.7	6.5 - 9	705	7.5 ± 0.4	97.4	6.7 - 9	955	7.5 ± 0.6	91.8	6.2 - 9.8	962	7.4 ± 0.7	87.7	6.7 - 9.4	155	7.7 ± 0.3	98.8	6.3 - 8.5	589
Water clarity	Total Suspended Solids (mg/L)	NS	ND	-	ND	0	4.9 ± 4.9	-	0.2 - 44.3	245	6.6 ± 4	-	0.6 - 30.1	115	ND	-	ND	0	3.2 ± 1.6	-	0.6 - 15.9	233
	Secchi depth (m)	≥ 1.2	0.5 ± 0.2	-	0.2 - 1	34	1.3 ± 0.4	-	0.2 - 3.2	129	0.9 ± 0.2	-	0.4 - 1.9	253	1 ± 0.3	-	0.5 - 1.6	74	2.3 ± 0.8	-	0.2 - 5.8	243
	Turbidity (NTU)	NS	12.5 ± 6.1	-	2.4 - 34	100	5.7 ± 3.6	-	0.7 - 29.9	601	8.2 ± 4.7	-	0.8 - 39.3	647	8.7 ± 4.6	-	0.4 - 25.9	121	5.4 ± 2.7	-	0.5 - 18.2	477

Table 4-5. Summary of water quality, Mystic River/Alewife Brook 2007 - 2011, continued.

Parameter		Water Quality Guideline or Standard	Alewife Brook				Upper Mystic				Lower Mystic Basin				Malden River				Mystic Mouth			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Bacteria (col/100mL)[2]	Fecal coliform	200 / 400[3]	671 (481-936)	2.7	82 - 63000	188	ND	-	ND	0	126 (15-1020)	42.9	10 - 2400	7	ND	-	ND	0	46 (34-62)	39.7	0 - 29100	438
	E. coli	126 / 235[3,4]	546 (490-608)	47.0	0 - 44100	638	130 (115-147)	75.9	0 - 15500	569	70 (59-82)	82.4	0 - 5790	499	87 (54-139)	78.6	0 - 11200	84	51 (32-82)	83.1	0 - 19900	89
	Enterococcus	33 / 61[3]	195 (169-226)	42.7	0 - 45700	639	24 (20-28)	77.5	0 - 6870	569	7 (6-9)	88.8	0 - 3080	502	8 (5-15)	83.5	0 - 3870	85	5 (4-6)	91.9	0 - 5170	534
Nutrients (µmol/L)	Phosphate	NS	ND	-	ND	0	0.46 ± 0.55	-	0.01 - 6.01	247	0.35 ± 0.23	-	0.01 - 0.98	115	ND	-	ND	0	0.77 ± 0.34	-	0.01 - 1.66	231
	Ammonium	NS	ND	-	ND	0	14.4 ± 12.2	-	0.5 - 44.8	247	10.3 ± 9.8	-	0.1 - 34.6	121	ND	-	ND	0	5.1 ± 6.8	-	0 - 63.5	236
	Nitrate+nitrite	NS	ND	-	ND	0	56.3 ± 24	-	15.1 - 224	247	36.9 ± 23.8	-	0 - 85.5	115	ND	-	ND	0	8.3 ± 8.9	-	0 - 59.9	231
Algae (µg/L)	Chlorophyll *a*	25[5]	ND	ND	ND	0	8.7 ± 5.7	98.4	0.9 - 36.7	247	19 ± 15.4	73.9	0.4 - 94.7	115	ND	ND	ND	0	3 ± 4	99.6	0.2 - 30.8	235

NS: no standard or guideline. ND: No data.

[1]Summer (June-September), Winter (December-March).

[2]For bacterial data, 95% confidence intervals are provided in lieu of standard deviations.

[3]First number is the all samples geometric mean limit - compare to the "Mean±SD" column; the second number is the single sample limit - compare to the "% meeting guideline" column. For marine locations, fecal coliform replaced *E. coli* in marine waters in 2009 for methodological reasons.

[4]*E. coli* or *Enterococcus* are acceptable indicators for Massachusetts Department of Public Health and MADEP to assess suitability for swimming in fresh water.

[5]NOAA guideline.

[6] Median and standard error of the median are shown for pH, not arithmetic mean and standard deviation.

4.4 Trends in water quality, 2011

This section reports spatial trends for water quality parameters measured in the Mystic River/Alewife Brook in 2011.

4.4.1 Physical measurements

Temperature. Summer mean temperatures for 2011 are shown for each sampling location in the uppermost graph of Figure 4-2. Temperatures are lowest in the Alewife Brook and at the river mouth, where the river meets Boston Harbor. Surface and bottom temperatures are similar, except in the downstream reach on the marine side of the dam where harbor temperatures are lower.

Dissolved Oxygen. Dissolved oxygen is shown in the center graph of Figure 4-2. Mean surface and bottom dissolved oxygen concentrations meet the State standard of 5.0 mg/L except bottom-water portions of Malden River (Station 176) and upstream of the Amelia Earhart dam (Station 167). Typically bottom-water dissolved oxygen is lowest at the Malden River location (Station 176). Unlike the Charles River, there is little evidence of stratification in the lower portion of the Mystic due to saltwater intrusion. Dissolved oxygen in the Alewife improved in 2011with all locations meeting bottom water DO standards on average, compared to 2010 when locations failed to meet standards (data not shown).

Water clarity. Water clarity is indicated by Secchi disk depth; shown for individual sampling locations in the bottom graph of Figure 4-2. Water clarity for much of the river is poor, with nearly all stations upstream of the Dam failing to meet the guideline of 1.2 meters except Station 056 in Medford. (Alewife Brook and several upper Mystic locations were too shallow to measure Secchi depth.) Clarity on the marine side of the Amelia Earhart dam improves substantially as the river meets Boston Harbor.

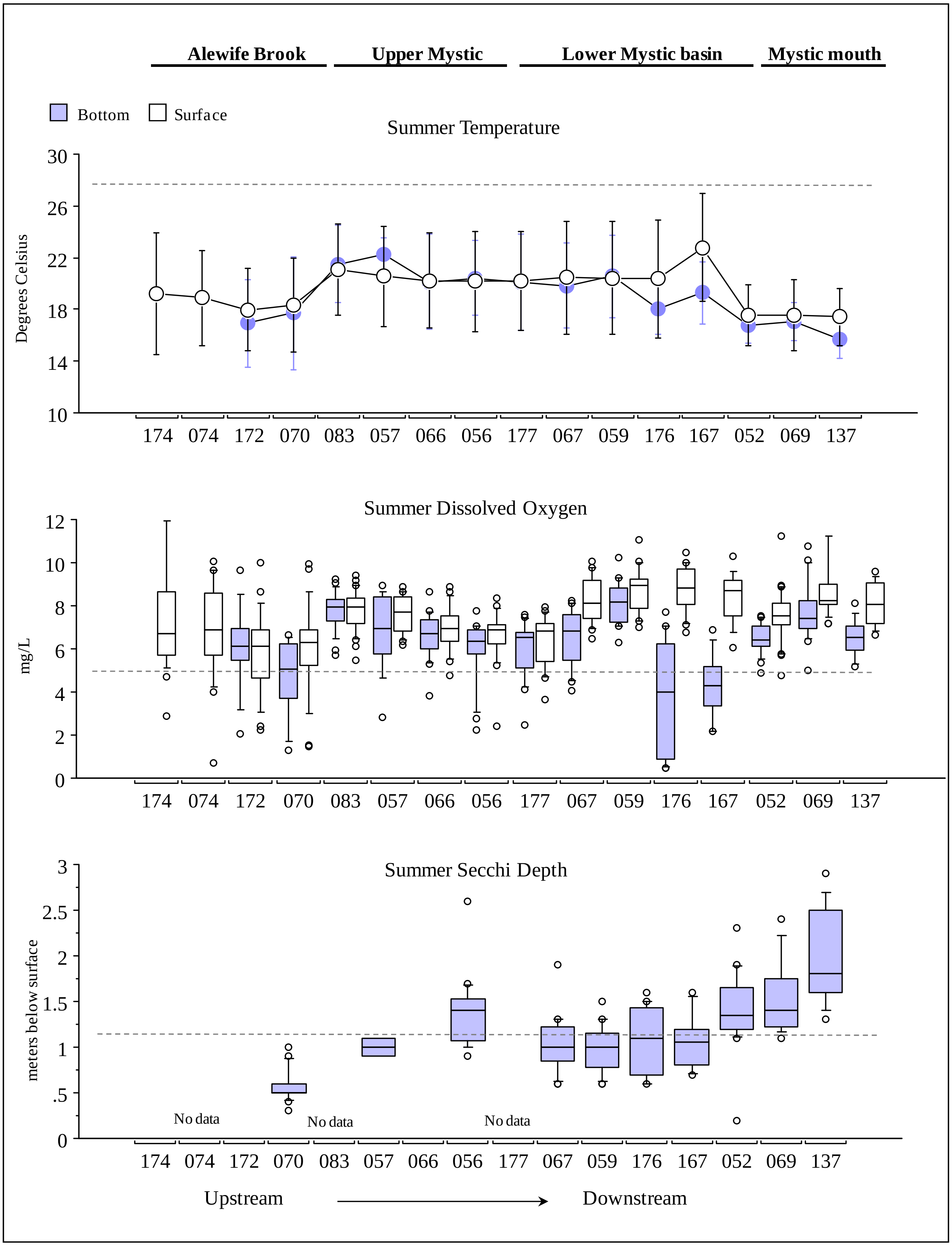

Figure 4-2. Summer temperature, dissolved oxygen, and Secchi depth, Mystic River, 2011.

Dashed lines are State standards or guideline (maximum for temperature, minima for DO and Secchi).
Brook locations are typically too shallow for measurements in the summer months.

4.4.2 Nutrients, TSS and chlorophyll

Figures 4-3 through 4-6 show monthly average total nitrogen, ammonium, nitrate/nitrite, total phosphorus, orthophosphate, total suspended solids, and chlorophyll *a* at the upstream Mystic locations (083 upstream of Alewife Brook and 066 at Boston Ave.), downstream (167 at Amelia Earhart Dam) and river mouth (137).

Ammonium and phosphate show strong seasonal effects as biological uptake increases during the summer months. Station 167, immediately upstream of the dam, is more eutrophic than either upstream or at the mouth of the river, with chlorophyll concentrations nearly double the concentrations of upstream locations. As in the Charles River, upstream locations have higher monthly average chlorophyll in the spring as opposed to later in the season, while downstream locations have the highest concentrations in late summer. 2011 chlorophyll concentrations were generally average compared to the five-year means, with the exception of the Mystic River mouth, which had monthly increases in June and August.

2011 results were in general similar to the 2006-2010 average for nutrient parameters, with the exception of TSS concentrations , which were more variable, and may reflect the influence of frequent rain events during the monitoring season. TSS concentrations in the Upper Mystic locations increased markedly in August, matching a similar pattern for TSS in the Charles River. Station 083 had unusually elevated nitrate/nitrite and phosphate concentrations in October 2011, with a sampling event following a 2-inch rainstorm.

In the cold weather months, when biological nutrient uptake is low, ammonium concentrations in the in the Upper Mystic are twice the concentration as in the Charles Basin. Nutrient concentrations on the marine side of the dam are generally much lower than upstream, particularly for nitrogen, chlorophyll, and total suspended solids.

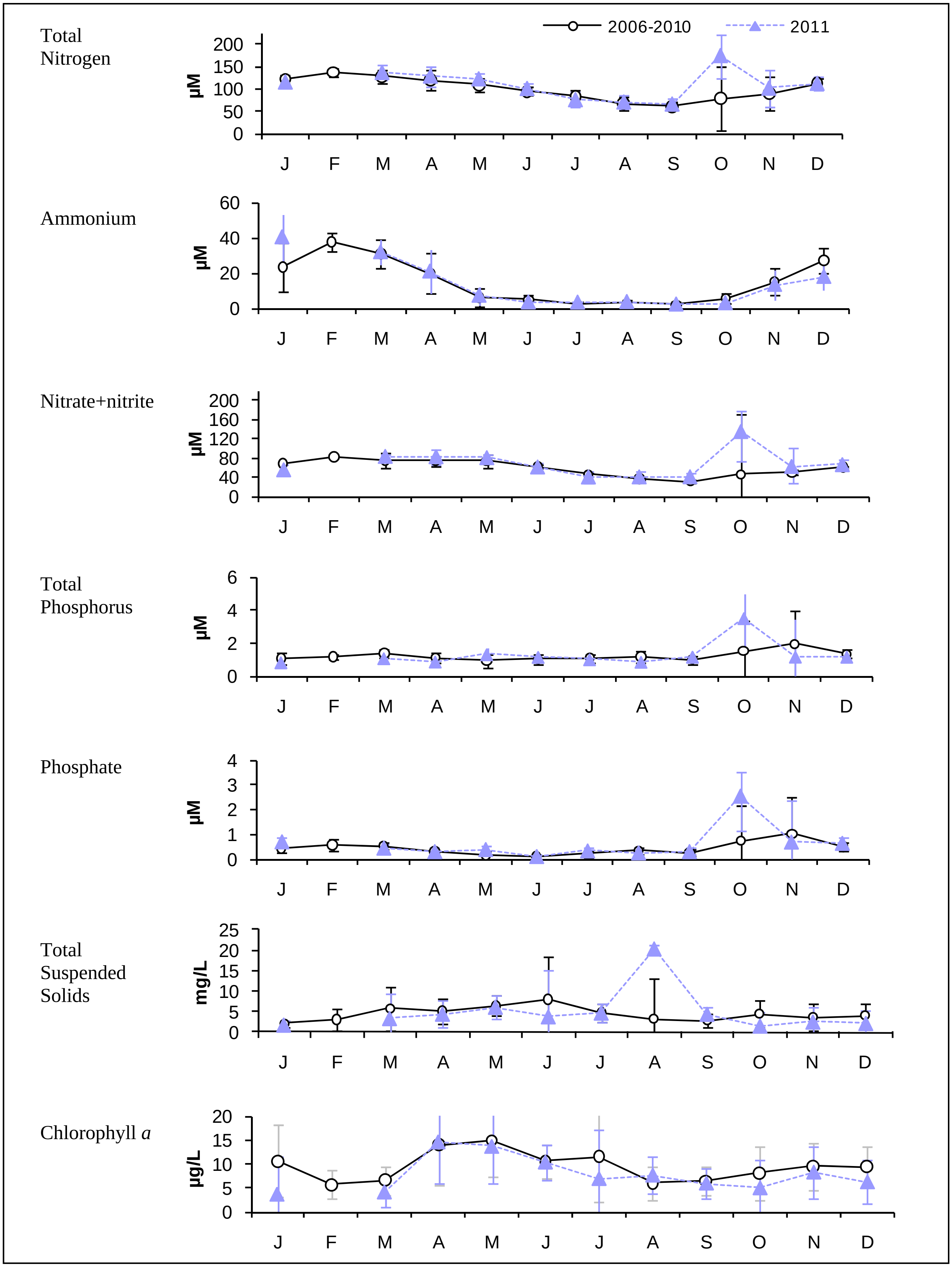

Figure 4-3. Monthly average nutrients, TSS and Chlorophyll 2006 – 2011, Station 083 (Mystic upstream of Alewife Br.)

Error bars are ± 1 SD. Note different scale for nitrate+nitrite, phosphate, chlorophyll and TSS than for Figures 4-5 and 4-6.

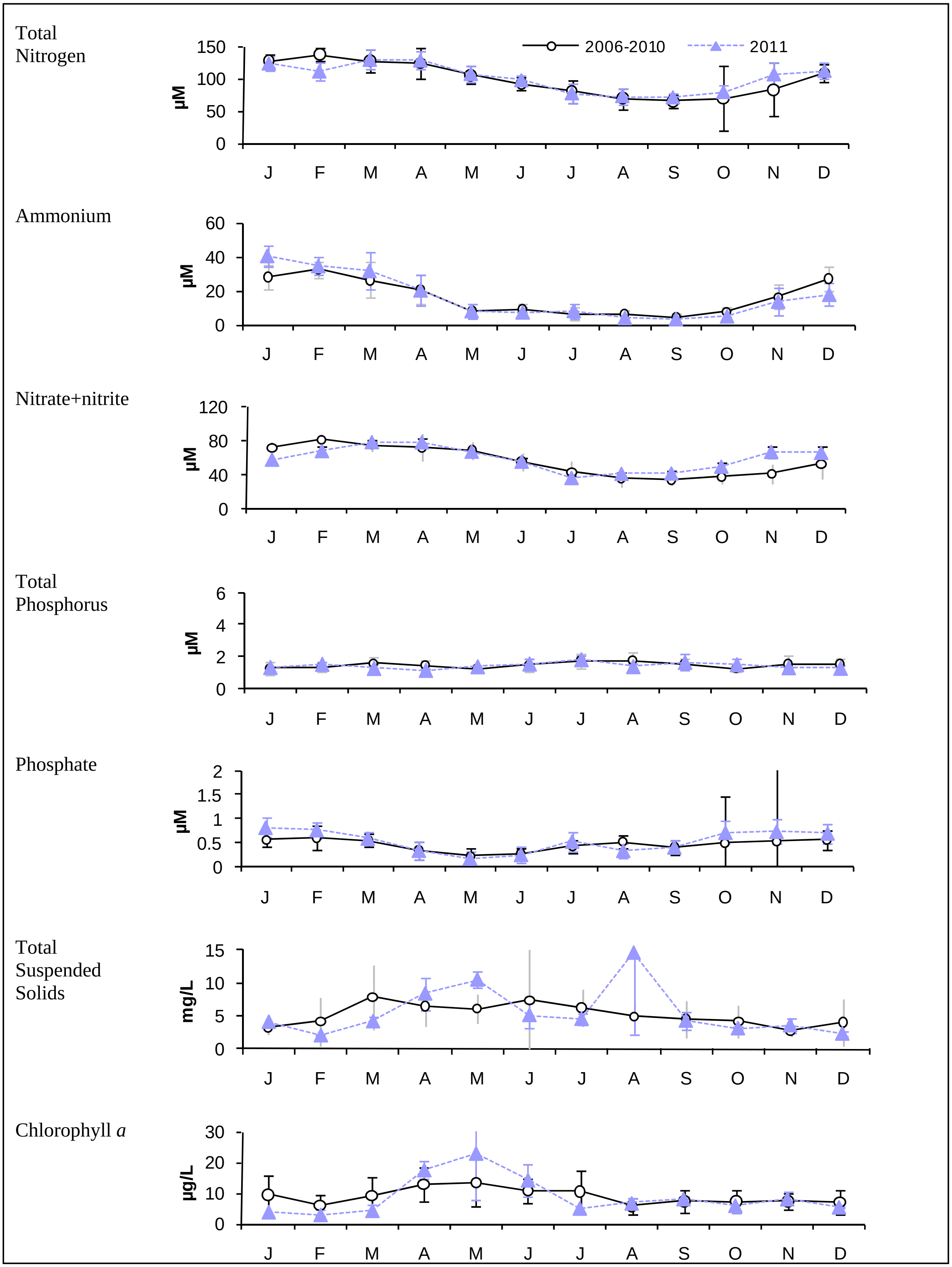

Figure 4-4. Monthly average nutrients, TSS and Chlorophyll 2006 – 2011, Station 066 (Boston Ave.)

Error bars are ± 1 SD. Note different scales than Figures 4-3, 4-5 and 4-6 for most parameters.

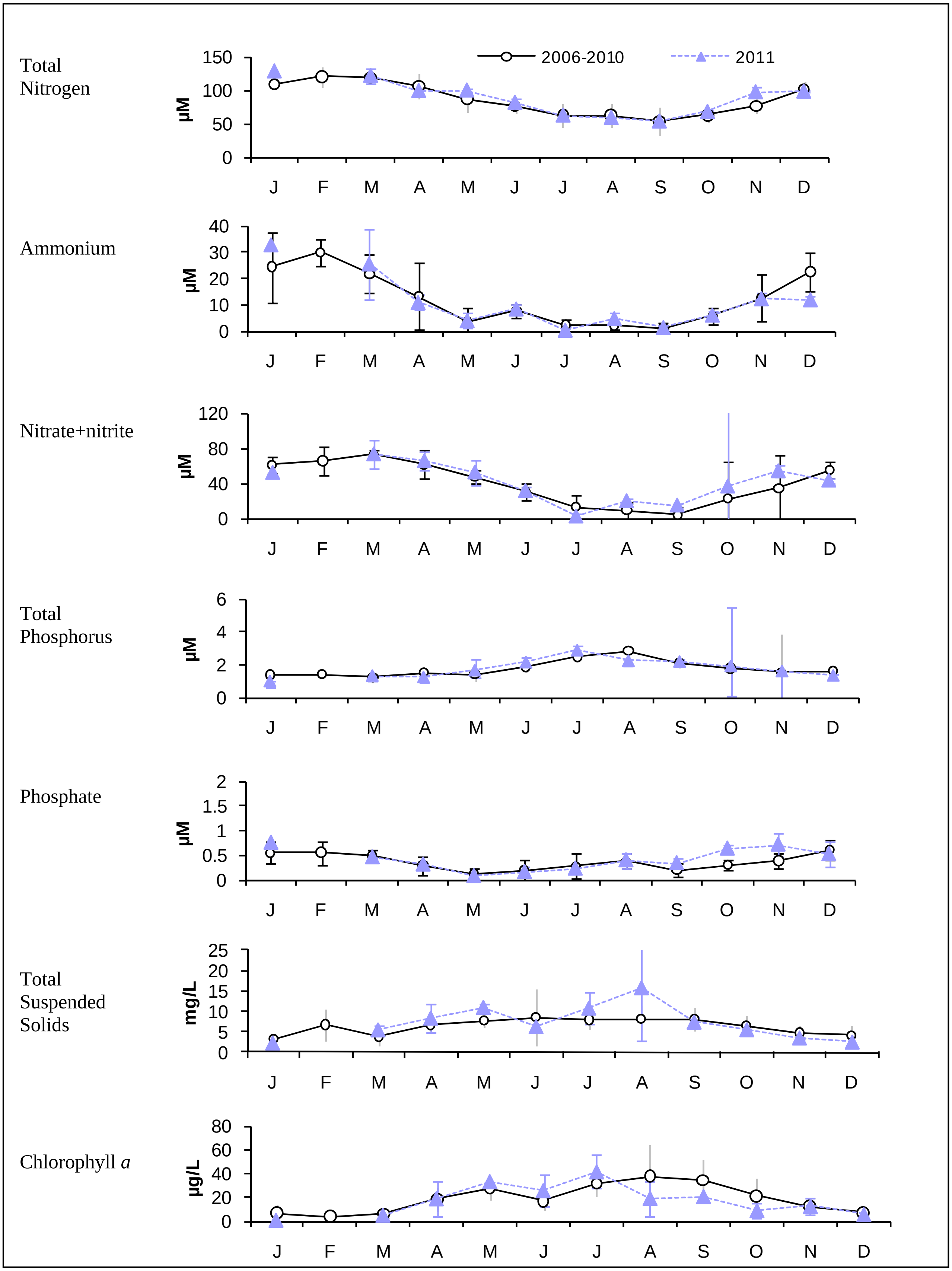

Figure 4-5. Monthly average nutrients, TSS and Chlorophyll 2006 – 2011, Station 167 (Amelia Earhart Dam (upstream/freshwater)).

Error bars are ± 1 SD. Note different scales than Figures 4-3, 4-4 and 4-6 for most parameters.

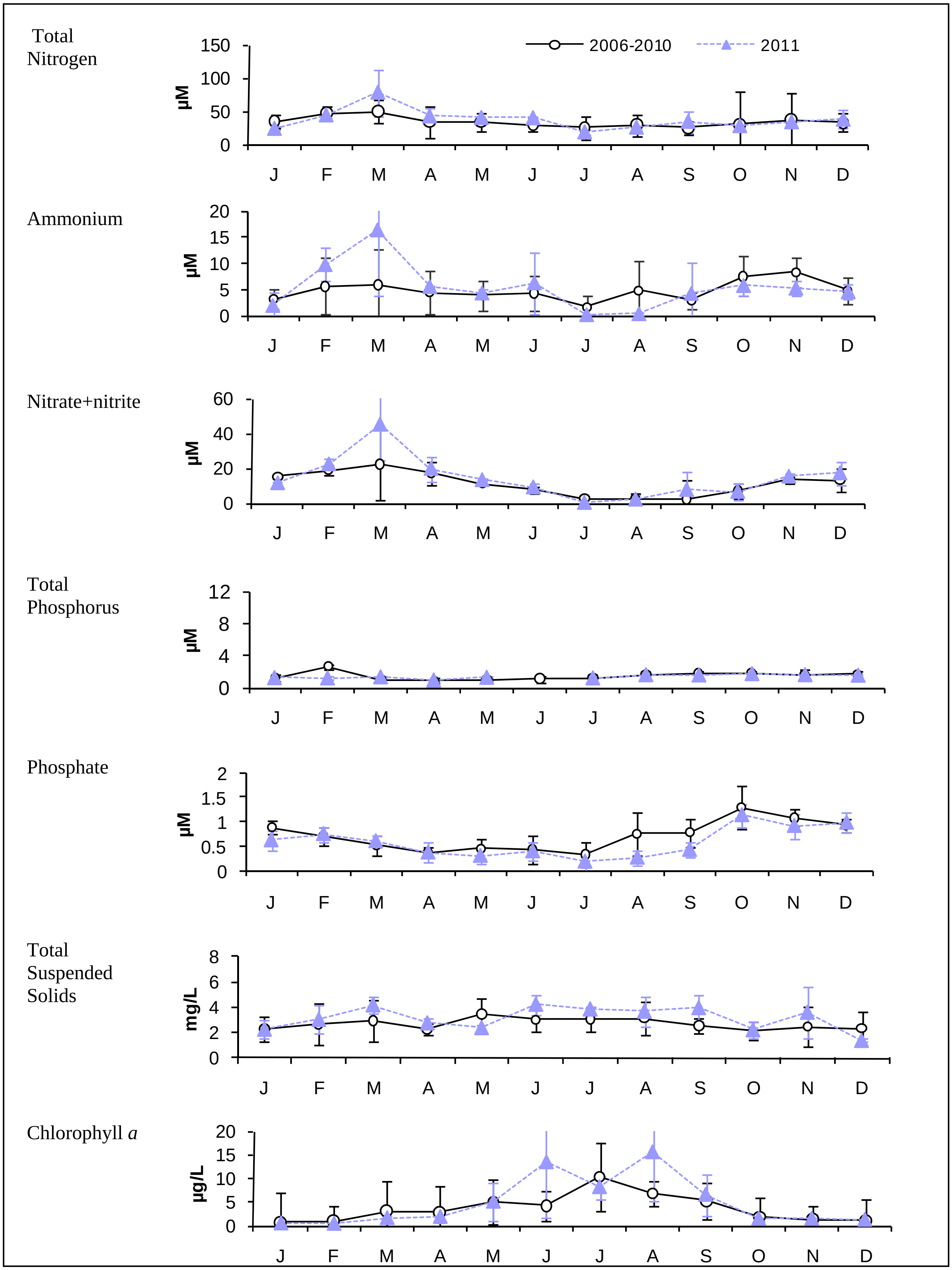

Figure 4-6. Monthly average nutrients, TSS and Chlorophyll 2006 – 2011, Station 137 Mystic River mouth (marine).

Error bars are ± 1 SD. Note different scales than Figures 4-3, 4-4 and 4-5 for most parameters.

4.4.3 Bacterial water quality

Figure 4-7 shows the current bacterial water quality at each location sampled in the Mystic River and Alewife Brook for 2011 for dry, damp, and wet weather. The Lower Mystic Basin has the best water quality, with the majority of stations meeting bacterial standards in dry and wet weather. In the Lower Mystic, *Enterococcus* met standards in both wet and dry weather except for the Malden River location (176), the Somerville Marginal outfall (Station 052) and Station 069. With the exception of the Alewife and the Rt 16 Bridge, all locations met standards in dry weather upstream of the Amelia Earhart Dam.

Geometric means for each indicator for all locations for 2006 - 2011 appear in Table 4-6. Annual geometric means meet standards for all locations in 2011 except for Alewife Brook, and are generally lower than the five year averages for both *Enterococcus* and *E. coli*. This trend was the opposite of the Charles River, which saw increased geometric means for 2011 at most locations.

Enterococcus. The uppermost graph in Figure 4-7 shows percentile plots of *Enterococcus* counts for each location, arranged from upstream to downstream for 2011. Figure 4-8 shows the impact of rainfall on the three river reaches on *Enterococcus* densities, along with the change at locations near CSO outfalls. Alewife Brook locations consistently fail to meet standards, in both dry and wet weather, though conditions improve in the river mainstem, moving downstream to the river mouth. At the Somerville Marginal Outfall, geometric means are highest in heavy rain but are also elevated in dry weather.

The change in *Enterococcus* concentrations over time in Alewife Brook and the Mystic River appear in Figure 4-9 through Figure 4-11. Results are grouped by phases of the Long Term CSO Plan improvements and include the geometric mean counts in each rainfall condition. These figures show little change over time in the Mystic River in dry and wet weather since the early 1990's.

E. coli. The center graph in Figure 4-7 shows percentile plots of *Enterococcus* counts arranged from upstream to downstream locations for 2011. *E. coli* shows a similar trend to *Enterococcus,* with basin locations generally meeting the geometric mean limit of 126 colonies/100 mL. As shown in Table 4-6, *E. coli* has significantly improved at all Mystic mainstem locations compared to the 5-year averages, with geometric means well within the standard.

Fecal coliform. Fecal coliform appears in the bottom graph in Figure 4-7. Fecal coliform analysis replaced *E. coli* in marine waters in 2008, due to methodological reasons and because it continues to be the indicator for shellfish growing waters. Analysis was conducted for Alewife Brook samples in 2011 because of methodological concerns about the change in *E. coli* methods in 2007. With the exception of Station 052 (MWR205), fecal coliform results in the marine portion of the river continue to meet the former state geometric mean standard of 200 colonies/100 mL.

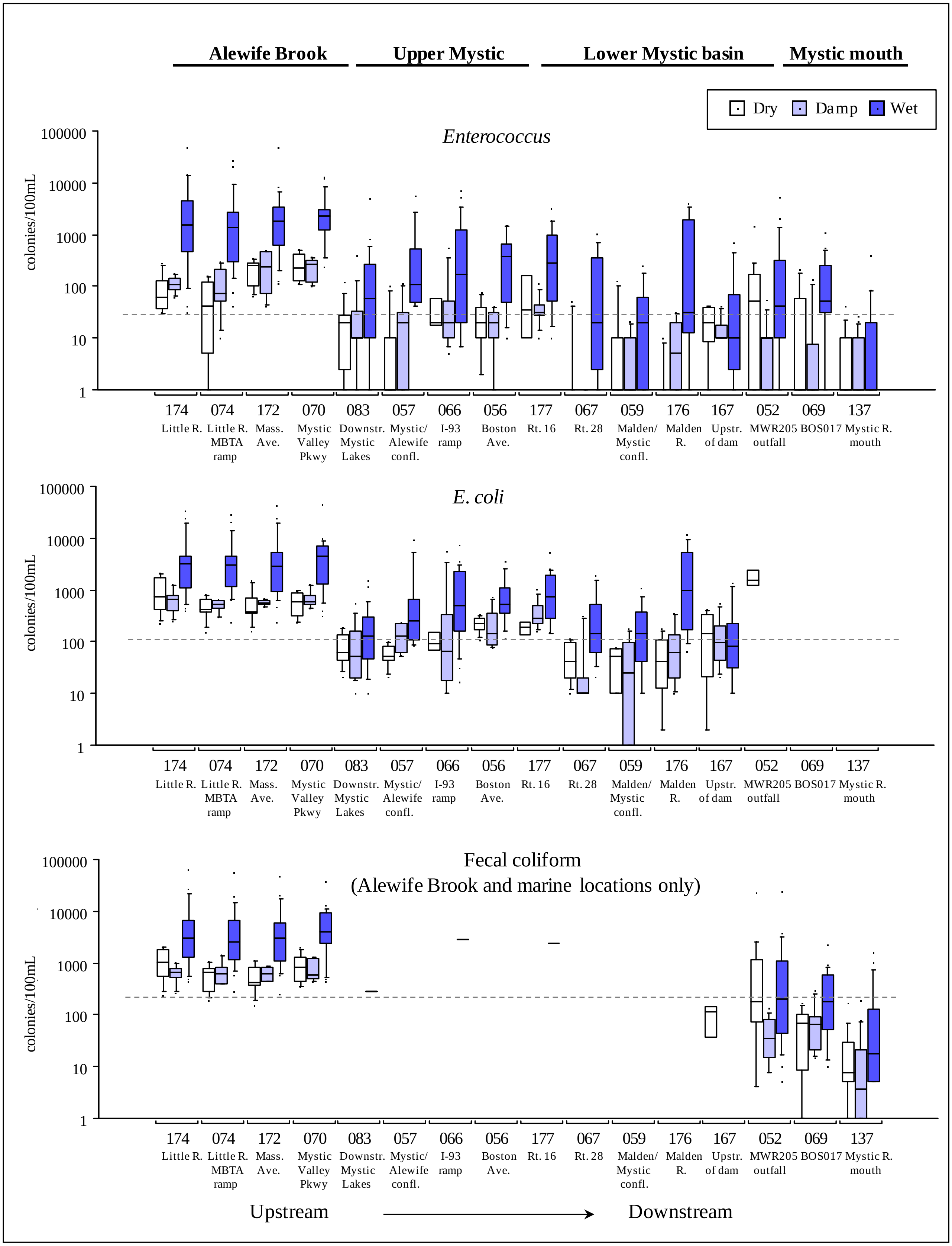

Figure 4-7. Indicator bacteria concentrations, Mystic River/Alewife Brook, 2011.

Dotted lines show MADEP *Enterococcus* and *E. coli* standard and former fecal coliform standard. *E. coli* testing was discontinued in 2008 in marine waters for methodological reasons. Dry: no rainfall for previous 3 days; Wet: at least 0.5 inches in previous 2 days; damp is everything in between.

Table 4-6. Geometric mean indicator bacteria, Mystic River/Alewife Brook, 2006 - 2011.

Station	Location	Surface or Bottom	Number of samples		*Enterococcus* (95% CI) colonies/100 mL		*E. coli* [1] (95% CI) colonies/100 mL	
			2006-'10	2011	2006 - 2010	2011	2006 - 2010	2011
174	Cambridge, Little River, upstream of Rt. 2 and off ramp to Alewife T station	S	114	35	117 (84-161)	130 (60-278)	361 (284-459)	493 (252-963)
074	Cambridge, Little River, at off ramp to Alewife T station	S	133	35	118 (84-165)	132 (79-219)	448 (353-569)	309 (142-673)
172	Arlington, Alewife Brook, upstream of Massachusetts Ave bridge, midchannel	S	118	35	141 (107-184)	231 (134-397)	365 (293-455)	649 (378-1116)
070	Arlington, Alewife Brook, off Mystic Valley Parkway bridge	S	134	35	230 (168-313)	245 (146-413)	463 (381-562)	859 (544-1357)
083	Medford, upstream of confluence of Mystic River and Alewife Brook	S	219	48	20 (15-27)	18 (9-35)	73 (60-89)	22 (12-42)
057	Medford, confluence of Mystic River and Alewife Brook	S	104	24	34 (24-48)	26 (11-58)	129 (99-168)	26 (9-71)
066	Medford, Mystic River, Boston Ave bridge	S	138	24	44 (31-63)	84 (40-175)	143 (108-188)	48 (21-109)
056	Medford, Mystic River, upstream of I-93 bridge	S	104	35	28 (19-41)	9 (3-23)	292 (235-363)	81 (37-175)
177	Medford, Downstream of Rt. 16 bridge, mid-channel	S	123	35	22 (15-31)	20 (8-46)	191 (154-236)	92 (48-177)
067	Medford, Mystic River, Rt. 28 bridge	S	106	24	5 (3-8)	2 (0-6)	36 (25-52)	4 (1-12)
059	Everett, confluence of Mystic and Malden Rivers	S	105	23	4 (2-6)	2 (1-6)	35 (24-50)	5 (2-12)
176	Malden River, upstream of Rt. 16 bridge	S	105	24	11 (7-17)	4 (1-11)	76 (51-112)	12 (3-41)
167	Medford, Mystic River, upstream side of Amelia Earhart Dam	S	126	26	5 (3-8)	5 (2-12)	43 (31-60)	12 (6-24)
052[2]	Somerville, Mystic River, near Somerville Marginal CSO facility (MWR205) - marine	S	117	36	13 (8-20)	2 (1-5)	*80 (42-150)*	*210 (99-444)*
		B	89	29	4 (3-7)	1 (0-3)	*25 (16-39)*	*11 (6-21)*
069[2]	Charlestown, near Schrafft's Center at BOS-017 outfall - marine	S	46	37	3 (1-5)	2 (0-5)	*27 (13-54)*	*80 (42-151)*
		B	21	29	2 (0-4)	3 (0-15)	*10 (4-25)*	*7 (1-37)*
137[2]	Mystic River, upstream of Tobin Bridge – marine/Inner Harbor	S	118	33	6 (4-9)	9 (3-23)	*51 (34-77)*	*32 (17-60)*
		B	117	47	2 (1-2)	1 (0-3)	*4 (3-6)*	*3 (2-5)*

[1]Results in italics are fecal coliform, not *E. coli*. *E. coli* testing was discontinued in 2008 in marine waters for methodological reasons. Geometric mean limit for *Enterococcus* is 35 cfu/100 mL in marine water, 33 cfu/100 mL in freshwater. The *E. coli* limit is 126 cfu/100 mL.

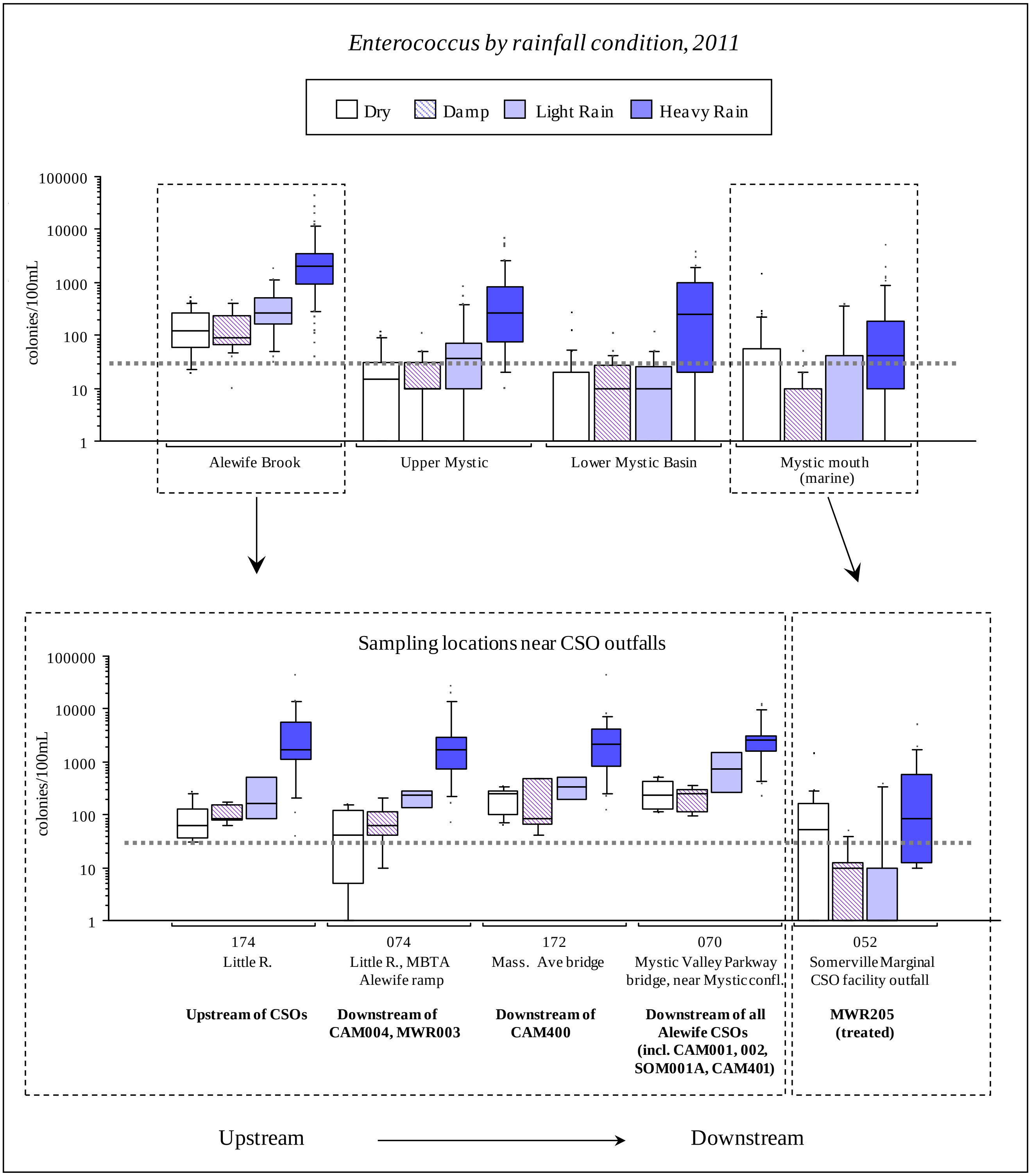

Figure 4-8. *Enterococcus* by rainfall condition, Mystic River/Alewife Brook, 2011.

Dotted line shows State standard of 33 colonies/100 mL for freshwater. Rainfall is NOAA rainfall from Logan airport. “Dry”: no rainfall for previous 3 days; “Heavy”: more than 0.5 inches in previous 3 days; “Damp” and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; “Light rain”: between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

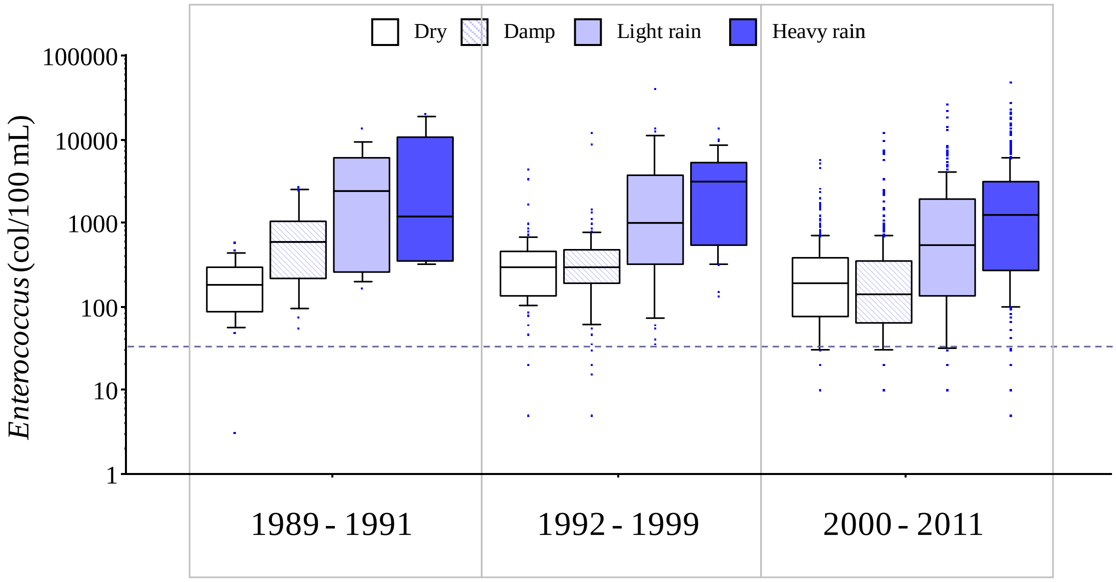

Figure 4-9. *Enterococcus* over time, Alewife Brook by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for stations 174, 172, 074 and 070. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

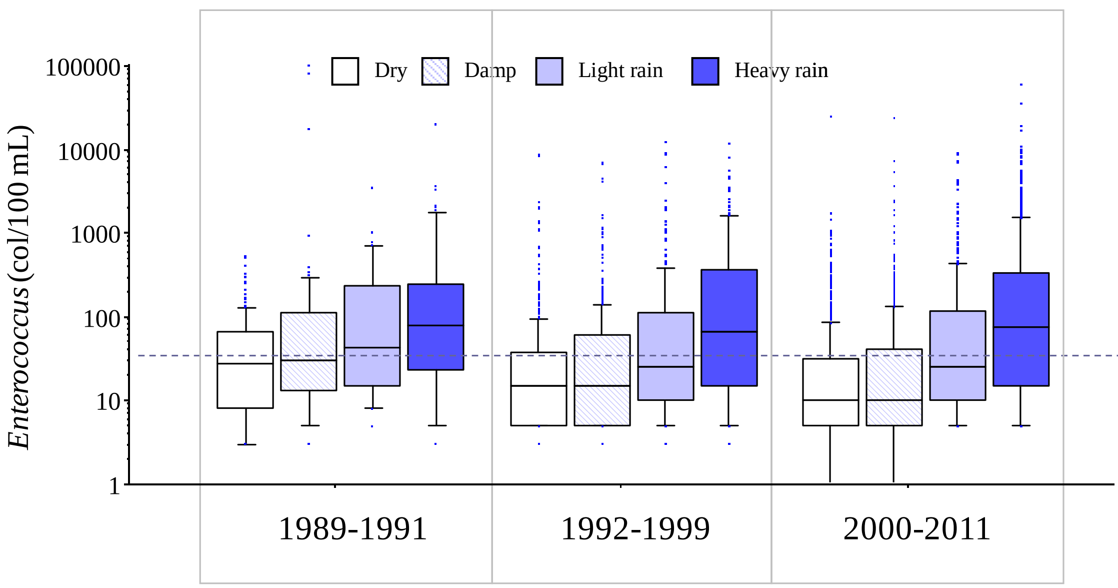

Figure 4-10. *Enterococcus* over time, Mystic River by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for all Mystic River stations excepting Alewife Brook. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

4.5 Summary of Mystic River/Alewife Brook water quality

Bacterial water quality in the Mystic River meets standards for much of the Lower Mystic Basin and Mystic River mouth, but fails to meet limits in the Alewife Brook, Malden River and Upper Mystic (in wet weather only; the Upper Mystic meets limits in dry weather). Bacterial counts in the Alewife consistently fail to meet standards in wet and dry weather; however water clarity and dissolved oxygen in the Alewife improved in 2011, with mean DO concentrations generally meeting the State standard. Downstream of the Alewife, water quality conditions improve in the river mainstem and at the river mouth.

With the exception of the Alewife, most locations in the Mystic River did meet *Enterococcus* geometric mean limits, and most locations showed a significant improvement in geometric mean *E. coli*. 2011 was a particularly wet year, and while conditions in the Alewife were adversely affected by wet weather discharges, concurrent improvements in the mainstem suggest a limited impact of Alewife Brook on downstream water quality.

2011 nutrient results were largely similar to previous years, with monthly concentrations near long term averages, except for TSS concentrations following the August 2011 storms. Locations near the Amelia Earhart dam and Malden River confluence were the most eutrophic, having the highest chlorophyll *a* and lowest dissolved oxygen, and pronounced changes in seasonal nitrogen concentrations.

REFERENCES

Bendschneider, K. and Robinson, R. J. 1952. A new spectrophotometric determination of nitrate in seawater. Journal of Marine Research 11: 87-96.

Clesceri, L. S., A. E. Greenberg, and A. D. Eaton. 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edition. American Public Health Association, American Water Works Association, Water Environment Federation.

Ellis B., Rosen J. 2001. Statistical Analysis of Combined Sewer Overflow Receiving Water Data, 1989 – 1999. Massachusetts Water Resources Authority. Report ENQUAD 2001-06.

Fiore, J. and O'Brien, J. E. 1962. Ammonia determination by automatic analysis. Wastes Engineering. 33: 352.

Gong G., Lieberman J., D. McLaughlin. 2003. Statistcal analysis of combined sewer overflow receiving water data, 1989-1996. Boston: Massachusetts Water Resources Authority. Report ENQUAD 98-09.

Holm-Hanson. O, Lorenzen, C. J, Holmes, R. W, and Strickland, J. D. H. 1965. Fluorometric determination of chlorophyll. J. Cons. Int. Explor. Mer. 30: 3-15.

Murphy, J. and Riley, J. 1962. A modified single solution for the determination of phosphate in natural waters. Anal. Chim. Acta. 27:31.

MADEP. 1996. Massachusetts surface water quality standards. Massachusetts Department of Environmental Protection, Division of Water Pollution Control, Technical Services Branch. Westborough, MA (Revision of 314 CMR 4.00, effective January, 2008).

MADEP. 2002. Boston Harbor 1999 Water Quality Assessment Report. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA. Report 70-AC-1.

MWRA. 2009. (DCN 5000.0). Department of Laboratory Services Quality Assurance Management Plan, Revision 3.0. Massachusetts Water Resources Authority, Boston, MA.

MWRA. 2011. Combined Sewer Overflow Control Plan, Annual Progress Report 2010. Massachusetts Water Resources Authority, Boston, MA.

MWRA 2012. Letter dated April 30 to USEPA and MA DEP regarding CSO Discharge Estimates and Rainfall Analyses for Calendar Year 2011. Massachusetts Water Resources Authority, Boston, MA.

Solarzano, L, and Sharp, J. H. 1980a. Determination of total dissolved phosphorus and particulate phosphorus in natural waters. Limnology and Oceanography, 25, 754-758.

Solarzano, L, and Sharp, J. H. 1980b. Determination of total dissolved nitrogen in natural waters. Limnology and Oceanography, 25, 750-754.

USEPA, Office of Water. 1986. Ambient Water Quality for Bacteria – 1986. Washington, D.C. Office of Water. EPA 440/5-84-002.

Wu D. 2011. NPDES compliance summary report, fiscal year 2011. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2011-06.