Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2013

Massachusetts Water Resources Authority

Environmental Quality Department

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Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2013

Prepared by:

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

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1 Introduction

This report summarizes data collected as part of the Massachusetts Water Resources Authority (MWRA) 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 the 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 2013 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 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 2013, 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, 2016. 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, 2016.

Under the agreement on the Long Term Control Plan (the "LTCP") reached by EPA, MADEP and MWRA in March 2006, MADEP agreed to issue a series of three-year variance extensions through 2020, and MWRA agreed to implement the approved LTCP by 2015 and verify system performance and the levels of control 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 LTCP and other conditions affecting the water quality and uses of these water bodies.

Conditions in the recent variance extensions require MWRA to implement the LTCP in compliance with federal court schedule milestones ("Schedule Seven") and require MWRA and the municipalities to continue to implement the Nine Minimum Controls of EPA's National CSO Control Policy. Conditions in the variance extensions also require all of the CSO permittees to report estimated CSO discharge frequencies and volumes 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.

CSO control progress in 2013 as it relates to the Charles River and Alewife Brook/Mystic River includes the following:

- The Town of Brookline completed the Brookline sewer separation project in April 2013, ahead of the July 2013 milestone in the court schedule. The project removed large volumes of stormwater from the Brookline and MWRA sewer systems and redirected the stormwater flows through CSO Outfall MWR010 to the Charles River Basin. The project involved the installation of large sanitary sewers in Beacon, St. Mary's, and Monmouth Streets and the conversion of existing combined sewers to storm drains. Several new connections were also created between the separated Brookline system and MWRA's Charles River Valley Sewer and South Charles Relief Sewer. The project has reduced treated CSO discharges to the Charles River at MWRA's Cottage Farm facility: model simulations performed by MWRA to support its annual reporting requirement show that the Brookline sewer separation project has reduced Typical Year CSO discharges from Cottage Farm from7 activations and 27.2 million gallons to 5 activations and 18.7 million gallons, a 31% annual volume reduction. Sewer separation programs by the City of Cambridge are expected to further lower the Cottage Farm discharges. This sewer separation project also resulted in the closing of a BWSC CSO regulator that contributed to CSO discharges at Outfall MWR010 and likely further reduced already infrequent overflows from MWRA's Charles River Valley Sewer to Outfall MWR010.

- Cambridge achieved substantial completion and beneficial use of the CAM004 stormwater outfall and wetland basin project in April 2013, in compliance with Schedule Seven. The wetland basin is intended to mitigate water quality and flooding impacts to the Little River and Alewife Brook of planned sewer separation in upstream areas along and surrounding Huron and Concord Avenues. The stormwater outfall and wetland basin will provide detention and wetlands treatment to the separated stormwater flows prior to discharge to the Little River as stormwater is removed from the Cambridge and MWRA sewer systems.

- The City of Cambridge also attained 70% completion of the first of three major construction contracts for the CAM004 Sewer Separation project (Contract 8A), commenced the second contract (8B) and advertised the third contract (9) for construction bids (Cambridge commenced Contract 9 in February 2014). This project is intended to close Outfall CAM004 and lower CSO discharges at other outfalls to Alewife Brook and is the CSO abatement centerpiece of MWRA's Alewife Brook CSO control plan. Cambridge expects to complete the project by December 2015 in compliance with Schedule Seven.

- MWRA achieved substantial completion of the construction contract for the Interceptor Connection Relief and Floatables Control at Outfall SOM01A project in December 2013, ahead of the June 2014 milestone in Schedule Seven. The project provides for floatables control at Outfall SOM01A, which discharges into Alewife Brook, and allows for an increase in the capacity of the connection from Somerville's Tannery Brook Conduit to MWRA's interceptor, lowering CSO discharges at SOM01A once the CAM004 sewer separation project is complete in 2015.

- MWRA attained 100% design of its Control Gate and Floatables Control at Outfall MWR003 and MWRA Rindge Avenue Siphon Relief project in December 2013 and plans to issue the notice to proceed with construction by August 2014, in compliance with Schedule Seven. The project is the last of six projects in MWRA's CSO control plan for Alewife Brook and the last of the 35 projects in the LTCP to move into construction. The project will improve sewer system performance, contribute to CSO reductions along Alewife Brook, and provide floatables control and sewer system relief at Outfall MWR003 in extreme storms in part to compensate for the closing of nearby Outfall CAM004 with completion of the CAM004 sewer separation project in December 2015.

As of the end of 2013, 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). BOS017 also discharges at the river mouth.

System-wide, average annual CSO discharge has been reduced from 3.3 billion gallons in 1988 to 463 million gallons as of the end of 2013, an 86% reduction, with 90% of current discharge volume receiving treatment at MWRA's four CSO treatment facilities. Other MWRA system improvements since the 1990s have also reduced the frequency and volume of CSO flows over the period of the monitoring program and have resulted in increased treatment of remaining flows. Figure 1-1 shows the estimated CSO flow reduction system-wide since 1988, and Figure 1-2 shows the CSO flow reduction by receiving water. For purposes of this report, receiving water quality data from 2008 to the present is considered representative of current conditions.

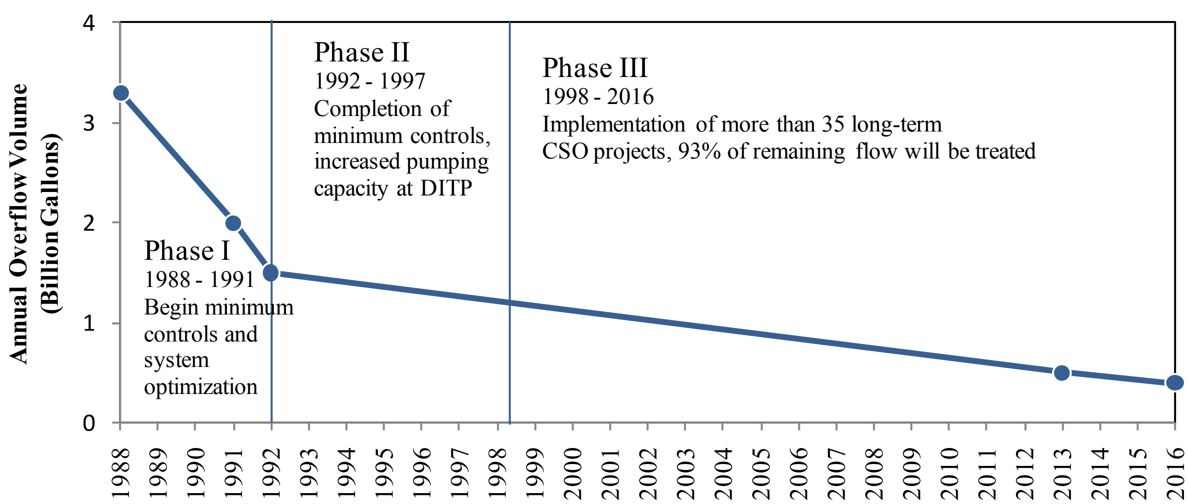


Figure 1-1. Estimated CSO flow reductions, 1988 – 2016.
Source: MWRA CSO Annual Progress Report 2013 (March 2014)

[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. CSO discharges at BOS-081, -082, -084, -085 and -086 are effectively eliminated, with a 25-year storm level of control.

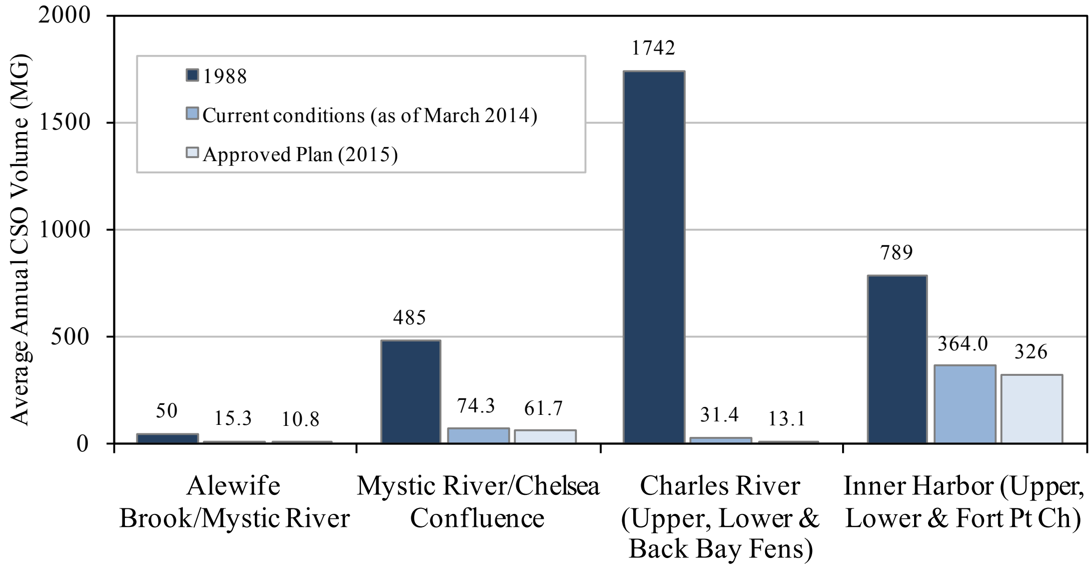


Figure 1-2. CSO Typical Year Discharge Volumes for 1988, Current, and Approved Long Term Control Plan model estimates

Source: MWRA CSO Control Plan Annual Progress Report 2013 (March 2014)

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 2013. 2013 rainfall totals are very close to the Typical Year predictions, suggesting that rainfall in 2013 was representative in terms of the effect of rainfall on system performance. Compared to 2012, there were approximately the same total number of storms, but more storms in the 0.25 to 0.5 inch category and fewer storms in the higher rainfall categories. (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, 2013 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
2013 Ward St. Headworks	42.9	91	46	20	9	12	4
2013 Columbus Park Headworks	43.37	97	54	20	7	12	4
2013 BWSC Charlestown	35.52	94	57	17	9	9	2
2013 Fresh Pond (USGS)	33.89	95	60	13	11	10	1

Source: MWRA CSO Discharge Estimates and Rainfall Analyses for Calendar Year 2013, 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 2013 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 2013 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 - 2008) YSI6600, YSI6820 (2009 - 2013) YSI 600XL for temperature, conductivity, dissolved oxygen (1999 – 2013)
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 2008).

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.

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 2007) Enterolert (for samples collected 2008 – 2013)
E. coli	Modified EPA 1103.1, membrane filtration (for samples collected 2000 – 2006) Colilert (for samples collected 2007 - 2013)
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 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles. Single measurements beyond these ranges (outliers) are displayed as dots.

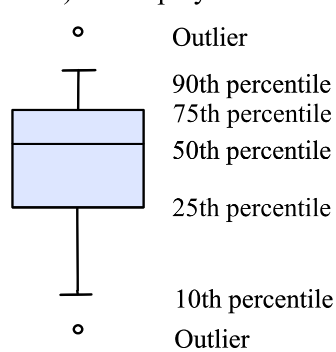


Figure 2-1. Percentile distributions indicated on percentile plots

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), MADPH, MADEP	*Enterococcus*	Single sample limit 61counts/100 ml (freshwater), 104 counts/100 ml (marine); geometric mean 33 counts/100 ml (freshwater), 35 counts/100 ml (marine)
Freshwater primary contact recreation (designated swimming area), MADPH, MADEP	*E. coli*	Single sample limit 235 counts/100 ml (freshwater only); geometric mean 126 counts/100 ml (freshwater only)
Former standard, primary contact recreation, MADEP (pre-2007)	Fecal coliform	Geometric mean ≤ 200 counts/100 ml, no more than 10% of samples above 400 counts/100 ml
Restricted shellfishing, MADMF	Fecal coliform	Geometric mean ≤ 88 counts/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 October 2013). 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.

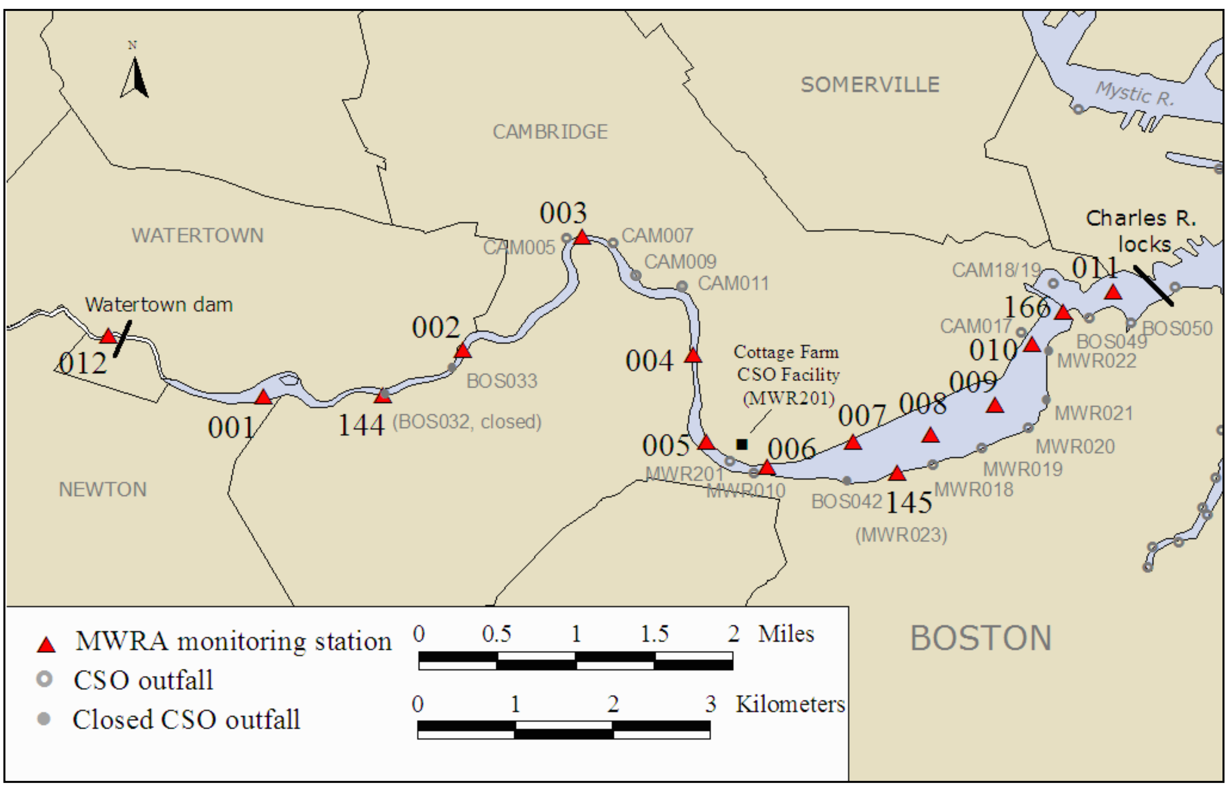


Figure 3-1. Map of MWRA Charles River sampling locations.

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 over the last two decades – from more than 20 activations in the late 1990s to 3 activations in 2013. 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 2013. Actual CSO volumes and activation frequency are available for the Cottage Farm CSO facility, while the remaining results are estimated using model data.

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 3 times in 2013	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 2013 system conditions and 2013 rainfall.[1]

CSO Outfall	Activation Frequency	Total Discharge Duration (hr)	Total Discharge Volume (million gallons)
Upper Charles			
CAM005	1	2.22	0.66
CAM007	1	2.22	0.63
TOTAL		4.44	1.29
Back Bay Fens (Muddy River)			
BOS046	2	18.89	13.07
TOTAL		18.89	13.07
Lower Charles			
CAM017	1	0.97	0.21
MWR010	0	0	0.00
MWR018	1	1.95	1.07
MWR019	0	0	0.00
MWR020	0	0	0.00
MWR201 (Cottage Farm Facility) [2,3]	3	11.24	30.26
MWR023 (Stony Brook)	2	1.80	0.08
TOTAL		15.96	31.61

[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
2008 - 2012	31% 790 samples	34% 878 samples	35% 893 samples	100% 2561 samples
2013	32% 220 samples	28% 190 samples	41% 279 samples	100% 689 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, 2009-2013

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 2009 - 2013.

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	21 ± 4.9	97.8	6.3 - 30.3	1049	20.3 ± 4.7	97.1	6.8 - 29.6	912	21.8 ± 4.6	88.4	8.4 - 29.9	267
	Winter		5.1 ± 5.1	100.0	-0.1 - 17.5	94	ND	ND	ND	23	4.4 ± 3.7	100.0	0.4 - 15.8	54
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	8.1 ± 1.6	97.5	1.6 - 14.5	1038	6.1 ± 3.3	68.9	0 - 12.6	901	7 ± 2.3	82.3	0.4 - 13.8	265
	Winter	5.0	13.4 ± 1.9	100.0	9.1 - 15.8	89	ND	ND	ND	23	13 ± 1.4	100.0	9.1 - 15.8	52
pH[6] (S.U.)		6.5-8.3	7.4 ± 0.3	99.6	6.7 - 8.6	1594	7.3 ± 0.5	96.1	6.2 - 9.3	1272	7.4 ± 0.5	96.5	6.4 - 9	457
Water clarity	Total Suspended Solids (mg/L)	NS	4.3 ± 5.5	-	0.3 - 37.5	128	ND	-	ND	0	4.7 ± 6.2	-	0.3 - 51.7	122
	Secchi depth (m)	NS	1.1 ± 0.3	-	0.5 - 2.5	484	1.2 ± 0.3	-	0.6 - 3.1	636	1.3 ± 0.3	-	0.7 - 2.6	160
	Turbidity (NTU)	NS	6.5 ± 3.4	-	0.2 - 25.6	1398	6.9 ± 3.5	-	0 - 35.1	1252	5.1 ± 2.9	-	0.1 - 16.9	357

Table 3-5. Summary of water quality, Charles River Basin 2009 - 2013, 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*	200 / 400[3]	147 (134-161)	88.3	0 - 24200	877	61 (55-68)	73.4	0 - 9800	1061	42 (35-49)	67.8	0 - 8660	339
	Enterococcus	126 / 235[3,4]	12 (10-14)	91.1	0 - 5790	879	6 (5-7)	80.9	0 - 15500	1061	5 (4-6)	69.9	0 - 1290	339
Nutrients (µmol/L)	Phosphate	NS	0.74 ± 0.38	-	0.01 - 2.46	130	ND	-	ND	0	0.65 ± 0.43	-	0.02 - 2.14	123
	Ammonium	NS	4.1 ± 3.3	-	0.4 - 25.5	130	ND	-	ND	0	5.5 ± 5	-	0 - 30.2	123
	Nitrate+nitrite	NS	42.5 ± 18.8	-	7.9 - 92.1	130	ND	-	ND	0	39.3 ± 20.2	-	0 - 110.5	123
Algae (µg/L)	Chlorophyll	NS	4.1 ± 4.3	100.0	0.4 - 22.7	130	ND	ND	ND	0	12.1 ± 11	89.4	0.6 - 52.8	123

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, 2013

This section provides an analysis of trends for water quality parameters measured in the lower Charles in the 2013 monitoring year.

3.4.1 Physical measurements

Temperature. Summer water temperatures for 2013 are shown for each sampling location in the top graph in Figure 3-2. Surface temperatures are relatively consistent upstream to downstream, particularly upstream of the lower basin. Bottom-water temperatures are consistently lower in the deeper waters downstream, particularly Station 009 (upstream of the Longfellow Bridge), where water depth exceeds 6 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 and bottom DO does meet the State standard of 5.0 mg/L at most locations in the Lower Charles, but mean bottom water DO failed to meet meets the standard at deeper water locations downstream, including stations 007, 009, 010 and 011. 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 near the Longfellow Bridge. 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 (measured June through September) are shown for individual sampling locations in the bottom graph in Figure 3-2. Station 12 at the Watertown Dam is too shallow for Secchi measurements but is typically clear to the river bottom. All locations in the Lower Charles have relatively consistent measurements, with Secchi depths at or near the standard of 1.2 meters.

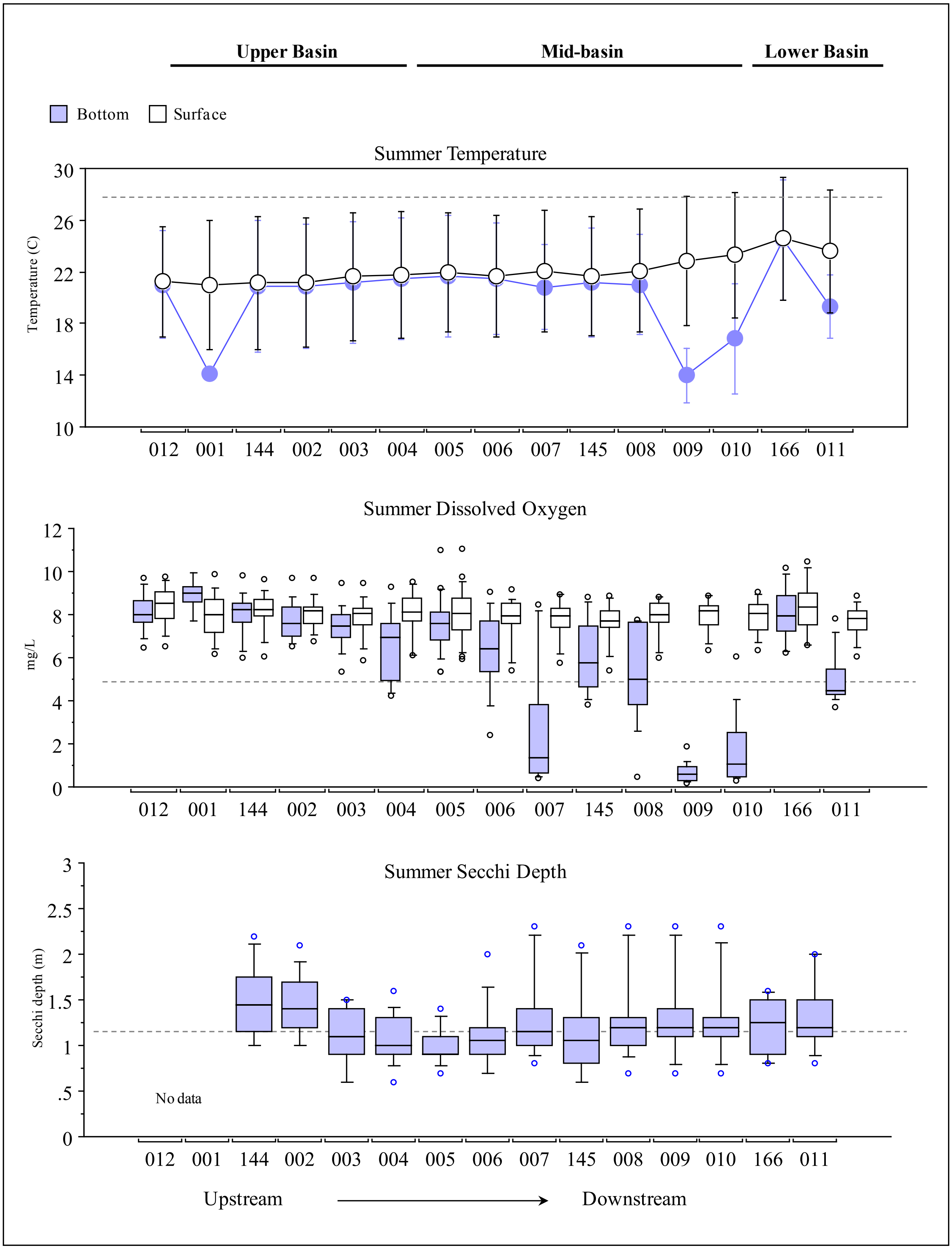


Figure 3-2. Summer temperature, dissolved oxygen and Secchi depth, Charles River Basin, 2013.
Dashed lines are State standards or guideline (maximum for temperature, minima for DO and Secchi).
No Secchi data are available for Station 012 because of shallow depth; the site is typically visible to bottom.

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. 2013 averages are plotted with the average of the previous five years (2008 – 2012) 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 differences between the two stations for chlorophyll *a*. Historically, Station 012 has the highest chlorophyll concentrations in spring, whereas the Lower Basin has highest concentrations in late summer. In 2013 chlorophyll at both locations was below the 5-year average for the late spring and summer months, particularly at the Science Museum location, though slightly above average for late fall.

Trends for the 2013 monitoring year are similar to the 2008 – 2012 averages for most parameters, though phosphate, TSS, and chlorophyll showed some differences for 2013. As in 2012, TSS concentrations were generally lower than the 5-year average. Phosphate concentrations were also below the 5-year average at the Lower Basin location near the Science Museum—as in 2012, nearly half the historical concentrations--but concentrations were about average upstream at the Watertown dam.

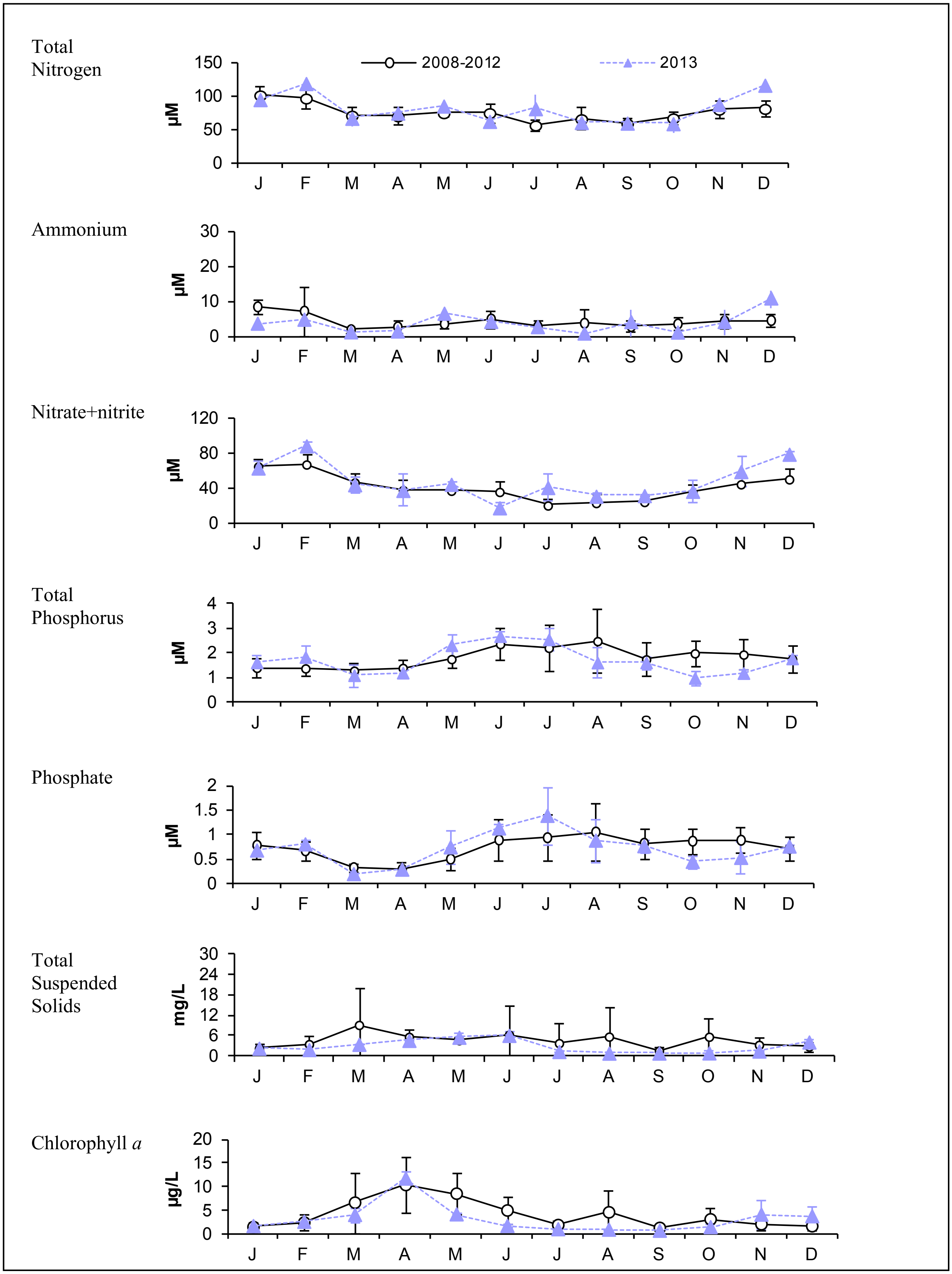


Figure 3-3. Monthly average nutrients, TSS and Chlorophyll 2008 – 2013, Station 012, Watertown Dam.
Error bars are ± 1 SD.

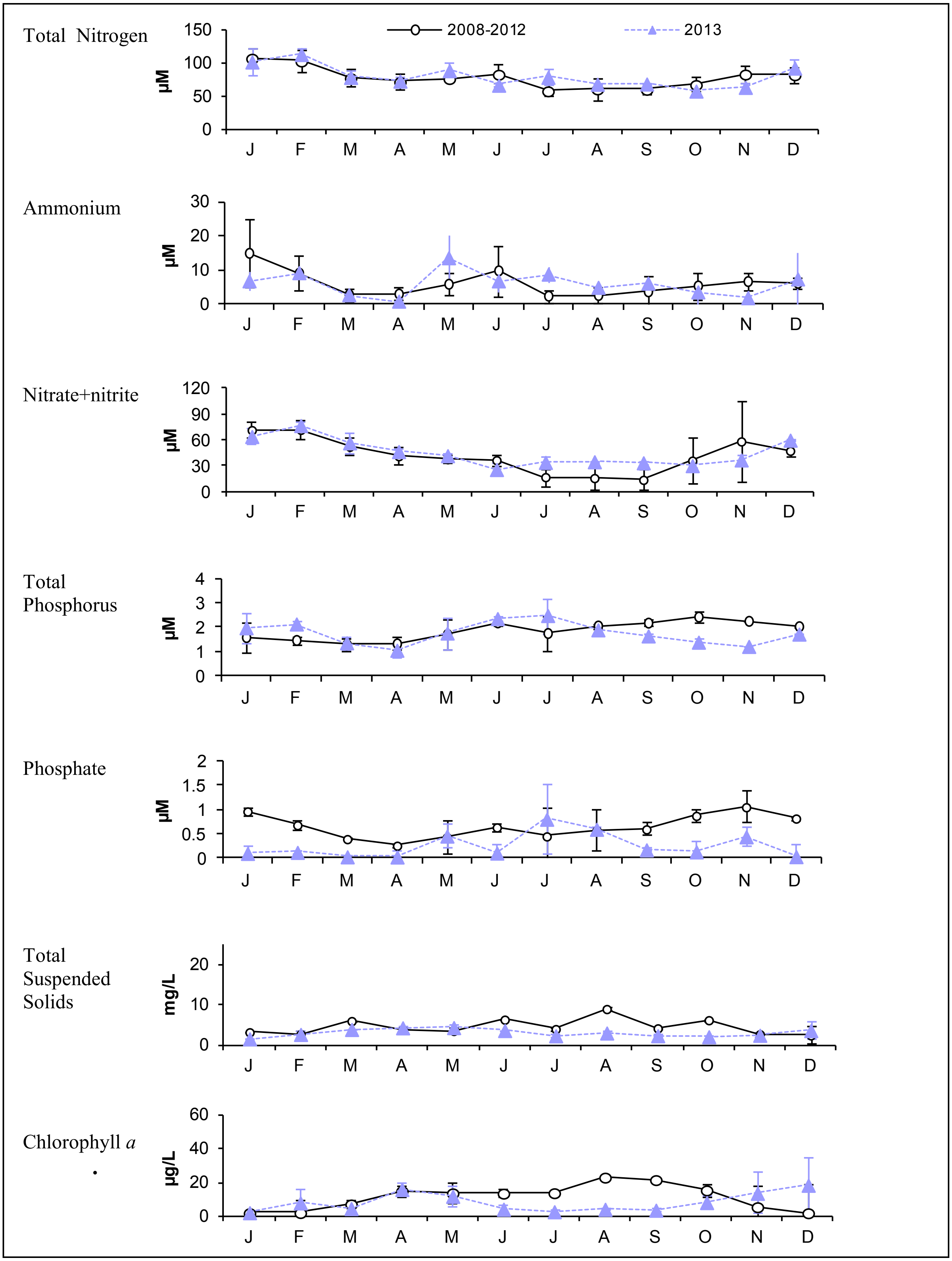


Figure 3-4. Monthly average nutrients, TSS and Chlorophyll 2008 – 2013, Station 166, Science Museum.
Error bars are ± 1 SD.

3.4.3 Bacterial water quality

Figure 3-5 shows the current bacterial water quality at each location sampled in the Charles for 2013, for dry, damp, and wet weather. Upstream reaches generally have more elevated bacteria counts than downstream locations, though this trend is less pronounced in 2013 than in past years, with a slight but continuing improvement in conditions at Watertown Dam.

Annual geometric means for each location for 2008 - 2013 appear in Table 3-6. Geometric means for 2013 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 ($\alpha = 0.95$). Without exception, 2013 bacterial concentrations at all locations are lower than the 5-year mean. This is particularly notable as a slightly higher proportion of samples were collected in wet weather in 2013 as compared to earlier years.

The top graph in Figure 3-5 shows percentile plots of *Enterococcus* counts arranged from upstream to downstream locations for 2013 (note log scale). The bottom graph in Figure 3-5 shows percentile plots of *E. coli* counts arranged from upstream to downstream locations for 2013. Generally, *E. coli* shows the same spatial trend as *Enterococcus*, with more elevated bacteria counts upstream relative to downstream locations. Locations downstream of the BU Bridge in Cambridge met geometric mean standards for both bacterial indicators in dry weather. Upstream locations met geometric mean standards in both weather conditions, with the exception of stations 012, 001 and 005 in wet weather, the same pattern as 2012. Annual geometric means shown in Table 3-6 met the *Enterococcus* geometric mean standard, and all but stations 001, 144, and 006 met the *E. coli* standard, again a pattern similar to 2012.

Figure 3-6 shows the impact of rainfall on the three Lower Charles reaches on *Enterococcus* densities, along with results for individual locations near CSO outfalls. Bacterial concentrations in light rainfall, damp and dry conditions met the geometric mean standard in all three reaches, failing to meet the standard during heavy rain.

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 meets the geometric mean swimming standard only in dry weather. The most pronounced change is in the lower Charles, which meets the geometric mean swimming standard in all conditions. The greatest improvement in bacterial water quality since the early 1990s has been in dry weather, followed by heavy rain conditions.

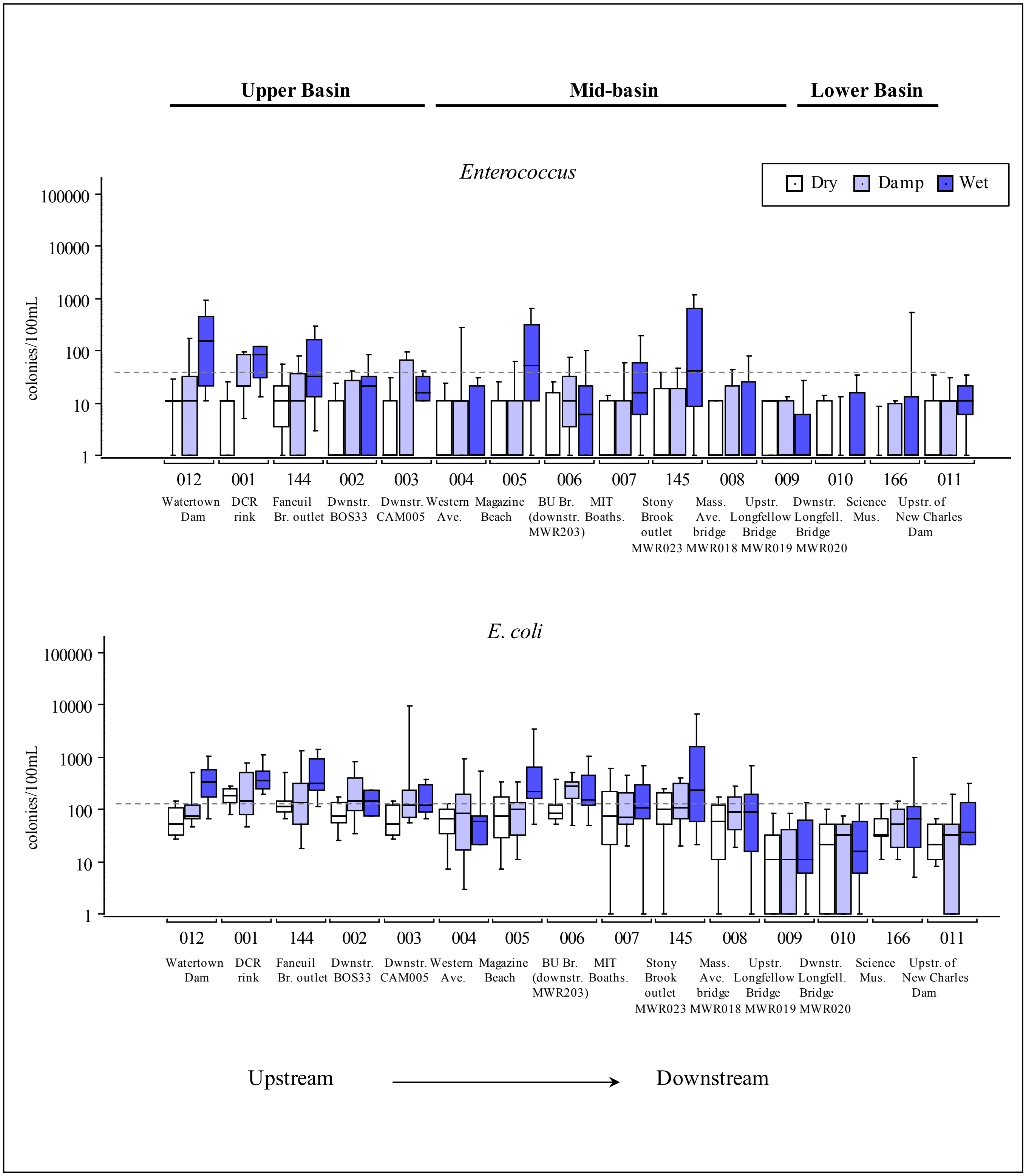


Figure 3-5. Indicator bacteria concentrations, Charles River Basin, 2013.
Dotted lines show MADEP *Enterococcus* and *E. coli* standard. Dry: no rainfall for previous 3 days; Wet: at least 0.5 inches in previous 2 days; damp is everything in between.

Table 3-6. Geometric mean indicator bacteria, Charles River Basin, 2008 – 2013.

Station	Location	Surface or Bottom	Number of samples 2008–'12	Number of samples 2013	*Enterococcus* (95% CI)[1] counts/100 mL DEP limit: 33 counts/100 mL 2008 – 2012	*Enterococcus* 2013	*E. coli* (95% CI)[1] counts/100 mL DEP limit: 126 counts/100 mL 2008 – 2012	*E. coli* 2013
012	Newtown/Watertown, footbridge upstream of Watertown Dam	S	126	27	28 (19-39)	19 (8-43)	173 (141-211)	116 (77-176)
001	Newton, near Nonantum Rd., rear of DCR skating rink	S	99	24	29 (20-43)	12 (6-25)	274 (227-330)	204 (145-287)
144	Brighton, downstream of N. Beacon St. bridge, Faneuil Brook outlet, BOS-032 (closed 1999)	S	94	25	31 (21-47)	10 (5-22)	307 (232-408)	168 (106-267)
002	Allston, downstream of Arsenal Street bridge, BOS-033	S	93	24	21 (13-32)	3 (1-7)	221 (178-275)	94 (57-156)
003	Allston/Cambridge, midstream, near Mt. Auburn Street, between CAM-005 and CAM-006	S	95	24	16 (10-24)	4 (2-9)	213 (168-271)	103 (62-171)
004	Allston/Cambridge, midstream, between River Street and Western Avenue bridges	S	99	24	7 (4-11)	2 (1-6)	90 (65-125)	45 (23-87)
005	Cambridge, near Magazine Beach, upstream of Cottage Farm	S	201	49	8 (6-11)	5 (2-10)	109 (88-136)	98 (61-157)
006	Cambridge/Boston, midstream, downstream of Cottage Farm, BU bridge	S	106	24	13 (8-19)	3 (1-8)	182 (139-238)	141 (96-208)
007	Cambridge, near Memorial Dr., MIT Boathouse	S	106	24	7 (4-10)	2 (1-6)	112 (82-154)	49 (23-106)
		B	106	24	16 (10-24)	4 (1-10)	183 (134-250)	71 (32-159)
145	Boston (Charlesgate), Muddy River/Stony Brook outlet	S	107	25	16 (10-24)	6 (2-16)	218 (155-307)	100 (46-218)
008	Cambridge/Boston, midstream, downstream of Harvard Bridge	S	106	24	6 (4-9)	2 (0-4)	104 (73-148)	41 (19-86)
		B	106	24	10 (7-15)	2 (1-5)	155 (112-214)	45 (21-93)
009	Cambridge/Boston, midstream, upstream of Longfellow Bridge near Community Sailing	S	106	24	3 (2-5)	1 (0-3)	59 (43-82)	20 (10-40)
		B	106	24	1 (0-1)	2 (1-4)	13 (9-19)	3 (1-5)
010	Boston, downstream of Longfellow Bridge, MWR-022	S	106	24	2 (1-4)	1 (0-2)	40 (28-58)	15 (6-34)
		B	106	24	3 (2-4)	1 (0-3)	28 (19-41)	10 (5-20)
166	Boston, old Charles River dam, rear of Science Museum	S	132	26	4 (3-6)	1 (0-3)	91 (69-120)	39 (23-67)
011	Boston, upstream of river locks (New Charles River Dam) and I-93, near Nashua St.	S	106	24	3 (2-4)	2 (1-3)	40 (30-55)	24 (14-40)
		B	106	24	8 (6-12)	9 (4-16)	44 (32-59)	21 (10-44)

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

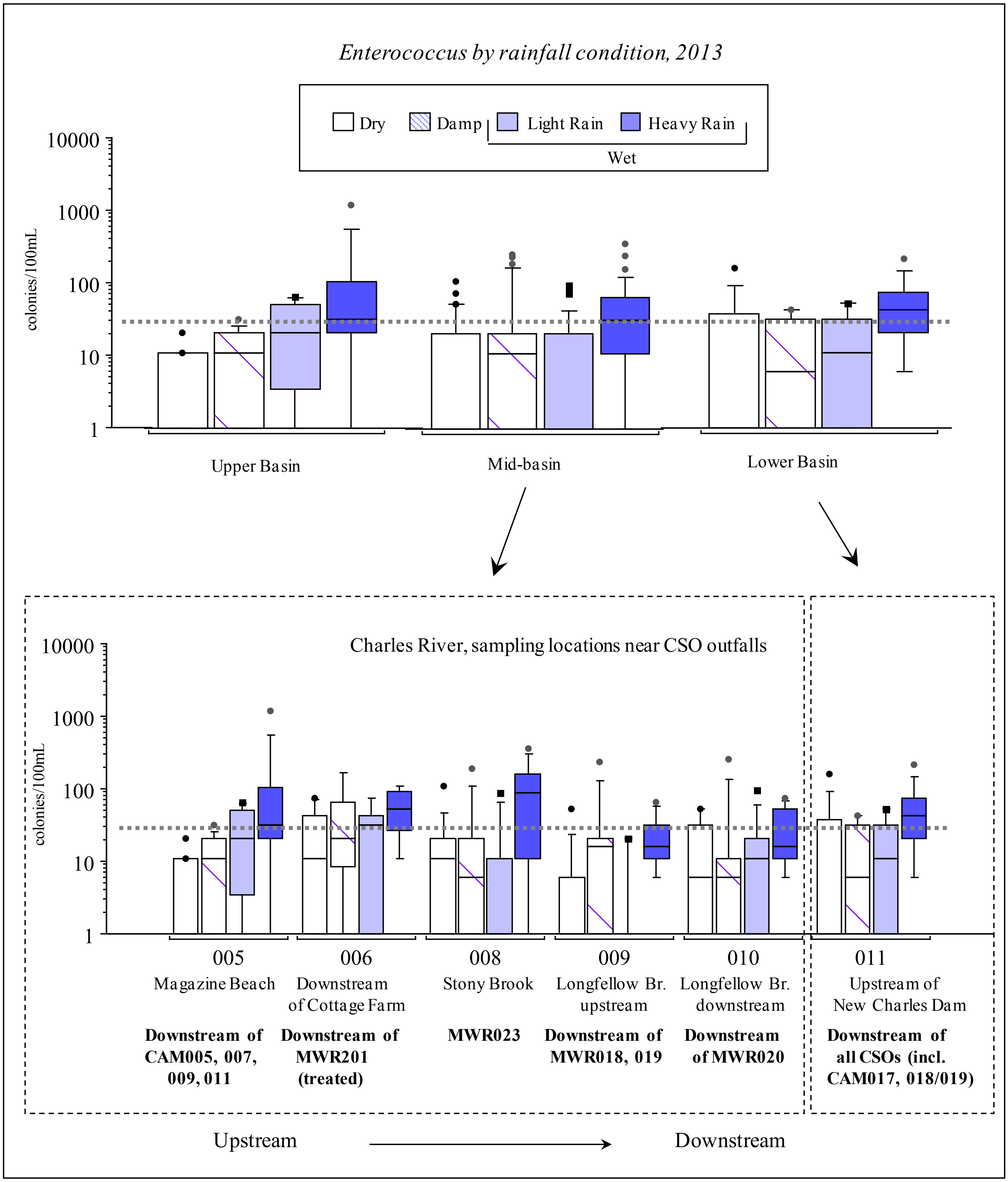


Figure 3-6. *Enterococcus* by rainfall condition, Charles Basin, 2013.

Dotted line shows MADEP standard of 33 counts/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.

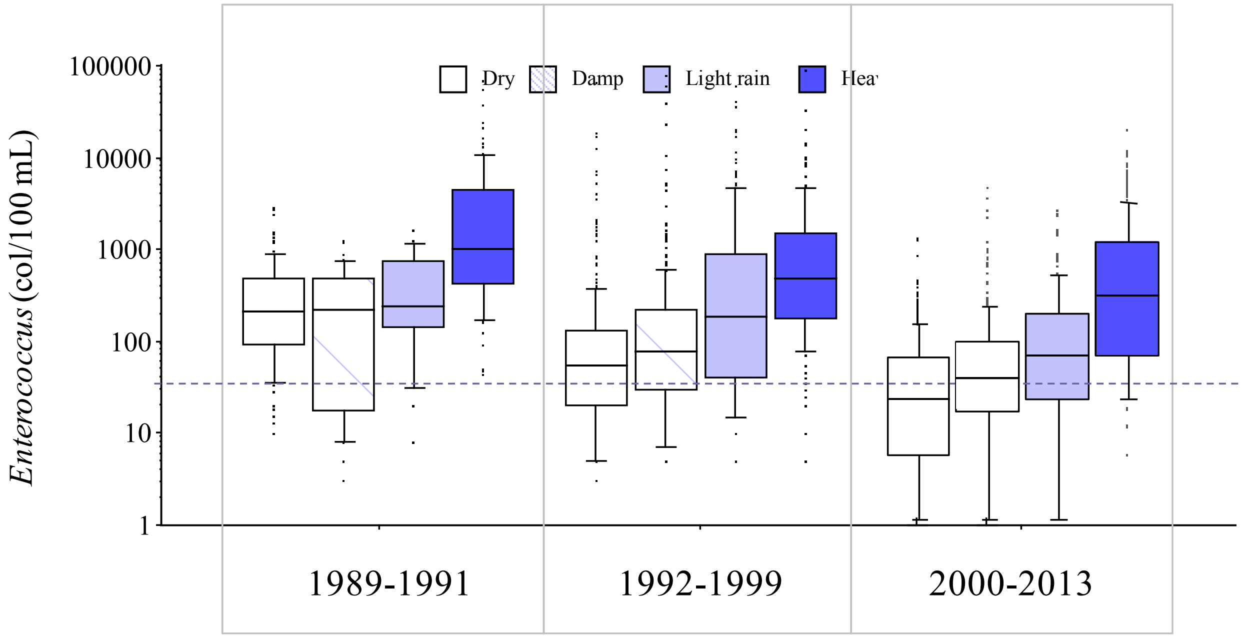


Figure 3-7. *Enterococcus* over time, Upper Charles Basin (upstream of CSOs) by phase of Long Term CSO Plan and rainfall condition.

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.

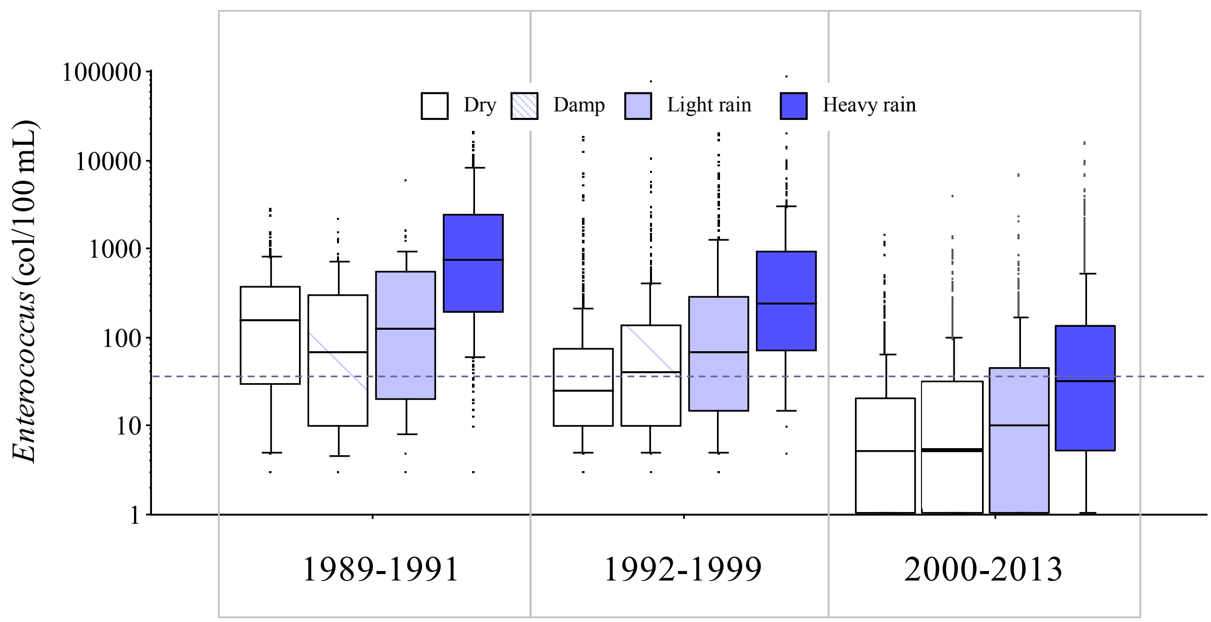


Figure 3-8. *Enterococcus* over time, Lower Charles Basin by phase of Long Term CSO Plan and rainfall condition.

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

2013 bacterial water quality in the Charles was generally consistent or better than five-year historical averages, with most individual locations meeting geometric mean standards for *E. coli* and *Enterococcus*, and individual locations in the Lower Basin having geometric mean bacteria counts below the five-year mean. In heavy rain conditions 2013 was consistent with past years, with the Mid-Basin and Lower Basin meeting geometric mean standards.

Spatially, water quality was for the most part 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.

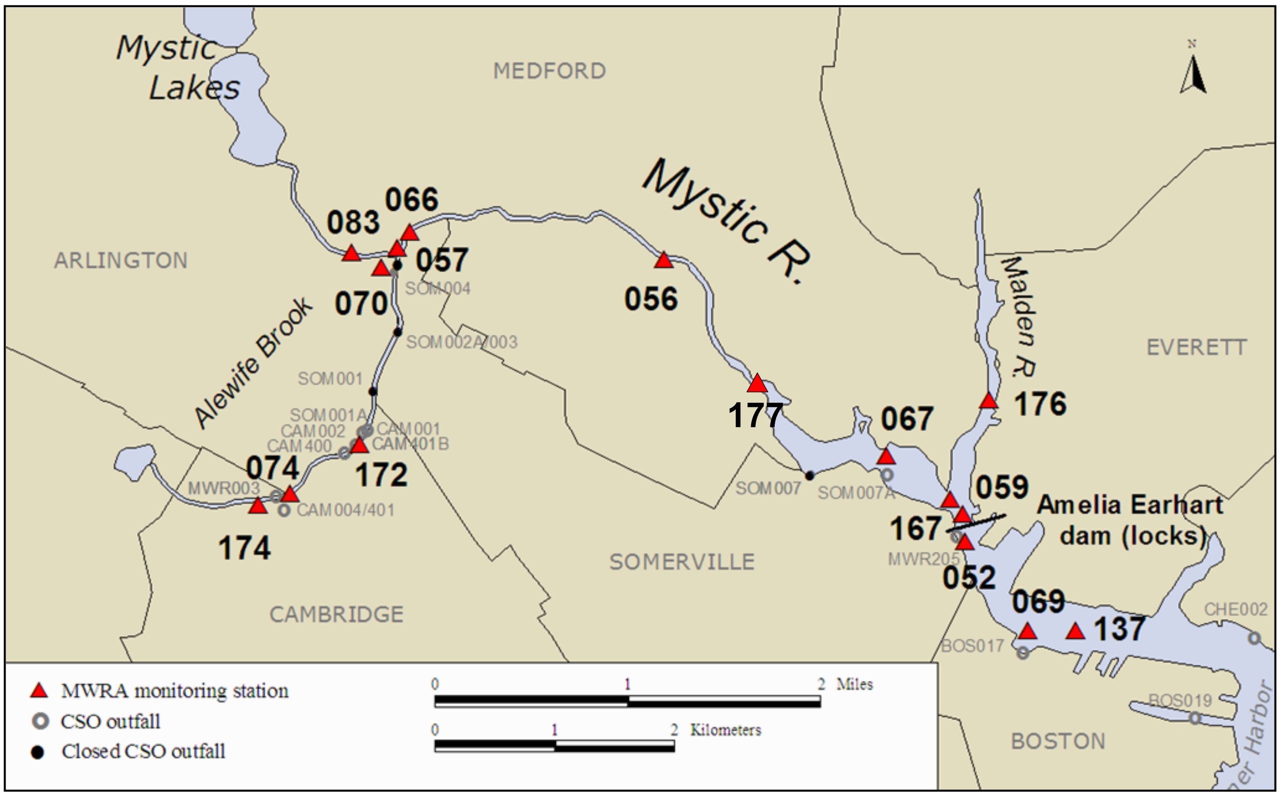
Bottom-water dissolved oxygen met standards in the Upper Charles Basin, but failed to meet standards in the lower Charles Basin, a pattern consistent with prior years. Seawater entering through the Charles locks in summer contributes to stratification of the basin, limiting exchange with surface waters and at least partially explains the lower bottom DO.

Nutrients and chlorophyll exhibited seasonal signals but matched long term averages overall. The exceptions were below-average summer chlorophyll and phosphate concentrations in the Lower Charles but near to average at the Watertown Dam.

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.



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 2013, Somerville Marginal 205A/SOM007A had five discharge events, and Somerville Marginal 205 had 19 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 2013. 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 2008 and 2013.

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 *CAM004 to be closed* CAM400 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 5 times in 2013	Yes Somerville Marginal (MWR205) Activated 19 times in 2013
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 2013 system conditions and 2013 rainfall.[1]

CSO Outfall	Activation Frequency	Total Discharge Duration (hr)	Total Discharge Volume (Million Gallons)
Alewife Brook			
CAM001	0	0.00	0.00
CAM002	1	0.73	0.06
MWR003	2	2.20	0.43
CAM004	6	8.99	1.87
CAM401A	2	2.43	0.43
CAM401B	8	12.56	1.05
SOM001A	2	2.49	1.59
TOTAL		29.41	5.43
Mystic River (upstream of dam)			
SOM007A/MWR205A (Somerville Marginal, high tide discharge only) [2]	5	4.56	9.75
TOTAL		4.56	9.75[4]
Mystic River mouth (downstream of dam, marine outfalls)			
MWR205 (Somerville Marginal Facility) [3]	19	87.35	64.46[4]
BOS017	0	0.0	0.0
TOTAL		87.35	64.46[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
2008-2012	31% 928 samples	32% 958 samples	36% 1077 samples	100% 2963 samples
2013	32% 292 samples	32% 286 samples	36% 322 samples	100% 900 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, 2009-2013

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 2009 - 2013.

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	18.2 ± 4	99.8	6.6 - 28.4	417	20.4 ± 4.1	99.2	8.3 - 28.5	524	20.2 ± 4.2	99.3	8.4 - 28.8	569	19.8 ± 3.9	100.0	9.2 - 27.3	131	17.3 ± 2.7	100.0	9.3 - 24.4	441
	Winter		4 ± 2	100.0	0.8 - 9.3	36	2.5 ± 1.9	100.0	0.4 - 8.1	61	3.3 ± 2.3	100.0	0.1 - 15.3	85	ND	ND	ND	0	2.8 ± 1.6	100.0	0.5 - 7.2	66
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	5.1 ± 2.3	51.9	0 - 15.1	414	7 ± 1.7	89.7	0.4 - 10.9	522	7.2 ± 2.4	82.8	0.5 - 12.2	569	6.2 ± 3.2	67.2	0.3 - 11.1	131	7.5 ± 1.5	96.6	2.5 - 15.4	441
	Winter	5.0	11.4 ± 1.2	100.0	8.9 - 13.9	36	12.2 ± 0.9	100.0	10 - 14.6	59	11.9 ± 1.9	100.0	6.6 - 15	81	ND	ND	ND	0	10.5 ± 0.9	100.0	7.9 - 13	66
pH[6] (S.U.)		6.5-8.3 (8.5 marine)	7.3 ± 0.3	99.5	6.7 - 9	638	7.5 ± 0.4	96.5	6.8 - 9	810	7.5 ± 0.6	93.0	6.2 - 9.2	908	7.5 ± 0.6	72.0	6.7 - 9.1	207	7.7 ± 0.3	99.0	6.3 - 8.5	
Water clarity	Total Suspended Solids (mg/L)	NS	ND	-	ND	0	5.2 ± 5.4	-	0.2 - 44.3	198	6.3 ± 4.3	-	0.6 - 30.1	120	ND	-	ND	0	3.5 ± 2.1	-	0.6 - 19.6	239
	Secchi depth (m)	NS	0.5 ± 0.2	-	0.2 - 1	38	1.3 ± 0.4	-	0.6 - 3.2	102	1 ± 0.2	-	0.4 - 1.9	275	1 ± 0.3	-	0.5 - 1.6	102	2.2 ± 0.8	-	0.2 - 5.8	254
	Turbidity (NTU)	NS	13.6 ± 7.1	-	3.5 - 34.7	141	5.8 ± 3.5	-	0.5 - 19.4	591	8.2 ± 4.9	-	0.3 - 44.2	724	9.8 ± 7.6	-	0.6 - 95.2	192	6.1 ± 3.9	-	0.4 - 58.6	652

Table 4-5. Summary of water quality, Mystic River/Alewife Brook 2009 - 2013, 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 (counts/100mL)[2]	Fecal coliform	200 / 400[3]	671 (481-936)	2.6	82 - 63000	196													37 (26-54)	18.9	0 - 29100	598
	E. coli	126 / 235[3,4]	742 (662-832)	78.2	0 - 50400	568	131 (114-150)	83.7	0 - 9210	467	67 (57-78)	90.5	0 - 5170	464	87 (54-137)	76.4	0 - 11200	106	1668 (1039-2678)	100.0	1140 - 2610	3
	Enterococcus	33 / 61[3]	238 (204-277)	76.4	0 - 45700	568	26 (21-31)	83.5	0 - 6870	467	7 (5-8)	94.4	0 - 3080	467	9 (5-15)	76.6	0 - 5480	107	5 (4-6)	96.8	0 - 5170	603
Nutrients (µmol/L)	Phosphate	NS	ND	-	ND	0	0.53 ± 0.68	-	0.01 - 6.01	201	0.35 ± 0.23	-	0.01 - 0.98	121	ND	-	ND	0	0.76 ± 0.33	-	0.01 - 1.74	239
	Ammonium	NS	ND	-	ND	0	14.2 ± 12	-	0.2 - 44.8	201	9.3 ± 9.1	-	0 - 33.2	127	ND	-	ND	0	4.3 ± 6.4	-	0 - 63.5	244
	Nitrate+nitrite	NS	ND	-	ND	0	55.8 ± 30.6	-	14.8 - 290	201	34.7 ± 22.7	-	0.1 - 85.5	121	ND	-	ND	0	7.3 ± 8.5	-	0 - 59.9	239
Algae (µg/L)	Chlorophyll *a*	25[5]	ND	ND	ND	0	9.1 ± 6.5	97.0	1.3 - 42.2	201	16 ± 11.4	83.5	0.4 - 72.4	121	ND	ND	ND	0	3.2 ± 4.1	99.6	0.2 - 30.8	239

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 2007 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, 2013

This section reports spatial trends for water quality parameters measured in the Mystic River/Alewife Brook in 2013.

4.4.1 Physical measurements

Temperature. Summer mean temperatures for 2013 are shown for each sampling location in the uppermost graph of Figure 4-2. Surface and bottom temperatures are similar, except in the downstream reach, on the marine side of the dam, where water depth is greater and harbor temperatures are lower.

Dissolved Oxygen. Dissolved oxygen is shown in the center graph of Figure 4-2. Mean surface and dissolved oxygen concentrations meet the State standard of 5.0 mg/L at all locations except for the lower Alewife Brook, and bottom water concentrations meet except in portions of Alewife Brook, and the lower Mystic River downstream of the Route 16 bridge (Station 177 and 067), Malden River (Station 176) and upstream of the Amelia Earhart dam (Station 167). Of any location in the Alewife and Mystic, bottom-water dissolved oxygen is typically lowest at the Malden River location (Station 176). Unlike the Charles River, there is little evidence of stratification due to saltwater intrusion in the lower portion of the Mystic.

Water clarity. Water clarity is indicated by Secchi disk depth, which appears for each sampling location in the bottom graph of Figure 4-2. Water clarity for all but the Mystic River mouth is poor, with nearly all stations upstream of the Dam failing to meet the guideline of 1.2 meters except for Station 056 and Station 166 in Medford, which typically meet water clarity limits (Alewife Brook and several upper Mystic locations are too shallow to measure Secchi depth, usually the river bottom is visible at these locations). Clarity on the marine side of the Amelia Earhart dam improves substantially at the marine portion of the river mouth.

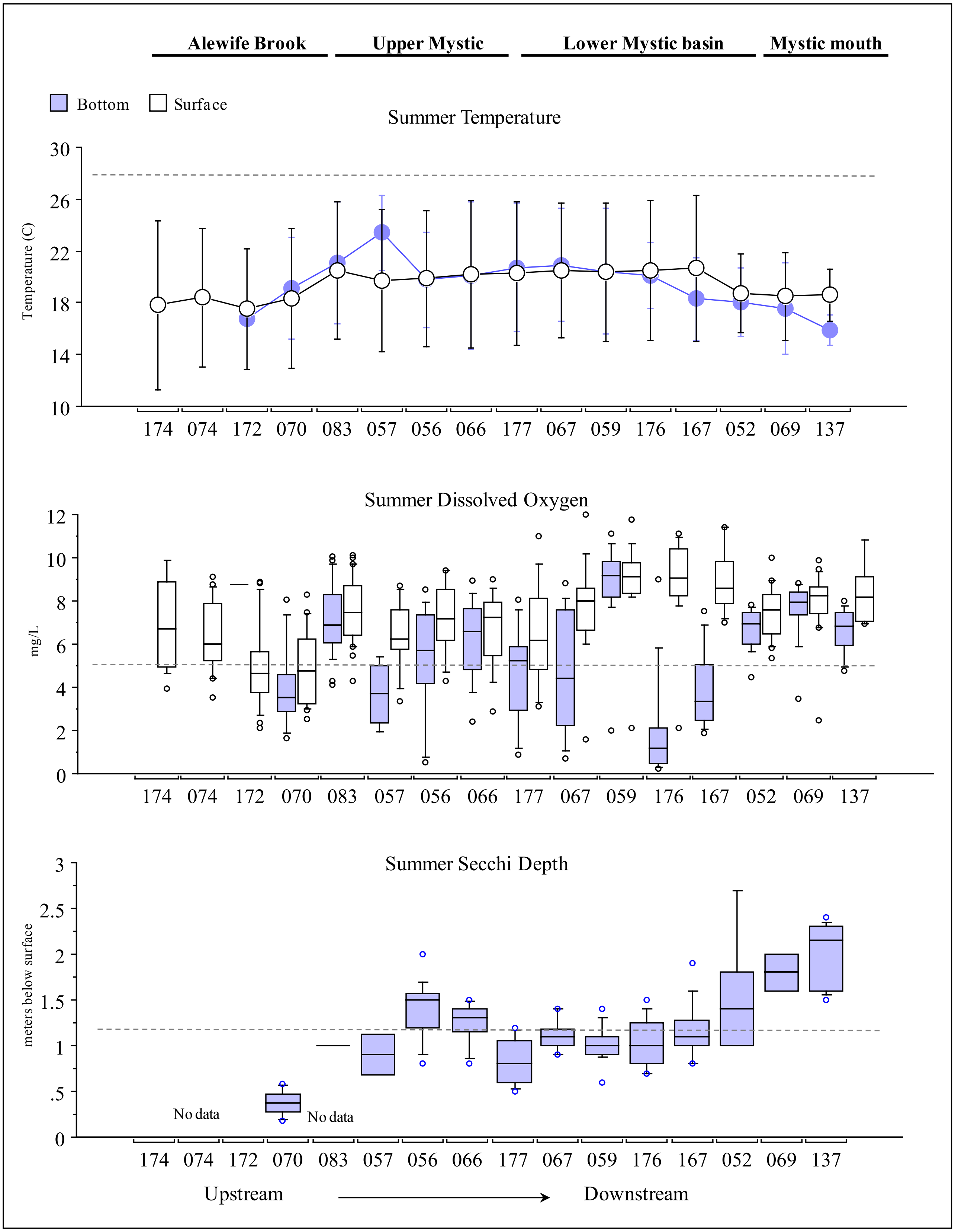


Figure 4-2. Summer temperature, dissolved oxygen, and Secchi depth, Mystic River, 2013.
Dashed lines are State standards or guideline (maximum for temperature, minima for DO and Secchi).
Brook locations are typically too shallow for measurements in the summer months.

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).

As biological activity increases during the summer months, ammonium and phosphate show relatively strong seasonal effects. Station 167, immediately upstream of the dam, is more eutrophic than either upstream or at the mouth of the river. Chlorophyll concentrations at Station 167 are typically more than double the concentrations of upstream locations, though summer chlorophyll was below average in 2013, as it was in downstream reach of the Lower Charles, suggesting a regional pattern. Monthly average chlorophyll upstream of the Mystic basin is most elevated in the spring as compared to later in the season, while concentrations are highest in late summer downstream of the basin.

In winter months, when biological nutrient uptake is low, ammonium concentrations in the in the Upper Mystic are more than double the concentration 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. In general, 2013 results were similar to the 5-year average for nutrient parameters, with the exception of chlorophyll and phosphate concentrations, which were slightly lower than average during the summer and early fall.

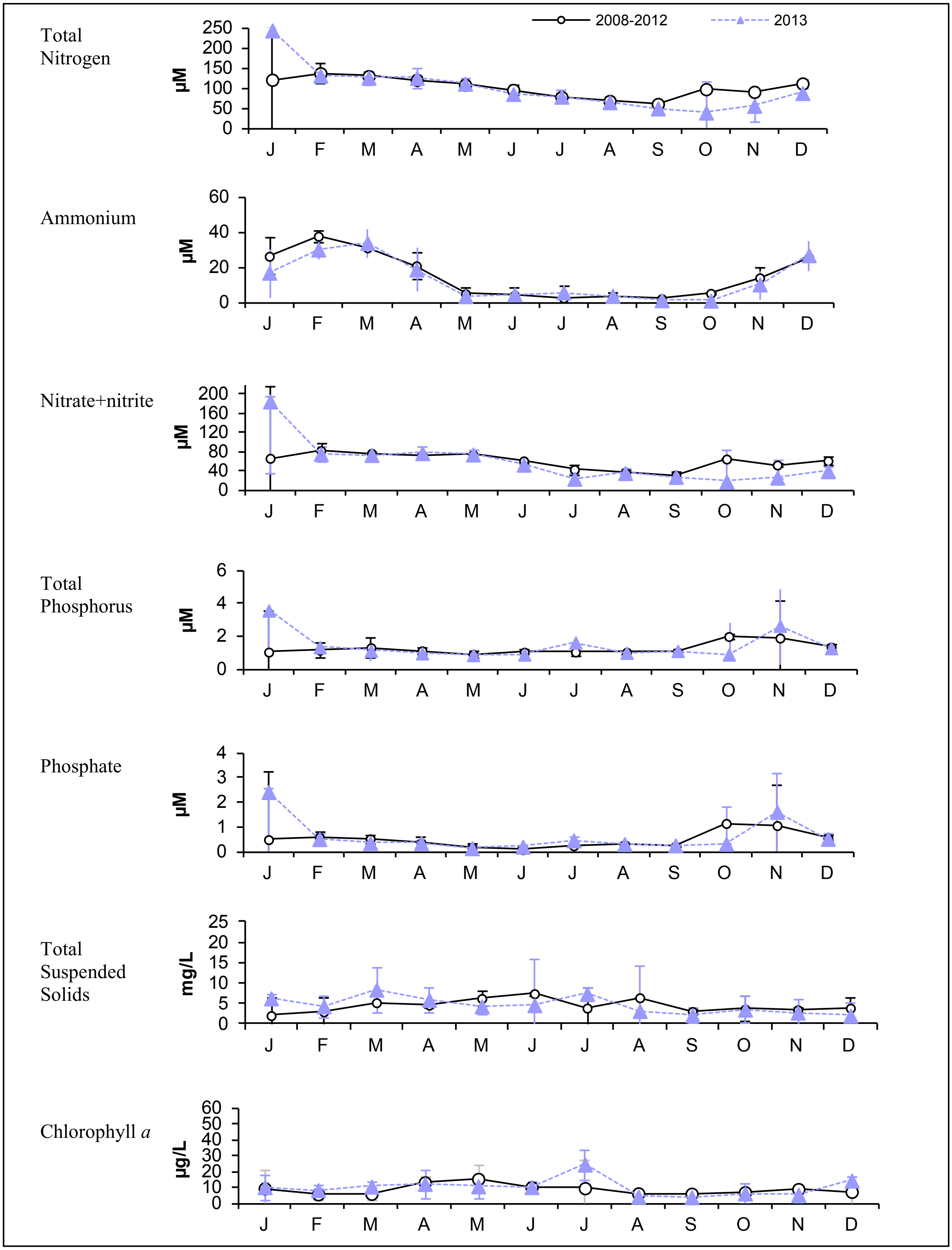


Figure 4-3. Monthly average nutrients, TSS and Chlorophyll 2008 – 2013, Station 083 (Mystic upstream of Alewife Br.)
Error bars are ± 1 SD. Note different scale for nitrate+nitrite, phosphate, chlorophyll and TSS than for Figures 4-5 and 4-6.

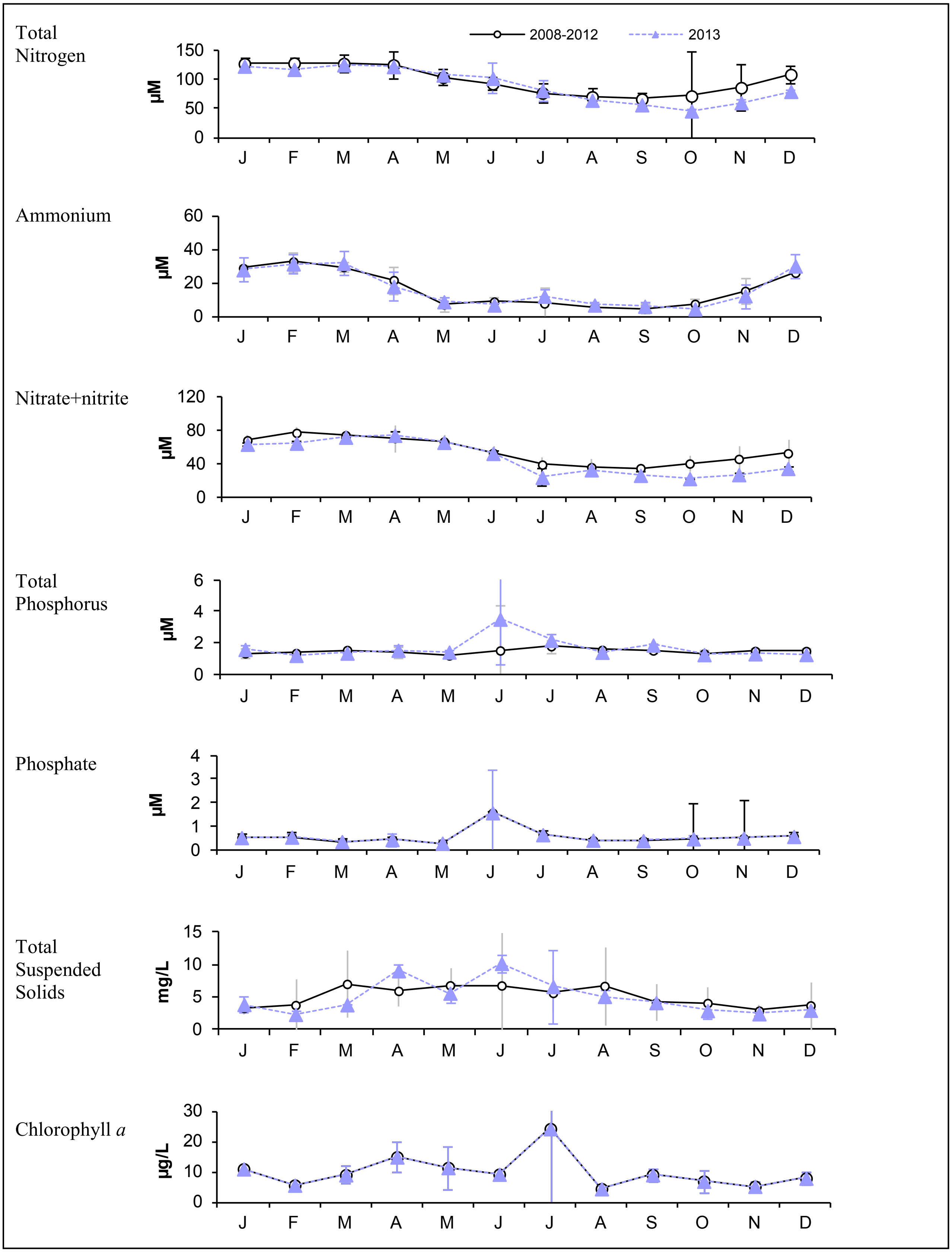


Figure 4-4. Monthly average nutrients, TSS and Chlorophyll 2008 – 2013, Station 066 (Boston Ave.)
Error bars are ± 1 SD. Note different scales than Figures 4-3, 4-5 and 4-6 for most parameters.

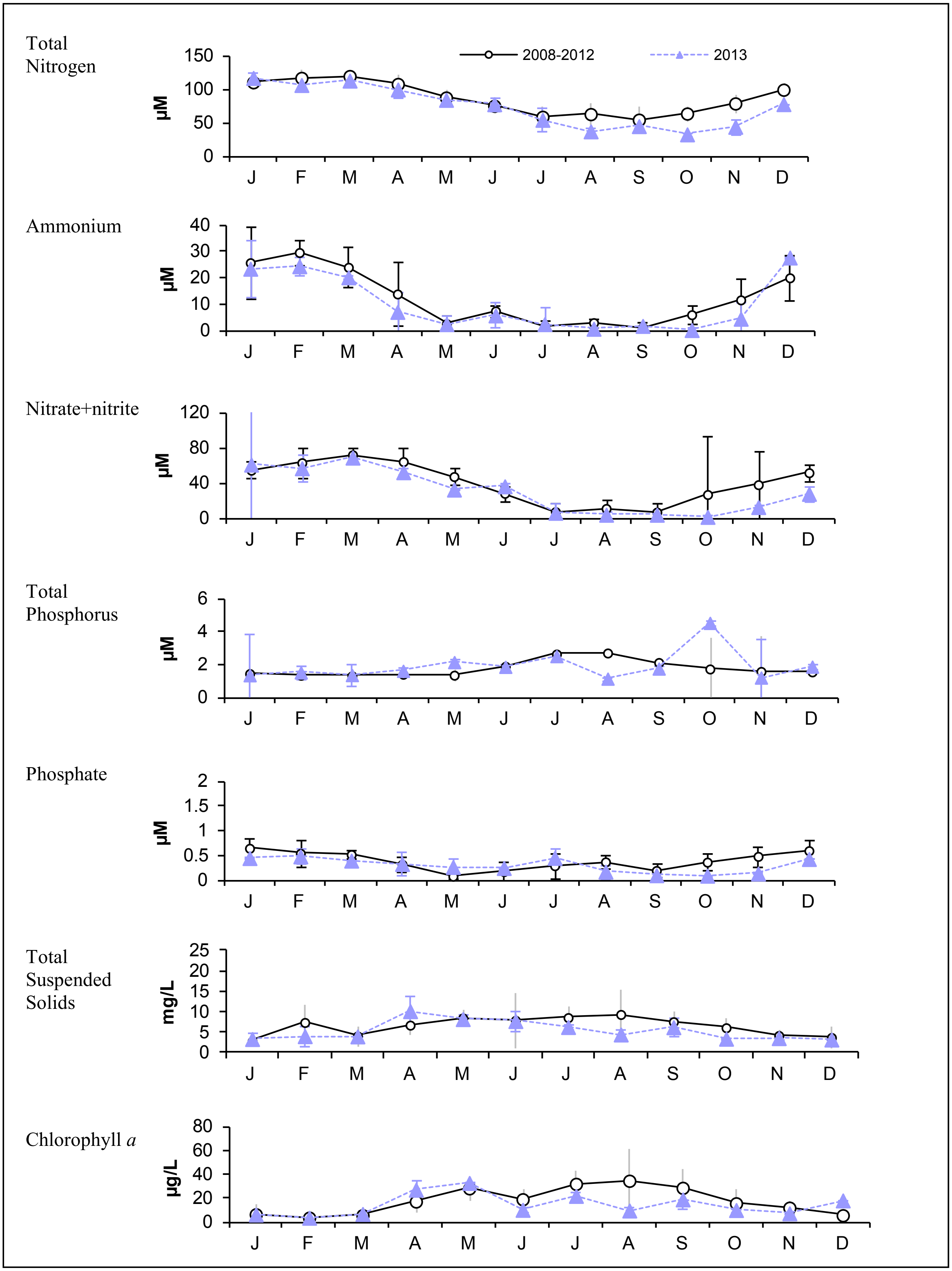


Figure 4-5. Monthly average nutrients, TSS and Chlorophyll 2008 – 2013, Station 167 (Amelia Earhart Dam (upstream/freshwater)).

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

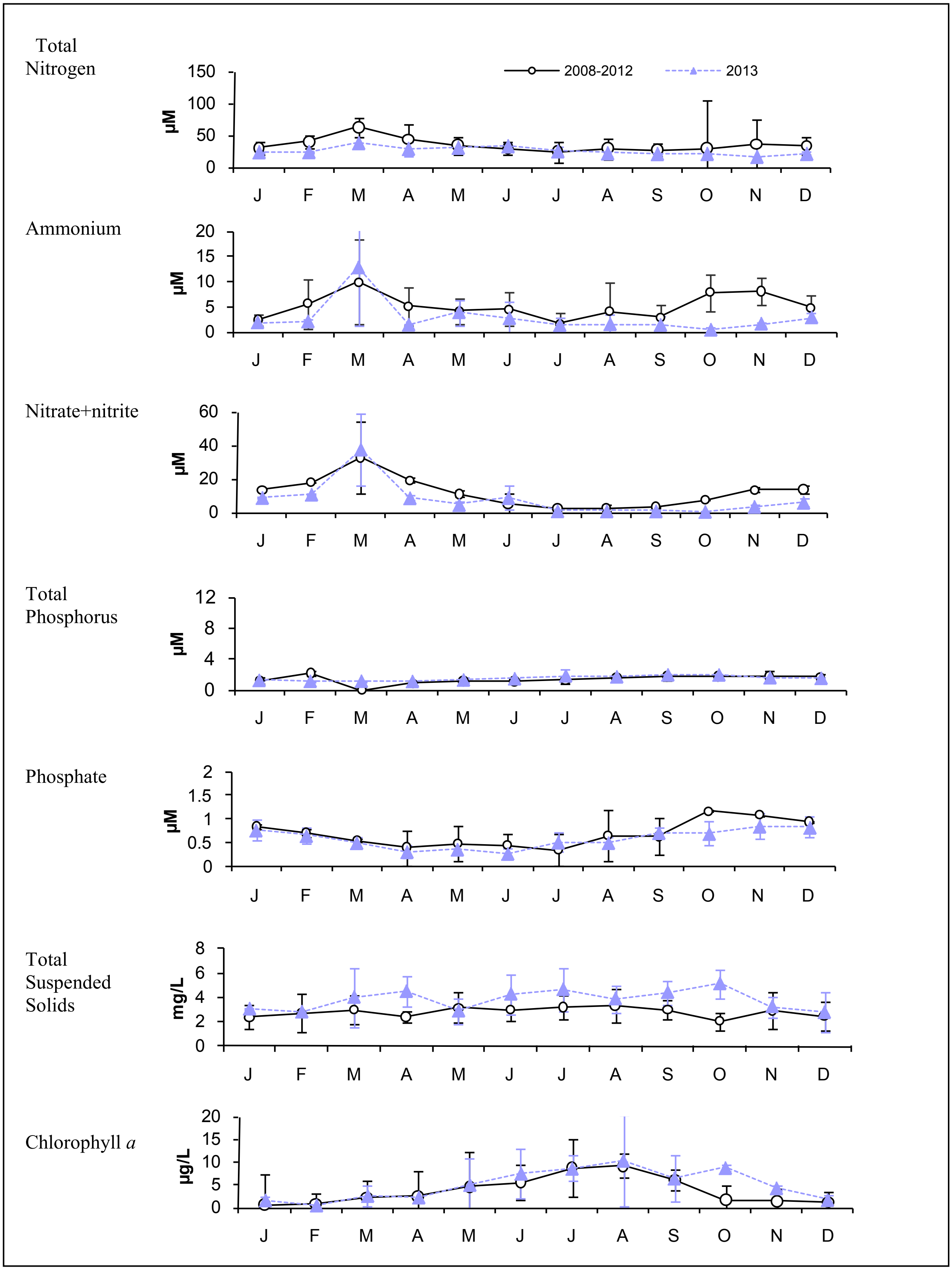


Figure 4-6. Monthly average nutrients, TSS and Chlorophyll 2008 – 2013, Station 137 Mystic River mouth (marine).

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 2013 for dry, damp, and wet weather. Water quality is relatively consistent downstream of the Mystic/Alewife confluence, with the majority of stations meeting bacterial standards in dry weather.

Geometric means for each indicator for 2008 - 2013 appear in Table 4-6. Consistent with recent years, annual geometric means meet standards for all locations in 2013 except for Alewife Brook, but are somewhat higher than the five-year averages for both *Enterococcus* and *E. coli*. Alewife Brook geometric means were substantially higher in 2013 compared to the five year historical average.

The uppermost graph in Figure 4-7 shows percentile plots of *Enterococcus* counts for each location, arranged from upstream to downstream for 2013. The center graph shows percentile plots of *E. coli* and the bottom graph fecal coliform, which is monitored in the marine portion of the Mystic River in place of *E. coli*.

E. coli shows a similar trend to *Enterococcus*, with Mystic basin locations generally meeting the geometric mean limit of 126 counts/100 mL in dry weather but not in wet conditions. As shown in Table 4-6, *E. coli* at most Mystic mainstem locations remained relatively consistent with the 5-year averages, with geometric means well within the standard. The geometric mean bacteria at Station 056, upstream of the I-93 bridge, improved substantially in 2013. The geometric mean for Station 052 (Somerville Marginal outfall MWR205) meets the former fecal coliform standard of 200 counts/100 mL and the Enterococcus standard of 35 counts/100 mL. Geometric means at Station 052 are elevated in heavy rain but meet standards in dry and damp weather. Further upstream in the Alewife, all 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.

The spatial and temporal change in *Enterococcus* concentrations in Alewife Brook and the Mystic River appear in Figure 4-8 through Figure 4-10. 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. With the exception of Alewife Brook, the Mystic River reaches meet *Enterococcus* standards in dry, damp and light rainfall conditions, but fail to meet standards in heavy rain. In the Alewife, all locations, even the Little River location upstream of CSOs, fail to meet standards in all rainfall conditions, suggesting persistent contamination problems in the entire length of the Brook. The CSO downstream of the Mystic Basin, Somerville Marginal Outfall 20,5 does meet standards in dry, damp, and light rainfall conditions but not in heavy rain.

Results in Figures 4-9 and 4-10 are grouped by phases of the Long Term CSO Plan improvements and include the geometric mean counts in each rainfall condition. *Enterococcus* results show little change over time in the Mystic River in dry and wet weather since the early 1990’s, with slight improvements in dry and damp weather.

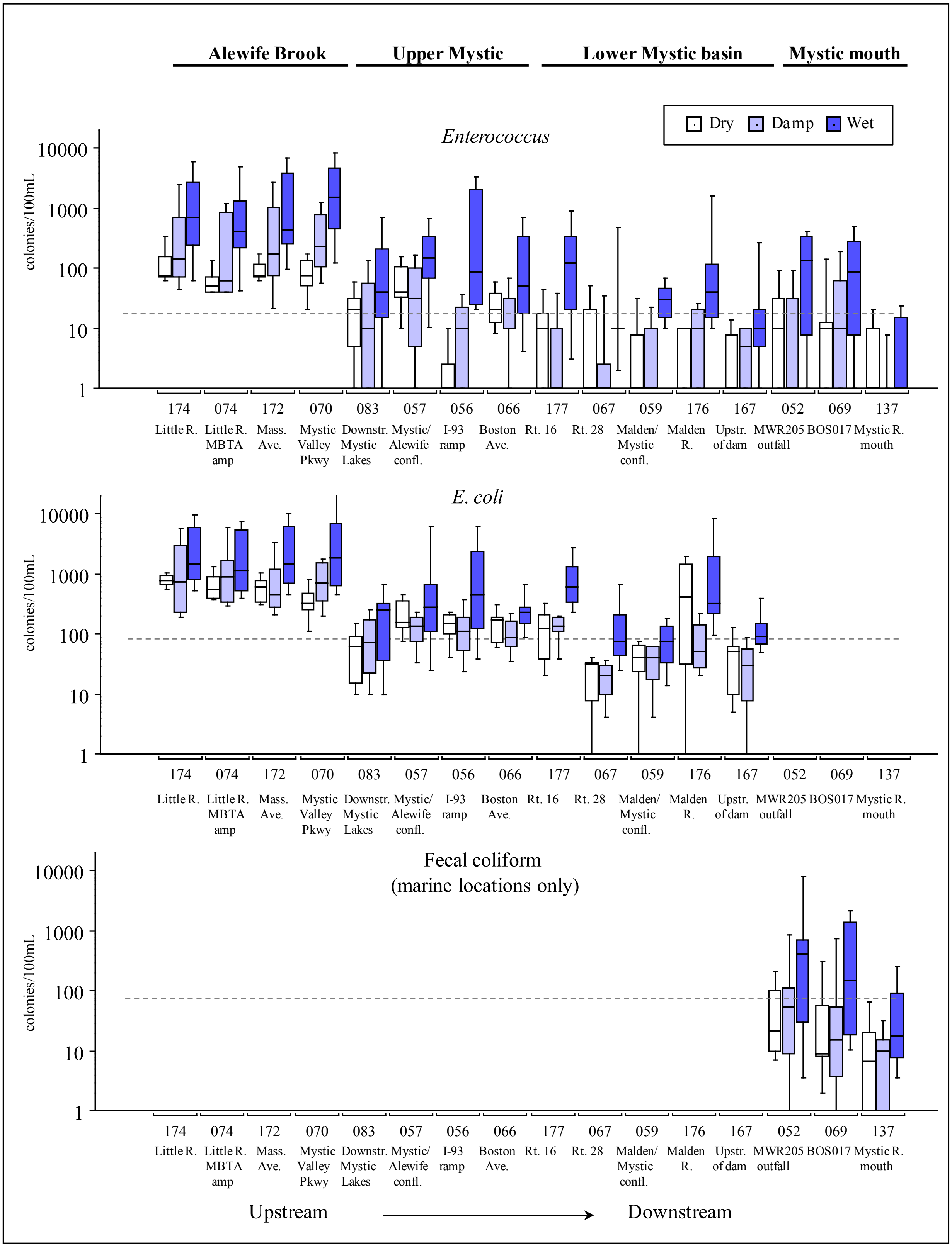


Figure 4-7. Indicator bacteria concentrations, Mystic River/Alewife Brook, 2013.

Dotted lines show MADEP *Enterococcus* and *E. coli* standard and former fecal coliform standard. *E. coli* testing was discontinued in 2007 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, 2008 - 2013.

Station	Location	Surface or Bottom	Number of samples		*Enterococcus* (95% CI) counts/100 mL DEP limit: 33 counts/100 mL		*E. coli* [1] (95% CI) counts/100 mL DEP limit: 126 counts/100 mL	
			2008-'12	2013	2008 - 2012	2013	2008 - 2012	2013
174	Cambridge, Little River, upstream of Rt. 2 and off ramp to Alewife T station	S	133	31	160 (113-226)	358 (203-630)	555 (431-714)	1335 (872-2045)
074	Cambridge, Little River, at off ramp to Alewife T station	S	133	31	102 (72-146)	248 (136-452)	535 (413-695)	1130 (751-1702)
172	Arlington, Alewife Brook, upstream of Massachusetts Ave bridge, midchannel	S	133	31	210 (157-282)	361 (182-716)	520 (408-662)	1055 (673-1654)
070	Arlington, Alewife Brook, off Mystic Valley Parkway bridge	S	133	31	275 (212-358)	456 (220-940)	609 (493-752)	1089 (664-1787)
083	Medford, upstream of confluence of Mystic River and Alewife Brook	S	232	47	17 (13-23)	15 (8-27)	79 (64-97)	59 (36-95)
057	Medford, confluence of Mystic River and Alewife Brook	S	108	20	31 (22-45)	39 (16-94)	147 (115-189)	170 (93-308)
066	Medford, Mystic River, Boston Ave bridge	S	140	26	46 (33-66)	24 (13-45)	279 (226-343)	183 (110-302)
056	Medford, Mystic River, upstream of I-93 bridge	S	106	21	18 (12-27)	12 (3-39)	187 (144-243)	26 (13-49)
177	Medford, Downstream of Rt. 16 bridge, mid-channel	S	140	25	27 (19-40)	9 (3-22)	316 (262-382)	31 (17-57)
067	Medford, Mystic River, Rt. 28 bridge	S	108	21	27 (19-40)	3 (1-8)	44 (32-61)	151 (63-361)
059	Everett, confluence of Mystic and Malden Rivers	S	105	21	3 (2-5)	5 (2-11)	38 (27-54)	37 (21-67)
176	Malden River, upstream of Rt. 16 bridge	S	107	21	9 (5-15)	10 (4-23)	92 (61-139)	12 (3-41)
167	Medford, Mystic River, upstream side of Amelia Earhart Dam	S	126	25	6 (4-8)	3 (1-6)	53 (38-72)	12 (6-24)
052[2]	Somerville, Mystic River, near Somerville Marginal CSO facility (MWR205) – marine	S	133	25	15 (10-23)	14 (5-35)	*107 (70-162)*	*56 (21-150)*
		B	69	12	3 (2-5)	3 (0-10)	*24 (17-35)*	*41 (12-131)*
069[2]	Charlestown, near Schrafft's Center at BOS-017 outfall - marine	S	133	25	7 (4-11)	16 (6-39)	*49 (32-75)*	*47 (17-127)*
137[2]	Mystic River, upstream of Tobin Bridge – marine/Inner Harbor	S	22	10	2 (0-4)	2 (0-4)	*11 (5-26)*	*7 (3-18)*
		B	113	24	5 (3-8)	5 (3-8)	*38 (27-51)*	*20 (10-37)*

[1]Results in italics are fecal coliform, not *E. coli*. *E. coli* testing was discontinued in 2007 in marine waters for methodological reasons. Geometric mean limit for *Enterococcus* is 35 counts/100 mL in marine water, 33 counts/100 mL in freshwater. The *E. coli* limit is 126 counts/100 mL.

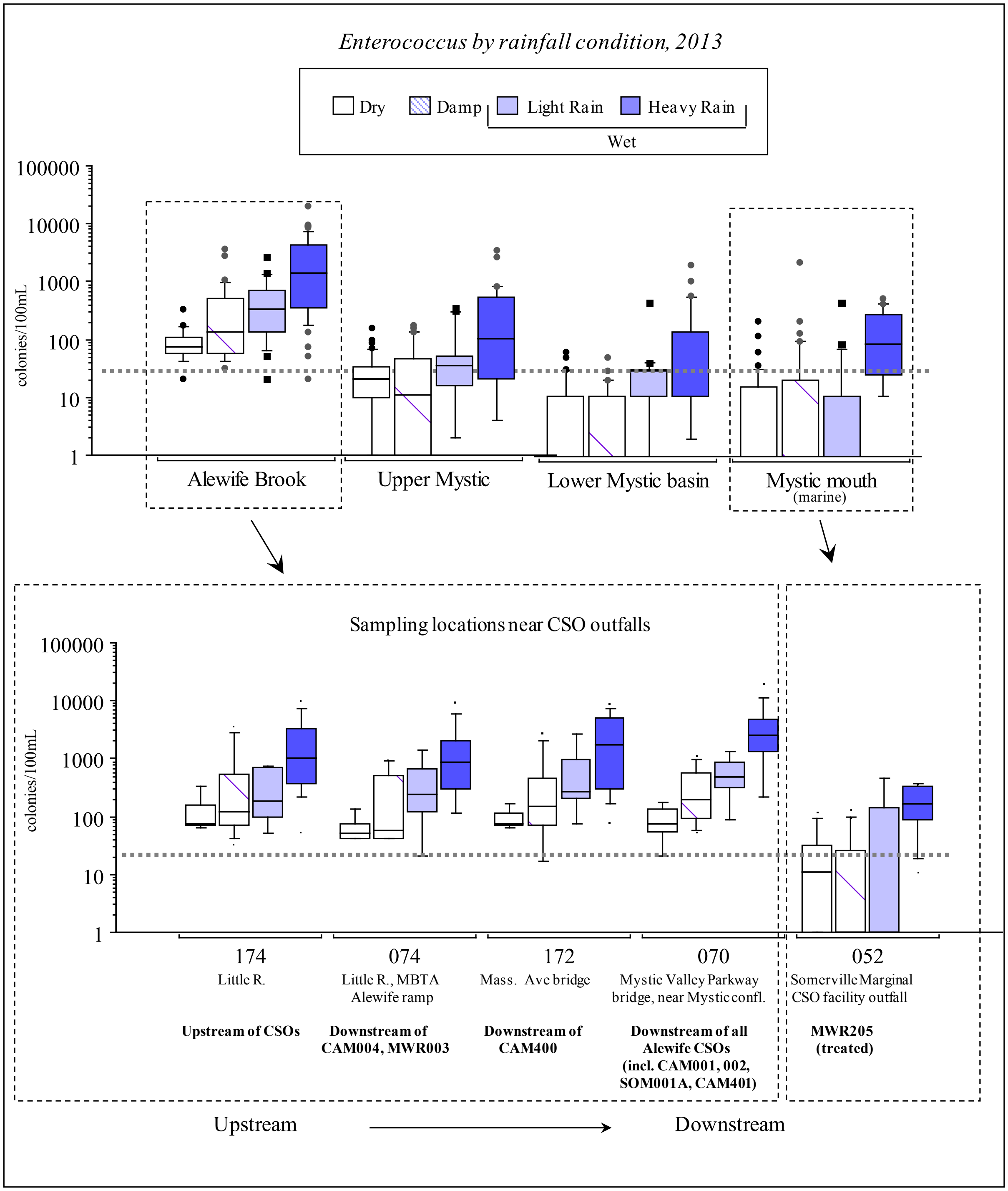


Figure 4-8. *Enterococcus* by rainfall condition, Mystic River/Alewife Brook, 2013.
Dotted line shows State standard of 33 counts/100 mL for freshwater. Rainfall is NOAA rainfall from Logan airport. “Dry”: no rainfall for previous 3 days; “Heavy”: more than 0.5 inches in previous 3 days; “Damp” and/or 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.

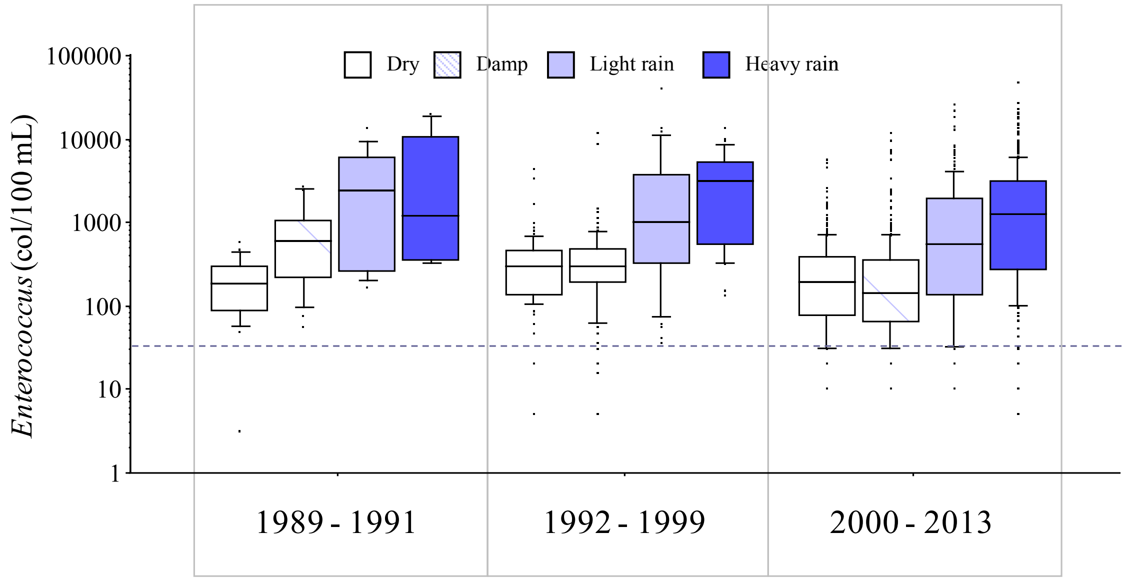


Figure 4-9. *Enterococcus* over time, Alewife Brook by phase of Long Term CSO Plan and rainfall condition.

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.

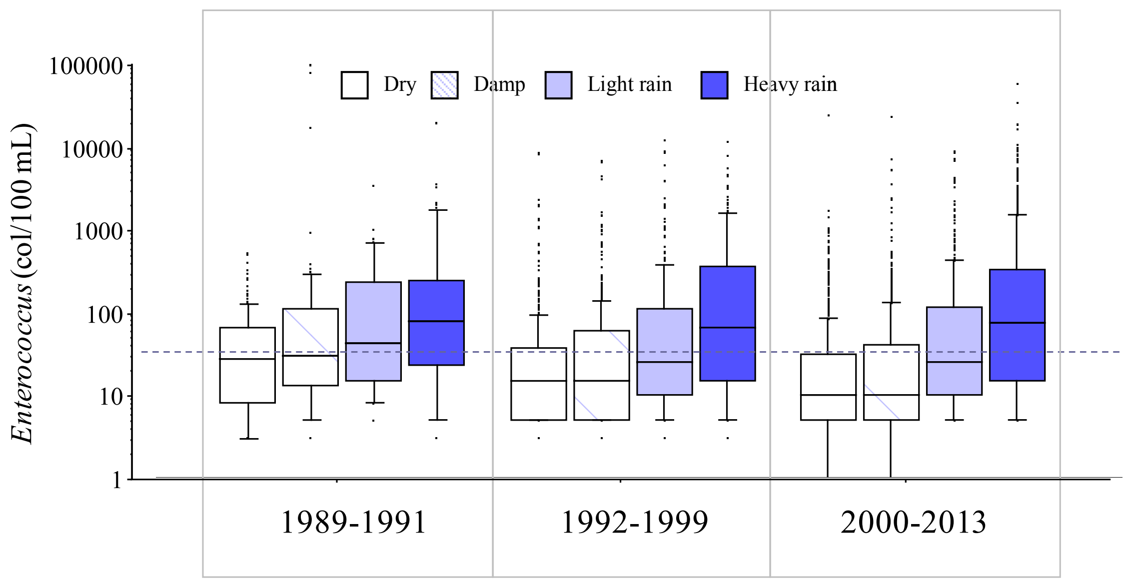


Figure 4-10. *Enterococcus* over time, Mystic River by phase of Long Term CSO Plan and rainfall condition.

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

In 2013, water quality conditions generally met clarity and dissolved oxygen standards downstream of the Alewife, in the river mainstem and at the river mouth, though bottom-water dissolved oxygen concentrations were lower than normal at some lower Mystic locations. The Alewife Brook did not meet standards for bottom-water dissolved oxygen or water clarity.

Overall, bacteria concentrations in the Mystic River met standards for much of the upper and lower Mystic Basin and Mystic River mouth in dry weather, damp and light rain, but failed to meet limits in heavy rain and in all conditions in the Alewife Brook, which had an increase in bacterial concentrations compared to past years, particularly at the most upstream location, in the Little River, upstream of all Alewife CSOs.

With the exception of the Alewife, most locations in the Mystic River did meet *Enterococcus* geometric mean limits overall. While the Alewife did not meet *Enterococcus* or *E. coli* standards in dry or wet weather, conditions in the mainstem downstream of the Alewife/Mystic confluence suggest a limited influence of Alewife Brook on bacterial water quality in the river mainstem.

With the exception of occasionally elevated upstream chlorophyll concentrations, 2013 nutrient parameters were largely similar to previous years, with monthly concentrations near long term averages. As in past years, the area upstream of the Amelia Earhart dam near Malden River confluence was the most eutrophic, with consistently elevated chlorophyll *a* and low dissolved oxygen relative to upstream locations, and the most 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 2013. 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.

APPENDICES

Appendix I
Mystic River, percent compliance with *Enterococcus* single sample limit by river segment

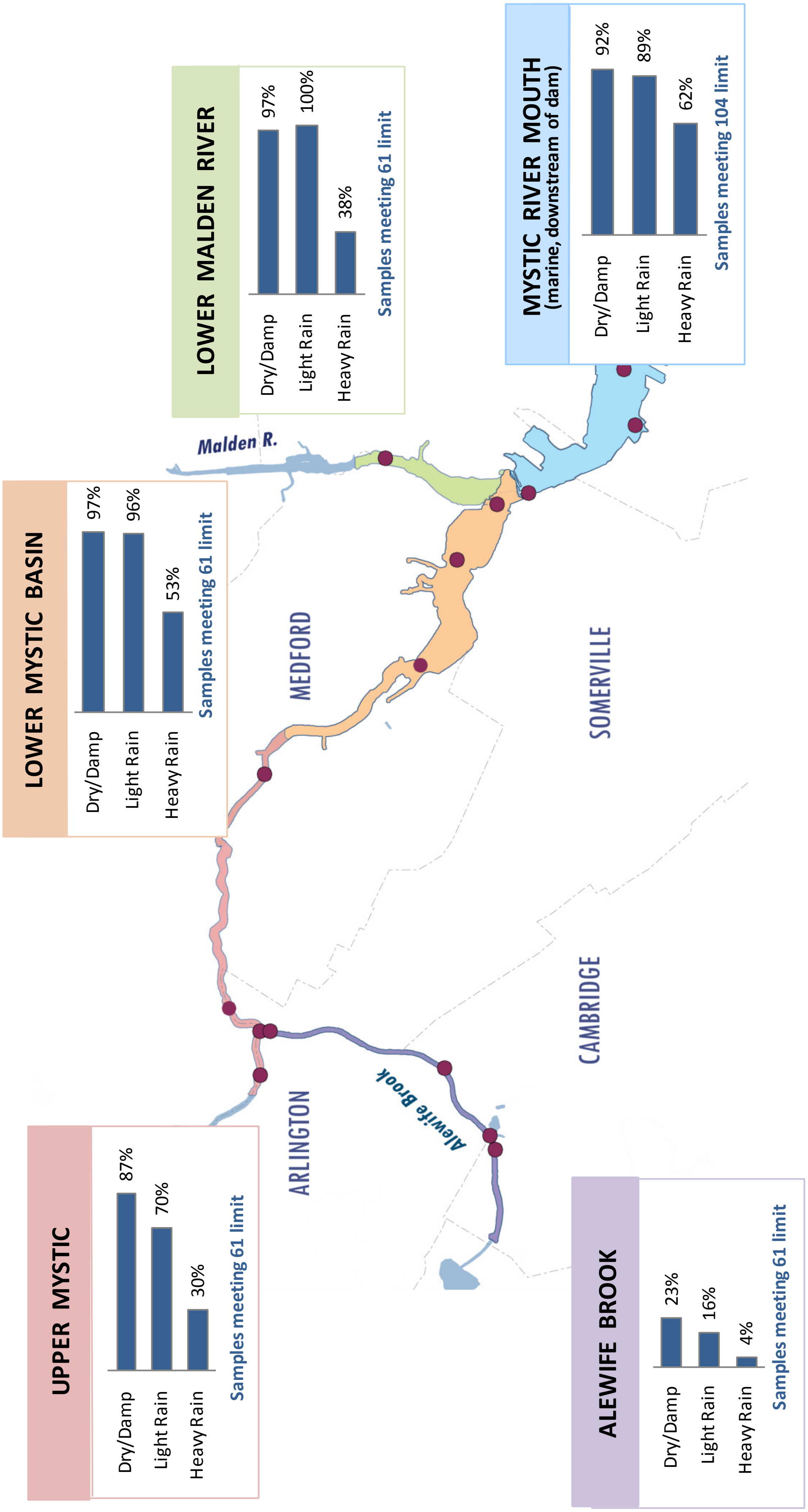
Appendix II
2013 raw data, laboratory analyses

Appendix III
2013 raw data, physical profile results

Appendix I

Mystic River: *Enterococcus* by river segment

Geometric means and percent of samples meeting State swimming standards, 2011-2013



Dots are sampling locations. State swimming standards for Enterococcus: single sample limit is 61 cfu/100 mL in freshwater, 104 cfu/100 mL in marine water. Rainfall: Heavy Rain is at least 0.5 inches of rain in previous 48 hours; Light Rain is between 0.1 and 0.5 inches of rainfall in previous 48 hours.

APPENDIX II

2013 raw data for laboratory results.

Non-detected results have been converted to detection limit for all results except for bacteria, which are converted to 0.

APPENDIX III

2013 raw data for physical profile results.

Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129
(617) 242-6000
www.mwra.com