Revised Scope of Work

MWRA Water Quality Monitoring in the Lower Charles River/Charles Basin and Alewife Brook/Upper Mystic River

November 10, 2016

Revised and updated November 3, 2017

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Tables and Figures

1. Introduction

The 2016 Variance Determinations for the Mystic and Charles Rivers ("Variances") had several requirements related to water quality monitoring in the receiving waters. This submittal focuses on the receiving water quality monitoring program, and also describes monitoring projects at the CSO treatment facilities.

1. Section D of the Variances required that the Massachusetts Water Resources Authority (MWRA) "develop a scope of work for the water quality monitoring program in consultation with MassDEP, and submit the complete scope to MassDEP for review on or before December 1, 2016". A draft was provided to the Massachusetts Department of Environmental Protection (MassDEP) on November 10, and MWRA met with DEP staff to review their comments on December 21, 2016, August 1, 2017, and September 8, 2017.
2. Section E of the Variances required that MWRA submit to DEP and EPA the scope of work for the CSO Long-Term Control Plan Post-Construction Compliance Monitoring Plan (PCCMP) by May 1, 2017. The PCCMP was submitted to DEP on May 1, 2017. During a meeting with DEP and EPA on August 1, 2017, it was requested that the water quality monitoring scope of work submitted in November 2016 be updated given changes made in the monitoring plan for the 2017 field season. This revised scope of work constitutes that update.

This submittal is intended to address comments made by DEP and EPA:

- Staff have performed field visits, contacted DEP for clarification, and coordinated with field and lab staff to determine how best to accommodate some of the location changes requested by DEP.
- DEP and EPA had expressed concern that sampling at the Cottage Farm CSO Facility and in the Charles River during a Cottage Farm CSO activation might be missed, given how rare these activations are. MWRA recognizes the challenges posed by the infrequent activation of the Cottage Farm CSO Facility and has established it as a priority for sampling in all storms likely to result in an activation.
- MWRA is committed to capturing storm events throughout the variance areas, with and without CSO discharges, so that data necessary to assess the duration and level of impacts will be available to support future assessments.
- MWRA has responded to several DEP monitoring requests by adding two new monitoring sites on Alewife Brook (locations 276 and 277), immediately upstream of the CAM401B CSO outfall and immediately downstream of the SOM001A CSO outfall (included here, see Table 2 and Figure 2). MWRA will also sample influent at the Cottage Farm and Prison Point CSO Facilities in conjunction with MWRA's NPDES permit-required effluent sampling.

This revised and updated scope of work for MWRA's water quality monitoring program reflects the methods used in the 2017 field season and planned for the 2018-2020 seasons. The current

design of the water quality monitoring program addresses the needs of both the Variances and the PCCMP. The goals and priorities for the implementation of this program are summarized below.

- The Variance regions of the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin have a number of active CSOs and so are higher priorities than the non-Variance Neponset/Dorchester Bay. Monitoring will continue in the non-Variance Neponset/Dorchester Bay region, which has CSO controlled to a 25-year storm standard, but at a lower priority. The prior monitoring program was split equally between the Charles, Alewife/Mystic, and Neponset, but will now focus on the Charles and Alewife/Mystic.
- "Recovery time" after wet weather events is a priority; in other words, sampling after a storm to capture impacts from CSO and non-CSO pollutant sources. Comparisons will be made between CSO events, non-CSO events, and dry weather conditions. This program has a focus on wet weather events, since those are periods of concern. Therefore, it is important to note that future results will have a bias towards wet weather. (The prior program sought to have a balance of dry, damp and wet events).

Based upon discussions with EPA and DEP regarding the monitoring program, the updates to this scope of work are intended to clarify MWRA's commitment to capturing water quality conditions in the Variance areas (especially in the Charles River after a discharge from the Cottage Farm CSO facility), during both dry and wet periods, and to focus on storm events, both with and without CSO's, and the recovery time after storms. MWRA has already captured ten events and recovery periods starting in May 2016 and continuing into October 2017:

- Six storm events in the Charles River
- Six storm events in the Mystic
- Eight of these events (all in 2017) were sampled over weekend days
- Five of these events had reported CSO discharges (four in the Mystic River, one in the Charles River)

Past results of the monitoring program are available at mwra.com,[1] in the *CSO Control Plan Annual Progress Report 2015*,[2] and the annual CSO Variance water quality monitoring reports required by the CSO Variances.[3] Results will be updated annually.

[1] Historical and previous year raw monitoring data is posted on the MWRA website: http://www.mwra.state.ma.us/harbor/html/wq_data.htm.

[2] The 2015 report is the final annual report to the Federal Court about the CSO program progress. It and older annual reports are available at http://www.mwra.com/cso/csoannualreports.htm.

[3] The most recent, *Summary of CSO Receiving Water Quality Monitoring in the Upper Mystic River/Alewife Brook and Charles River, 2016* is available at http://www.mwra.state.ma.us/harbor/enquad/pdf/2017-04.pdf. Older reports are on the Technical Report Archive page at http://www.mwra.state.ma.us/harbor/enquad/trlist.html.

2. Monitoring Program

Receiving Water Monitoring

MWRA's receiving water quality monitoring program is carried out by MWRA's Department of Laboratory Services (DLS). The DLS field sampling team is based at the Central Laboratory at the Deer Island Treatment Plant in Winthrop, MA and samples from both boat and shoreline, depending on project and weather conditions. Program and data management assistance is provided by staff in the Environmental Quality Department (ENQUAL).

MWRA water quality monitoring in Boston Harbor and the harbor's tributary rivers dates back, in one form or another, to 1989. In the 1998-2015 field seasons, the monitoring program focused on collecting approximately equal numbers of daily samples in dry, damp, and wet weather conditions while maintaining a day-to-day rotation amongst the river regions (Mystic, Charles, and Neponset/Dorchester Bay), and on biweekly nutrient and eutrophication monitoring. The daily monitoring focused primarily on the rivers along with selected locations in the harbor, with an emphasis on bacterial water quality and potential CSO impacts. The biweekly monitoring focused on selected locations in the rivers, and stations harbor-wide.

Beginning with the 2016 field season, MWRA has started to sample for two-week blocks exclusively, rather than rotating between the regions from day to day. This change allows the program to capture data in dry weather (baseline), through a rainstorm, and then during the "recovery" period several days after a storm. Over time, this new sampling program will provide a picture not only of dry and wet weather conditions, but also the transitions between them. This should not be construed as rigid "prescheduling" of the regions. As necessary, DLS and ENQUAL will extend sampling blocks to "follow" wet weather events and shorten blocks to sample wet weather events in different regions with higher priorities. Additionally (since 2017), MWRA has added weekend sampling during/after storm events so that recovery time can be monitored over consecutive days (at least 8 weekend sampling events per year).[4] MWRA believes this will be an important part of both the Variances and the Post-Construction Compliance Monitoring Plan (PCCMP).

The 15 monitoring stations in the Lower Charles River/Charles Basin and the 16 stations in the Alewife Brook/Upper Mystic River that are reported in MWRA's annual CSO Variance water quality monitoring report are distributed among three DLS monitoring projects: Combined Sewer Overflow Receiving Water (CSO-RW), Boston Harbor Water Quality Monitoring – Rivers (BHWQMR), and Boston Harbor Water Quality Monitoring (BHWQM). CSO-RW monitoring is more spatially and temporally intensive, and focuses on measuring physical parameters and bacterial water quality. The BHWQMR and BHWQM projects focus on nutrients and eutrophication effects, although bacterial samples and physical

[4] See Sections 4 and 5 for more details.

parameter data are also collected.[5] These programs are discussed in more detail in Appendix 1, and the quality control and quality assurance procedures are detailed in Appendix 2.

CSO Facility Monitoring

MWRA is required to sample CSO facility effluent four times a permit year (a permit year runs from August 9 to August 8 of the next year) under the requirements of MWRA's NPDES permit (permit number MA0103284). This applies to the Cottage Farm, Prison Point, and Somerville Marginal CSO Facilities. Only the Cottage Farm Facility (MWR201) and the freshwater discharge of the Somerville Marginal Facility (MWR205A) discharge into Variance waters. Parameters to be tested and required frequencies are laid out in Section 16 of the NPDES permit.[6] This effluent sampling has been ongoing since August 2000, when the permit was put into effect.

Additionally, on August 18, 2017, MWRA received draft comments from the Massachusetts Department of Environmental Protection (MassDEP) on the Post-Construction Compliance Monitoring Plan. DEP made three requests for further characterization of CSO discharges:

1. Sampling of overflow at MWR018, which discharges to the Charles River
2. Sampling of the influent to the Cottage Farm CSO treatment facility, which also discharges to the Charles River
3. Sampling of overflow at CAM401B and/or SOM001A, both of which discharge to the Alewife Brook

MWRA and DEP staff met to discuss these requests. During this meeting, MWRA pointed out that the target number of annual discharges from MWR018 in MWRA's Long-Term Control Plan in a Typical Year is zero, and that MWRA's system-wide hydraulic model indicates that MWR018 would not discharge with Typical Year rainfall under 2016 system conditions. MWRA proposed to instead sample the influent of the Prison Point CSO treatment facility, which is downstream of the MWR018 regulator structure. MWRA believes that Prison Point influent will be reasonably representative of discharges from untreated combined sewer overflows upstream of the facility, including MWR018, and the facility influent will be easier to safely sample than the MWR018 outfall or regulator structure. DEP agreed to this plan.

MWRA also agreed to DEP's request that MWRA sample the influent at the Cottage Farm CSO treatment facility. Please note that the Cottage Farm facility discharges to the Charles River very infrequently; it discharged once in 2016, and the projected discharges under the LTCP for a Typical Year are two.

[5] More details are available in the following Combined Work/Quality Assurance Project Plans – for the Alewife Brook/Upper Mystic River: http://www.mwra.state.ma.us/harbor/enquad/pdf/2003-ms-75.pdf, and for the Lower Charles River/Charles Basin: http://www.mwra.state.ma.us/harbor/enquad/pdf/2003-ms-80.pdf.

[6] https://www3.epa.gov/region1/npdes/mwra/pdf/mwrafpm1.pdf

3. Project Scheduling

Receiving Water Monitoring

As mentioned above, sampling is scheduled in two-week blocks in the Charles, Mystic, and Neponset/Dorchester Bay regions (daily sampling; the CSO-RW project). The first two regions correspond to the Variance regions, and have priority (especially in wet weather) over the Neponset/Dorchester Bay region. Additionally, the field sampling team has other project responsibilities above and beyond those that are in support of the CSO Variances and PCCMP.

Although the blocks are scheduled in advance, DLS and ENQUAL make changes to the schedule as needed to respond to rain events. For example, if a storm arrives on Day 12 of a block in the Charles, DLS will continue to sample past the two-week mark of Day 14. MWRA's goal is to measure the "recovery time," regardless of the confines of the two-week block. As data are collected, MWRA staff will review the results to assess the amount of time after a storm that sampling is needed to capture the full recovery period. Currently, the goal is to capture five days after the storm. As data are reviewed, this duration will be evaluated and adjusted if appropriate.[7]

Additionally, before 2017, samples were collected only on weekdays, potentially missing two days of "recovery time" after a storm. Beginning in 2017, weekend sampling was added to better capture storm events and recovery periods. Section 4 gives more details; the weekend sampling sites are shown in Figures 2 and 3.

MWRA's goal is to capture storm events and their recovery period, including over weekends, divided evenly between the Charles and Mystic regions. If possible, it is also MWRA's goal that these events be divided evenly between events with CSO discharges and events without CSO discharges.

The extended storm sampling will only occur in the Charles or Mystic regions (the Variance regions), and the sampling team will be moved out of the third region, Neponset/Dorchester Bay, to sample in either the Mystic or the Charles if a particularly large storm is forecast or ongoing. Monitoring through the recovery period will be prioritized, unless a NPDES permit-required project cannot be rescheduled for another time. This occurrence should be rare. Also, the biweekly nutrient and eutrophication projects (BHWQM and BHWQMR) will be placed on temporary hold. It is possible that in some instances, two sampling projects may occur on the same day if staffing and logistics are favorable.

Note that Charles River CSOs, including the Cottage Farm CSO treatment facility that discharges into the Charles, activate very infrequently due to improvements at the facility and in the collection system. Collecting samples in the Charles after an activation of the Cottage Farm facility is a top priority for the program. In the event of a Cottage Farm discharge that was not anticipated, DLS staff will immediately shift to the Charles region to conduct sampling, and continue through the recovery period. There is the potential that a storm large enough to result in a Cottage Farm activation could also trigger other

[7] The five days of sampling are the goal as of October 2017; if data indicate that the length of time post-storm can be shortened, MWRA reserves the right to do so.

adverse/flood/regulatory related issues, impacting staffing and priorities. While this is not likely, it is possible, but staff will prioritize as much as possible sampling of the Charles River when CSOs there discharge, as indicated by a Cottage Farm activation.

CSO Facility Monitoring

For both CSO facilities, influent sampling will occur simultaneously with effluent sampling required by the NPDES permit (see Section 2). Therefore, this influent sampling will occur a maximum of four times per permit year per facility, when the facility is actively discharging.[8] MWRA's Wastewater Operations Department coordinates with the Toxic Reduction and Control Department for CSO facility sampling. Samples are analyzed by the MWRA's Department of Laboratory Services.

Given the low frequency of Cottage Farm discharges as noted above, it is likely less than four activations with sampling will occur at Cottage Farm. Influent samples at Cottage Farm will be collected at the frequency specified in the MWRA effluent sampling protocol while the facility is discharging. Due to the configuration of the Prison Point facility where the influent and effluent sampling points are widely separated, influent samples will be taken only at the beginning and near the end of the discharge activation.

4. Shoreline Sampling and Weekend Sampling Special Projects

While sampling is typically conducted by boat, under certain weather conditions that may not be safely possible. If the boat cannot go out, a shoreline sampling plan is activated. There is a subset of stations within each region suitable to safely sample from the shoreline or from bridges. The same parameters (bacteria and physical parameters) are collected as the CSO-RW project when the shoreline sampling protocol is activated on a weekday; the only difference is that only surface samples are taken. The same shoreline monitoring locations are used for all weekend sampling (i.e., there is no boat-based sampling on weekends). However, on a weekend, only bacteria samples are collected and analyzed (again, only surface samples). Shoreline sampling stations are noted in Figures 2 and 3 and are also listed in Tables 2 and 3 as "shoreline sampling station(s)."

[8] Untreated CSO outfalls upstream of the Cottage Farm and Prison Point CSO Facilities (CAM005 and CAM007; MWR018, MWR019, MWR020, and CAM017) are expected to discharge less than four times per year. Collecting influent samples at Cottage Farm or Prison Point more often, in smaller storm events, would compromise representativeness.

5. Receiving Water Monitoring Sampling Locations

Table 1. Lower Charles River and Charles Basin Sampling Locations

Sampling Location	Project	Latitude / Longitude	Description	Nearby CSO Outfalls
012 (Watertown)	BHWQMR	42.365073, -71.190224	Watertown Dam at footbridge	Upstream of all CSOs
001 (Newton)	CSO-RW	42.359186, -71.170092	Downstream of Newton Yacht Club; shoreline sampling station	Upstream of all CSOs
144 (Allston)	CSO-RW	42.359692, -71.155559	Faneuil Brook outlet	Upstream of all CSOs
002 (Allston)	CSO-RW	42.363051, -71.145688	Downstream of Beacon St. Bridge; shoreline sampling station	Upstream of all CSOs
003 (Cambridge)	CSO-RW	42.373688, -71.131794	Downstream of Eliot Bridge, Cambridge side; shoreline sampling station	Downstream of CAM005
004 (Cambridge/Allston)	CSO-RW	42.362948, -71.116901	Between River St. and Western Ave. bridges	
005 (Cambridge)	CSO-RW	42.355081, -71.115513	10 m off of Magazine Beach; shoreline sampling station	Upstream of MWR201A/B/C (Cottage Farm)
006 (Cambridge/Boston)	CSO-RW	42.3525, -71.1085	BU Bridge, downstream side	Downstream of MWR201A/B/C (Cottage Farm)
007 (Cambridge)	CSO-RW	42.354999, -71.096893	MIT Boathouse, Cambridge side, surface and bottom samples; shoreline sampling station	
145 (Boston)	CSO-RW	42.35193, -71.092007	Stony Brook outlet, Boston side; shoreline sampling station	At MWR023
008 (Cambridge/Boston)	CSO-RW	42.3545, -71.0895	Mass. Ave Bridge, downstream side, surface and bottom samples	Downstream of MWR023, MWR018
009 (Cambridge/Boston)	CSO-RW	42.3575, -71.076444	Longfellow Bridge, upstream side, surface and bottom samples; shoreline sampling station	Near MWR020
010 (Boston)	CSO-RW	42.363851, -71.074809	Longfellow Bridge, downstream side, surface and bottom samples	
166 (Boston)	BHWQMR	42.366177, -71.070201	Science Museum, upstream of old dam	Downstream of all Lower Basin CSOs
011 (Boston)	CSO-RW	42.368284, -71.067075	Between Science Museum and New Charles River Dam/locks, surface and bottom samples; shoreline sampling station	Downstream of all Lower Basin CSOs

Sampling locations are midstream unless otherwise noted.

Table 2. Alewife Brook and Upper Mystic River Sampling Locations

Sampling Location	Project	Latitude / Longitude	Description	Nearby CSO Outfalls
174 (Cambridge/Arlington)	CSO-RW	42.397029, -71.144994	Little River, upstream of Rt. 2 and off ramp to Alewife T station; shoreline sampling station	Upstream of all CSOs
074 (Cambridge/Arlington)	CSO-RW	42.397422, -71.143511	Alewife Brook, off ramp to Alewife T station; shoreline sampling station	Downstream of CAM401A, MWR003
277 (Cambridge/Arlington)	CSO-RW	42.40065, -71.137138	50 yards upstream of CAM401B, sampled from the western shore of Alewife Brook; shoreline sampling station	Upstream of CAM401B, CAM001, CAM002, SOM001A
172 (Cambridge/Arlington)	CSO-RW	42.400918, -71.136386	Alewife Brook, upstream side of Mass. Ave. bridge; shoreline sampling station	Downstream of CAM401B; upstream of CAM001, CAM002, SOM001A
276 (Cambridge/Arlington)	CSO-RW	42.4022583, -71.13517	10 yards downstream of SOM001A, sampled from the western shore of Alewife Brook; shoreline sampling station	Downstream of CAM401B, CAM001, CAM002, SOM001A
070 (Arlington/Somerville)	CSO-RW	42.414428, -71.132413	Alewife Brook, Mystic Valley Parkway bridge; shoreline sampling station	
083 (Arlington/Medford)	BHWQMR	42.415203, -71.137041	Upstream of confluence of Mystic River and Alewife Brook; shoreline sampling station	
057 (Medford)	CSO-RW	42.415224, -71.132393	Confluence of Mystic River and Alewife Brook; shoreline sampling stations	
066 (Medford)	BHWQMR	42.417263, -71.130664	Boston Ave. bridge, downstream side	
056 (Medford)	CSO-RW	42.414769, -71.105322	Upstream of I-93 bridge, near Medford Square off ramp; shoreline sampling station	
177 (Medford)	CSO-RW	42.405722, -71.096351	Downstream of Rt. 16 bridge	
067 (Medford)	CSO-RW	42.399765, -71.082831	Rt. 28 bridge, downstream side; shoreline sampling station	Near Somerville Marginal CSO facility outfall (MWR205A)
176 (Medford/Everett)	CSO-RW	42.4053, -71.07191	Malden River, upstream of Rt. 16 bridge; shoreline sampling station	
059 (Somerville/Everett)	CSO-RW	42.396667, -71.077	Confluence of Mystic and Malden Rivers	
167 (Somerville/Everett)	BHWQMR	42.395, -71.075833	Amelia Earhart Dam, upstream side; shoreline sampling station (construction may prevent use)	
052 (Somerville)	CSO-RW	42.394215, -71.075816	Downstream of Amelia Earhart dam, surface and bottom samples; shoreline sampling station	Near Somerville Marginal CSO facility outfall (MWR205)
069 (Charlestown)	CSO-RW	42.385905, -71.068735	Rear of Schrafft's Center, surface and bottom samples; shoreline sampling station	At BOS017 outfall

Sampling Location	Project	Latitude / Longitude	Description	Nearby CSO Outfalls
137 (Charlestown/Everett)	BHWQM	42.386763, -71.062829	Upstream of Tobin Bridge near confluence of Mystic, Chelsea Rivers and upper inner harbor, surface and bottom samples	

Sampling locations are midstream unless otherwise noted. **Bold** indicates new sampling locations added fall of 2017.

Figure 1. Map of sampling locations, Lower Charles River and Charles Basin

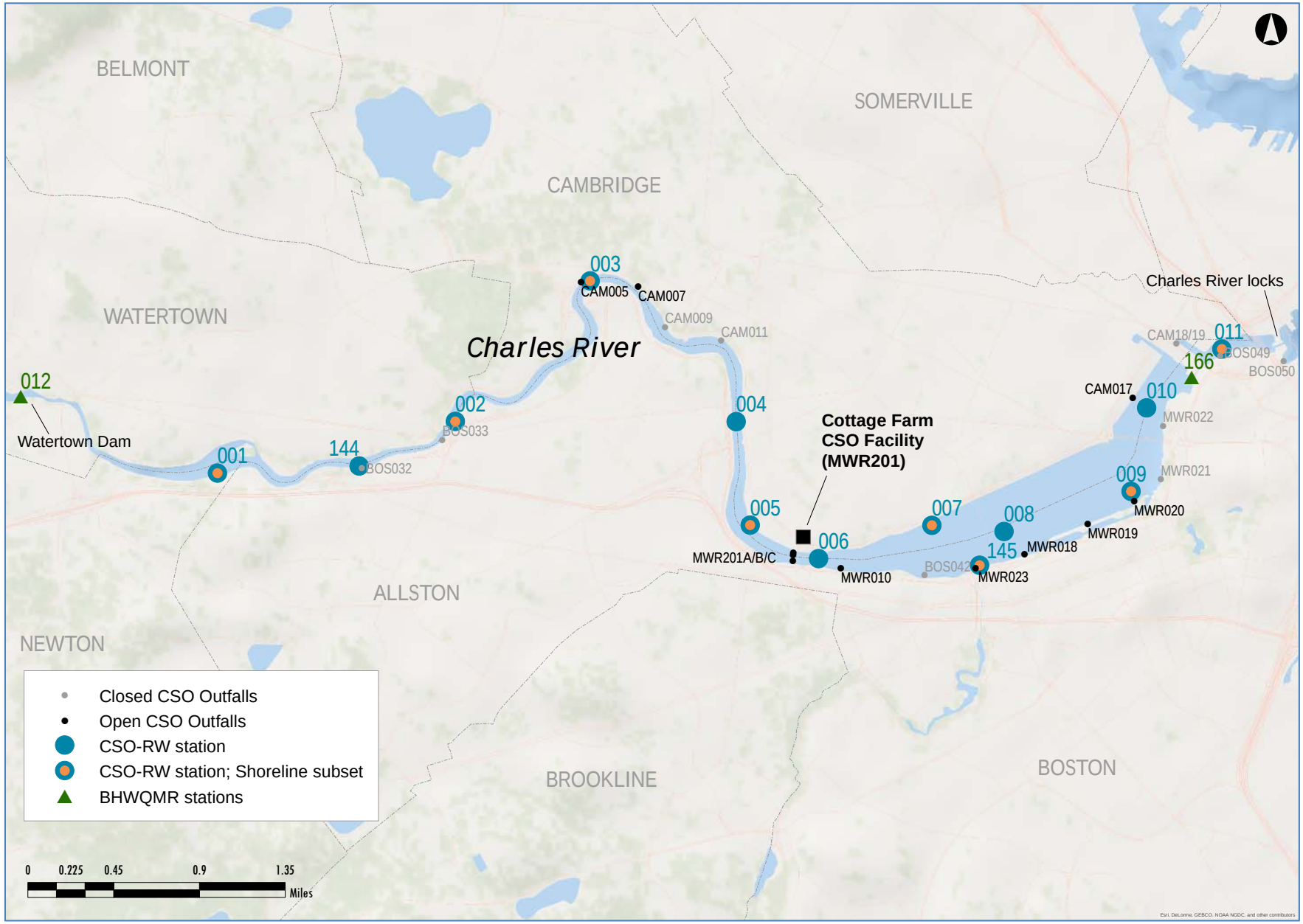


Figure 2. Map of sampling locations, Alewife Brook and Upper Mystic River

6. Project Codes and Test Parameters

Receiving Water Monitoring

There are three major sampling projects that collect data for the CSO Variances and the PCCMP in the receiving waters: CSO-RW, BHWQMR, and BHWQM. All three projects encompass areas larger than the CSO Variance areas of the Lower Charles/Charles Basin and the Alewife Brook/Upper Mystic River.

Table 3 summarizes, by project, the various parameters sampled for laboratory analysis or field data collection.

Table 3. Summary of Receiving Water Laboratory and Field Analyses

Laboratory Analyses

	CSO-RW	BHWQMR	BHWQM
Fecal coliform	✓		✓
E. coli	✓	✓	
Enterococcus	✓	✓	✓
Total suspended solids		✓	✓
Ammonium		✓	✓
Nitrate/nitrite		✓	✓
Orthophosphate		✓	✓
Silicate		✓	✓
Total nitrogen and total phosphorus		✓	✓
Total dissolved nitrogen and phosphorus			✓
Particulate carbon and particulate nitrogen			✓
Particulate phosphorus			✓
Chlorophyll *a* and phaeophytin		✓	✓

Field Analyses (YSI 6600s or 6820s sonde, YSI 650 MDS data logger)

	CSO-RW[2]	BHWQMR	BHWQM
Salinity	✓	✓	✓
Dissolved oxygen	✓	✓	✓
DO % saturation	✓	✓	✓
Specific conductivity	✓	✓	✓
Turbidity	✓	✓	✓
pH	✓	✓	✓
Chlorophyll	✓	✓	✓
Secchi depth[1]	✓		✓
PAR			✓

[1] Limnological or oceanographic Secchi disks used as appropriate.

[2] Shoreline CSO-RW surveys on weekends do not include field analyses, only laboratory analyses.

CSO Facility Monitoring

Effluent samples from the CSO treatment facilities are collected by MWRA staff from the Toxic Reduction and Control (TRAC) Department. With the exception of *E. coli* and *Enterococcus*, all parameters collected are required by the MWRA's NPDES permit (permit number MA0103284).

Influent grab samples will be collected by TRAC staff at both facilities for pH, *E. coli*, and *Enterococcus*. pH will be measured only on the first grab sample, which is the same protocol used for the effluent compliance samples.

Similar to the effluent samples, influent samples will be transported to the Department of Laboratory Services Central Laboratory for analysis. Since influent concentrations of bacteria are expected to be higher than effluent concentrations, different dilutions for both indicator species will be used for influent samples to give a low detection limit of <100 colonies/100mL, and a high detection limit of 24.2 million colonies/100mL (versus <10 colonies/100mL to 24,200 colonies/100mL in the effluent).

All tests for both influent and effluent samples are done using EPA approved methods, and must meet method holding times between sample collection and sample analysis. Table 4 summarizes the tests conducted on CSO facility influent and effluent.

Table 4. Summary of CSO Facility Monitoring Analyses

	Influent	Effluent
Fecal coliform		✓
E. coli	✓	✓
Enterococcus	✓	✓
pH	✓	✓
Total suspended solids		✓
Biochemical oxygen demand		✓ (composite)
Total chlorine residual		✓

All samples are grabs unless otherwise noted. Effluent parameters (with the exception of *E. coli* and *Enterococcus*) are stipulated in the MWRA's NPDES permit.

APPENDIX 1. Receiving Water Monitoring Project Background

CSO Receiving Water Monitoring (CSO-RW)

The CSO-RW project has existed in various forms since 1989, and remains ongoing. The project has multiple purposes: to measure the effect of CSOs on harbor and tributary river water quality, especially bacterial water quality; to satisfy MWRA's NPDES permit requirements including CSO Variance monitoring; to relate bacterial water quality to rainfall; and to measure changes in water quality over time as CSO control plans are implemented. Note that data collection and reporting for CSO Variance purposes is only one of the objectives of the CSO-RW project.

Monitoring locations for CSO-RW were chosen both near and far from active CSO outfalls to measure both "nearfield" and "farfield" effects. Because the spatial extent of the chosen monitoring stations is too large for all of them to be visited in a single survey, CSO-RW monitoring has been divided into three major regions around Boston Harbor: the Charles River; the Mystic River and Inner Harbor (MYS/IH); and the Neponset River, Fort Point Channel, Dorchester Bay and Outer Harbor (Neponset/Dorchester Bay). Note that to accommodate the larger number of sites in the Alewife Brook (with the addition of the two new locations), Fort Point Channel stations which were previously in the MYS/IH region have been grouped with the Neponset/Dorchester Bay region starting in 2018.

The two CSO Variance areas of the Lower Charles River/Charles Basin (Table 1 and Figure 1) and the Alewife Brook/Upper Mystic River (Table 2and Figure 2) encompass the entire Charles region and a subset of the MYS/IH region, respectively. Within the MYS/IH region, if staffing or logistics are limited during a sampling day, the Alewife Brook and Upper Mystic River sites are prioritized over Inner Harbor sites as the latter are outside the CSO Variance area. The Neponset/Dorchester Bay region has no locations related to the CSO Variances, so data collected there are not included in any CSO Variance reports. However, as this region historically received CSO discharges (and potentially can continue to receive them, as there are some CSO outfalls connected to the South Boston tunnel that are controlled to a 25-year standard, as well as CSO outfalls in Fort Point Channel), MWRA continues to sample stations in this region to monitor trends in water quality. Weekend, or extended storm sampling, is not scheduled for Neponset/Dorchester Bay, only for the Charles and the Mystic, and the Charles and Mystic regions will take priority for any wet-weather sampling.

MWRA visits each of the three regions in two week rotating blocks. During a two-week block, the sampling team will sample in the chosen region exclusively on weekdays, although some days may be lost to other sampling projects. As mentioned above, extended storm sampling late in the two-week block will extend the team's stay in that region; sampling may also take place on weekends if the weekend protocol is activated. CSO-RW sampling runs roughly from April to October. Depending on weather and river ice conditions, the start and finish of the field season may be earlier than April or later than October. MWRA attempts to collect samples from each station a minimum of 20 times per year. With the greater focus on the Charles and Mystic, MWRA expects those regions to easily meet the goal; since Neponset/Dorchester Bay is a lower priority, that region may not reach 20 samples per station per year.

Samples are taken by small boat or from the shoreline for CSO-RW, depending on the monitoring location.

At each station, water samples are collected at the surface and – at deeper stations – at the bottom. Physical parameters are measured by a water quality sonde at each station at the surface and bottom. Secchi depth (a measure of water transparency) is also measured at each station.

Boston Harbor Water Quality Monitoring - Rivers (BHWQMR)

This region-wide project focuses on nutrients and eutrophication effects in the major rivers tributary to the harbor – the Mystic, Charles, and Neponset. Bacteria samples are also collected. This monitoring project began in late 1995 and has continued to this day. The project objectives (which also pertain to BHWQM below) are to measure water quality changes as wastewater quality was improved and discharges were transferred offshore from Boston Harbor to Massachusetts Bay, as well as to measure nutrient loadings from tributaries to the harbor. Like the CSO-RW project, data collection and reporting for CSO Variance purposes is only one of the objectives of the BHWQMR project.

The project includes stations upstream of any potential MWRA-related influences, and at easily accessible locations as far downstream as possible, while staying in fresh water.

Surveys occur biweekly, year-round, unless the stations are iced in. Stations are sampled from the shoreline.

All stations in the project that are located in the CSO Variance areas are freshwater stations, and only surface samples are collected at those locations. Sonde readings for physical parameters are taken at the surface and bottom.

Boston Harbor Water Quality Monitoring (BHWQM)

This region-wide project began in 1993. It is similar in objectives to BHWQMR except with a different spatial focus, as BHWQM monitoring locations are located in Boston Harbor and its embayments. Despite this Boston Harbor focus, results from one station downstream of the Amelia Earhart Dam are reported in the annual CSO Variance water quality monitoring report as relevant to the Alewife Brook/Upper Mystic River Variance area (although the location is not actually in the Variance area). Like the other two projects, data collection and reporting for CSO Variance purposes is only one of the objectives of the BHWQM project.

Monitoring locations for this project were selected to create a spatially representative picture of the harbor and its many embayments. Many of the locations are stations that were monitored in historic long-term monitoring programs undertaken by the Department of Environmental Protection and the New England Aquarium. Some of the parameters measured are also continuations of earlier monitoring programs.

Sampling is via boat, twice a month, year-round, dependent on weather conditions. The sampling schedule for this project is arranged so surveys occur at high tide and low tide once each per month to minimize tidal influences on the results.

Sample collection occurs at the surface, at one meter, and at the bottom. Sonde readings for physical parameters are taken at the surface and bottom. Secchi depth is also measured, along with photosynthetically active radiation (PAR; another measure of water transparency).

Sample Collection, Processing, and Analysis Procedures

For most CSO-RW and BHWQM surveys and stations, samples are collected by MWRA staff operating from a small boat. For some CSO-RW stations (and for all shoreline sampling, be it for the shoreline special project or weekend sampling), and all BHWQMR stations, samples are collected from the shoreline, which includes sampling from bridges. As mentioned above, any small boat sampling will be weather dependent. DLS staff make the decision about whether weather conditions will prevent sampling from being safely conducted. The CSO-RW shoreline sampling special project may be activated if the boat is unable to safely go out (see Section 4 for details).

For all three projects, surface water samples for laboratory analyses (bacteria, nutrients, etc.) are collected with plastic bottles on sampling sticks (from boat or shoreline), a Van Dorn water sampler (from a bridge), or directly in a bottle (if wading). Bottle size and plastic composition are parameter-specific. Bacterial samples are collected in sterilized bottles. All bottles are pre-labeled for tracking and sample management in LIMS. Along with the bottle labels, chain of custody (COC) forms are also generated by LIMS before each survey. The COC forms allow each bottle to be tracked, minimizing the problems of lost or mixed-up samples. Sample custody procedures are laid out in the DLS *Quality Assurance Management Plan* (QAMP; DCN 5000.[9])

Bottom samples are collected using a vertical Kemmerer sampler if depth at the location allows it.

Once collected, bottles are stored in a cooler. All samples are delivered to the DLS Central Lab on Deer Island within the parameter-specific holding times for either analysis or preservation/storage. The DLS standard operating procedures (SOPs) for the analysis specify the required holding time. If holding times are exceeded, then the sample is flagged in LIMS as exceeding holding time.

DLS samplers also deploy YSI sondes (currently, models 6600 and 6820) to measure physical parameters as well as Secchi disks at all CSO-RW and BHWQM stations to measure Secchi depth. Sonde data are recorded by a YSI 650 MDS data logger. Light sensors are used to collect photosynthetically active radiation (PAR) data at BHWQM stations. Sample collection, sonde deployment, and in-field storage procedures are documented in a DLS SOP, *Water Quality Monitoring in Boston Harbor and Its Tributaries* (DCN 4002.2).

Additionally, field logbooks are used to record field activities performed during the survey. Upon arriving at each station, date and time of sampling, sample depth, Secchi depth, wind conditions, sampler's initials and any other relevant information are documented (e.g., site-specific environmental conditions including presence of wildlife, floatables, algae, etc.).

[9] DCN stands for "Document Control Number." Each DLS SOP (or QAMP/QAMP section) has a unique DCN to simplify organization and revision tracking.

When the sampling team returns to the Central Laboratory, the samples are hand delivered to the microbiology and biology laboratories for sample processing. The COC forms are reviewed, and the pre-labeled, bar coded bottles are scanned into LIMS using a barcode reader. Sample collection times are entered into LIMS manually. At this point, any necessary pre-processing is done and the samples are then stored for analysis. Bacterial samples, due to their short holding time, go directly to the microbiology lab. Internal transfers of the samples within DLS are documented in the chain of custody system.

Table 5 summarizes sample collection and handling procedures.

Table 5. Summary of Sample Storage and Handling

Parameter (LIMS test code)	Sample Container	Necessary Collection Volume	Sample Processing	Maximum Holding Time to Analysis
Fecal coliform (FCOLSWMFL)	Sterile 250 mL LDPE bottle	100 mL	Store at <10°C until analysis, analysis should begin as soon as possible; incubation must start within 8 hours of collection.	8 hours
E. coli (ECOLAQC18)				
Enterococcus (ECOCAQDST)				
Total suspended solids (TSS-SWGRV)	1 L wide-mouth LDPE bottle	500 mL	Store at 4°C until filtration. Pass through pre-weighed Nucleopore filter and dry filter in dessicator until analysis.	7 days
Total dissolved nitrogen (BHWQM) Total nitrogen (BHWQMR) (TNP-SWAAN)	1 L amber wide-mouth HDPE bottle	20-100 mL	TDN/TDP samples for BHWQM must be passed through glass fiber filters. TN/TP samples for BHWQMR are not filtered. Freeze within 24 hours of collection until analysis.	28 days
Total dissolved phosphorus (BHWQM) Total phosphorus (BHWQMR) (TNP-SWAAN)				
Ammonium (DIN-SWAAN)		50 mL	Pass through Nucleopore filter within 6 hours of collection; freeze in upright position until analysis.	90 days
Nitrate/Nitrite (DIN-SWAAN)		50 mL	Pass through Nucleopore filter within 6 hours of collection; freeze in upright position until analysis.	
Orthophosphate (DIN-SWAAN)		50 mL	Pass through Nucleopore filter within 6 hours of collection; freeze until analysis	
Particulate phosphorus (PP--SWOXA)		200 – 500 mL	Pass sample through Whatman GF/F	28 days
Particulate nitrogen (PCPNSWCHN)		200 – 500 mL	Pass sample through previously combusted Whatman GF/F	
Particulate carbon (PCPNSWCHN)				
Chlorophyll *a* (CHLAAQFLU)		1 L	Pass sample through Whatman GF/F within 8 hours of collection. Fix with saturated $MgCO_3$ solution. Wrap filter in foil and freeze until analysis.	28 days
Phaeophytin (CHLAAQFLU)				
Dissolved silicate (DIN-SWAAN)		50 mL	Pass sample through glass Nucleopore filter within 6 hours of collection; freeze in upright position until analysis	90 days

Data stored in the YSI 650 MDS data logger is downloaded to a laboratory computer after return to the laboratory. Sampling team staff then reformat the raw data files into electronic data deliverables.

All laboratory analytical methods used are documented in DLS SOPs, listed in Table 6 and in the References section. These documents are also available on MWRA's intranet.

Table 6. Summary of Laboratory Analytical Methods

Parameter	LIMS Test Code	Units	Instrument	DLS SOP DCN, Analysis Method
Fecal coliform	FCOLSWMFL	CFU/100 mL	Stereoscopic microscope with fluorescent light source.	DCN 1163.5, SM 9222D
E. coli	ECOLAQC18	MPN/100mL	IDEXX Quanti-Tray/2000	DCN 1167.6, SM 9222B
Enterococcus	ECOCAQDST	MPN/100mL	IDEXX Quanti-Tray/2000	DCN 1217.4, Enterolert®
Total suspended solids	TSS-SWGRV	mg/L	Sartorius 6-place balance	DCN 1104.4, EPA 160.2
Total nitrogen	TNP-SWAAN	µM	Skalar Autoanalyzer	DCN 1072.5, Valderrama, 1981
Nitrate/Nitrite	DIN-SWAAN	µM	Skalar Autoanalyzer	DCN 1007.9, EPA 353.2
Ammonium	DIN-SWAAN	µM	Skalar Autoanalyzer	DCN 1005.9, EPA 350.1
Total phosphorus	TNP-SWAAN	µM	Skalar Autoanalyzer	DCN 1072.5, Valderrama, 1981
Orthophosphate	DIN-SWAAN	µM	Skalar Autoanalyzer	DCN 1006.7, EPA 365.1
Chlorophyll *a*	CHLAAQFLU	µg/L	Turner Trilogy Fluorometer	DCN 1108.6, EPA 445.0 (modified)
Phaeophytin	CHLAAQFLU	µg/L	Turner Trilogy Fluorometer	DCN 1108.6, EPA 445.0 (modified)
Particulate carbon	PCPNSWCHN	µM	Perkin Elmer 2400 Series II CHNS/O Elemental Analyzer	DCN 1156.3, EPA 440.0
Particulate nitrogen	PCPNSWCHN	µM	Perkin Elmer 2400 Series II CHNS/O Elemental Analyzer	DCN 1156.3, EPA 440.0
Particulate phosphorus	PP--SWOXA	µM	Skalar Autoanalyzer	DCN 1102.2, see SOP references 11.1 and 11.2
Dissolved silicate	DIN-SWAAN	µM	Skalar Autoanalyzer	DCN 1017.3, EPA NERL 366.0

APPENDIX 2. Quality Assurance/Quality Control Procedures for Receiving Water Monitoring

Quality Objectives for the Monitoring Program

- For the CSO-RW study, to ensure that parameters measured adequately describe the effects of CSO discharges on bacterial water quality of receiving waters;
- For the BHWQM and BHWQMR studies, to ensure that parameters measured adequately describe the eutrophication status of Boston Harbor and its tributary rivers;
- To ensure that sample results are representative of the location sampled and are accurate, and;
- To reduce uncertainty associated with assessing the status and trends of bacterial water quality and nutrient effects in Boston Harbor and its tributary rivers.

The first two objectives are met by examining data collected on CSO-RW, BHWQM, and BHWQMR surveys and ensuring that stations selected for sampling will provide the information necessary to quantify nutrient and/or bacterial concentrations in the receiving waters of interest. The third objective is met by collecting samples with relatively high frequency over time (i.e., at least 20 times per year for multiple years per location, especially in the high priority areas of the Charles and Mystic) and analyzing laboratory replicates and other quality control samples to ensure reproducibility of results. The final objective is met by repeated measurements collected at the same locations over time to quantify the variability of results within each region.

Special Training Requirements

The monitoring requires no non-routine field sampling techniques, field analyses, laboratory analyses, or data validation. Specialized training is therefore not required. However, all field personnel are experienced in standard protocols specified in the DLS QAMP and SOPs for sampling water and storing/preparing samples for analysis.

Nutrient, bacteria, and chlorophyll measurements for the studies use routine laboratory analyses, therefore specialized training is not required. DLS analysts are certified in the analyses that they perform according to the requirements detailed in Section 3.0 of the DLS QAMP. Each analyst's test-specific training is documented in their training file, maintained by the DLS QA Team. Also, all DLS analysts and supervisors are experienced in standard protocols specified in the DLS QAMP for handling, storing, and preparing samples for analysis.

Quality Control Procedures

Quality Control (QC) samples are run with every analytical batch of 20 samples or fewer. The suite of QC samples specified for a particular analytical batch will depend on the parameters being analyzed, and are detailed in the QAMP or specific DLS SOP for the analysis. Results from the QC samples are available in LIMS.

Instrument Maintenance and Calibration

Maintenance and calibration procedures for the various instruments used in the laboratory analyses are detailed in the analysis-specific DLS SOPs, or in the manufacturer's documentation. Probes on the YSI sondes used to collect physical parameters are calibrated on a set schedule depending on the type of probe, as detailed in DLS DCN 4002.2. All maintenance and calibration activity for both laboratory and field instrumentation is logged.

Data Management

The DLS QAMP addresses the validation and reporting procedures used by DLS for laboratory analytical data. In summary, there is a three-step process of review, validation, and approval before DLS considers the data to be fit for use. Data that DLS deems unfit for use are not used in any further analyses, or passed to ENQUAL for the next step below. Unfit for use data remain in LIMS.

Once DLS finishes its review procedure, ENQUAL staff review the laboratory analytical data for technical reasonableness. Data from the QC samples are provided to the reviewers. On rare occasions, ENQUAL staff may flag data as not fit for use based on comparison of field replicates or evidence of nonrepresentativeness (e.g., evidence of mud in a bottom sample due to the sampling equipment disturbing the bottom); these data will be excluded from further analyses. Data may also be passed as fit for use, but with explanatory or contextual comments.

Once ENQUAL staff finish their review, the data are loaded into ENQUAL's Environmental Monitoring and Management System (EM&MS) Oracle database.

Sonde data are checked (and if necessary, flagged and commented on) by sampling team staff and then transferred monthly to ENQUAL data management staff via a web based application (HOML; Harbor and Outfall Monitoring Loading) to be loaded into EM&MS.

APPENDIX 3. MWRA Storm Log, 2017 to date

Table 7. Storm data, 2017 to date

Rain Start	Rain End	Chelsea Creek rainfall (inches)	CSO discharges during rain event (relevant variance region in parentheses)[1]	Sampled when CSO discharges were present?	Region Sampled (*=includes weekend)	Notes
3/31/17	4/1/17	2.84	MWR205, **MWR205A (Mystic)**, MWR203	Yes	Mystic/Alewife	Sampled 4/3 to 4/6. More rain expected so push was to begin next weekend, most of this storm was snow. CSOs discharged during this event.
4/4/17	4/4/17	0.94	None	N/A	Mystic/Alewife	More rain expected, sampling continues
4/6/17	4/6/17	1.56	MWR205, MWR203, **SOM001A (Alewife)**	Yes	Mystic/Alewife*	Sampled 4/7 to 4/12, continuing previous sampling since 4/3. First weekend sampled, full 5-days. CSOs discharged during this event.
4/25/17	4/26/17	1.81	MWR205, MWR203, SOM001A	No	Charles*	Sampled 4/26 to 5/1. No CSO discharges in sampled region.
5/5/17	5/6/17	0.87	MWR205, **MWR205A (Mystic)**, MWR203, **SOM001A (Alewife)**	Yes	Mystic/Alewife*	Sampled 5/6 to 5/10. CSOs discharged during this event.
5/14/17	5/15/17	0.98	MWR205, MWR203	No	Mystic/Alewife	Sampled 5/15 to 5/19. No weekend required. No CSO discharges in variance region. Inner Harbor near MWR205 discharge sampled 5/15 to 5/17
5/25/17	5/26/17	1.47	MWR205, MWR205A (Mystic), MWR203, SOM001A	No	Charles*	Sampled 5/26 to 5/30. Includes Memorial Day. No CSO discharges in sampled region.

Rain Start	Rain End	Chelsea Creek rainfall (inches)	CSO discharges during rain event (relevant variance region in parentheses)[1]	Sampled when CSO discharges were present?	Region Sampled (*=includes weekend)	Notes
6/5/17	6/6/17	1.78	MWR205, MWR203	No	Charles	Sampled 6/6 to 6/9. Rain fell Monday into Tuesday, Sampled Charles Tuesday through Friday. Did not sample weekend due to expected rain.
6/12/17	6/13/17	0.49	MWR205, MWR203, SOM001A	No	Charles	Sampled 6/13 to 6/16. Rain anticipated for 6/16. No CSO discharges in sampled region.
6/16/17	6/16/17	2.29	MWR201B, MWR215, MWR205, MWR205A, MWR203, SOM001A	No	None	Sail Boston prevented weekend sampling, could not get samples to lab. Missed Cottage Farm discharge.
6/27/17	6/27/17	0.29	MWR205, **SOM001A (Alewife)**	Yes	Mystic/Alewife*	Sampled 6/27 to 7/4. Includes Independence Day. CSOs discharged during this event.
7/7/17	7/8/17	0.76	None	N/A	Dorchester Bay	Sampled 7/10 to 7/12. No CSO discharges in sampled region.
7/11/17	7/13/17	2.17	MWR205, MWR205A, MWR203, CAM002, SOM001A	No	Charles*	Sampled 7/13 to 7/18. No CSO discharges in sampled region.
7/18/17	7/18/17	0.77	MWR205, MWR205A	No	Dorchester Bay	Sampling 7/19 to 7/20. No CSO discharges during this event.
7/24/17	7/24/17	1.6	MWR205, **MWR205A (Mystic)**, MWR203, MWR215	Yes	Mystic/Alewife*	Sampled 7/24 to 7/29. CSOs discharged during this event.
8/2/2017	8/2/2017	1.11	MWR203	No	Dorchester Bay	Sampled 8/2 to 8/4. Continued in Dorchester Bay to get some wet weather data in region
8/18/2017	8/18/2017	0.24	None	No	Charles*	Sampled 8/19 to 8/25.
8/23/2017	8/23/2017	0.03	MWR205	No	Charles	Continued sampling 8/18 rain event

Rain Start	Rain End	Chelsea Creek rainfall (inches)	CSO discharges during rain event (relevant variance region in parentheses)[1]	Sampled when CSO discharges were present?	Region Sampled (*=includes weekend)	Notes
9/6/2017	9/7/2017	1.00	MWR205, **MWR205A (Mystic),** MWR203, MWR215	Yes	Mystic/Alewife*	Sampled 9/7 to 9/11. CSOs discharged during this event.
9/14/2017	9/14/2017	0.04	MWR205, SOM001A	No	Boston Harbor	Rain totals higher at West Cambridge gauge (Banneker school)
9/15/2017	9/15/2017	0.06	SOM001A	No	None	Rain totals higher at West Cambridge gauge (Banneker school)
9/30/2017	9/30/2017	1.75	MWR205, MWR205A	No	None	High intensity storm Saturday morning. Rain fell mostly north of Boston, close to the coast. WBZ Allston gauge only 0.21 inches, Banneker School gauge (Cambridge) only 0.01 inches
10/25/2017	10/26/2017	1.52	MWR205, MWR205A, MWR203	No	Charles*	Sampled 10/24 to 10/29
10/29/2017	10/30/2017	2.37	**MWR201 (Charles)**, MWR215, MWR205, MWR205A, MWR203, SOM001A, CAM002	Yes	Charles	Nor'easter bringing heavy rain and strong winds. Sampled 10/30 to 11/3. Includes sampling directly after Cottage Farm discharge from approx. 2:30AM to 7:00AM.

[1] MWR201: Cottage Farm CSO Facility; MWR203: Prison Point CSO Facility; MWR205: Somerville Marginal CSO Facility, marine outfall; MWR205A: Somerville Marginal CSO Facility, freshwater relief outfall; MWR215: Union Park CSO Facility; SOM001A: Somerville community CSO (not under MWRA control)

APPENDIX 4. Preliminary Storm Results, 2017

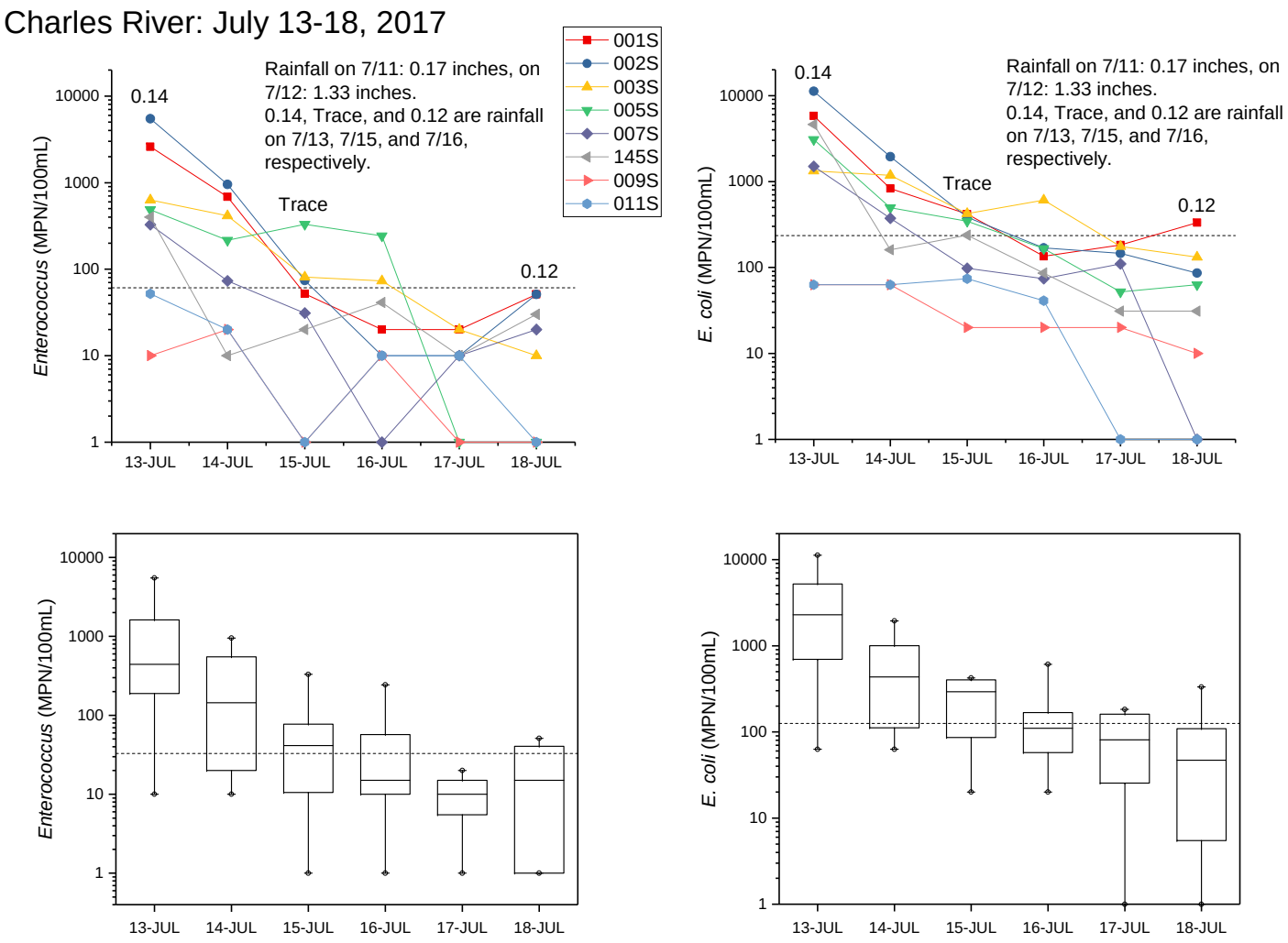
This appendix presents some preliminary results from the new sampling program, and illustrates how the program enables MWRA to "follow" impacts on water quality. Below are the results from two storms that were sampled in 2017.

Figure 3 shows the results from the July 12, 2017 storm, which totaled 1.33 inches of rainfall. Sampling commenced in the Charles River on July 13, and continued until July 18. In this storm, no CSOs were known to have activated. Results of both *Enterococcus* and *E. coli* are presented, both by monitoring location (the line plots) and aggregated by day (the box plots). Relevant water quality standards (single sample on the line plots and geometric means on the box plots) are shown by dotted lines.

Figure 4 presents data in an identical fashion except the results are from the May 5, 2017 storm, and the sampling occurred in the Mystic River and Alewife Brook. 0.64 inches fell on May 5, and sampling occurred on May 6, and continued through May 10. The storm caused the activation of the community CSO SOM001A in Somerville on the evening of May 5.[10] Station 070 is the closest monitoring location downstream of the discharge.

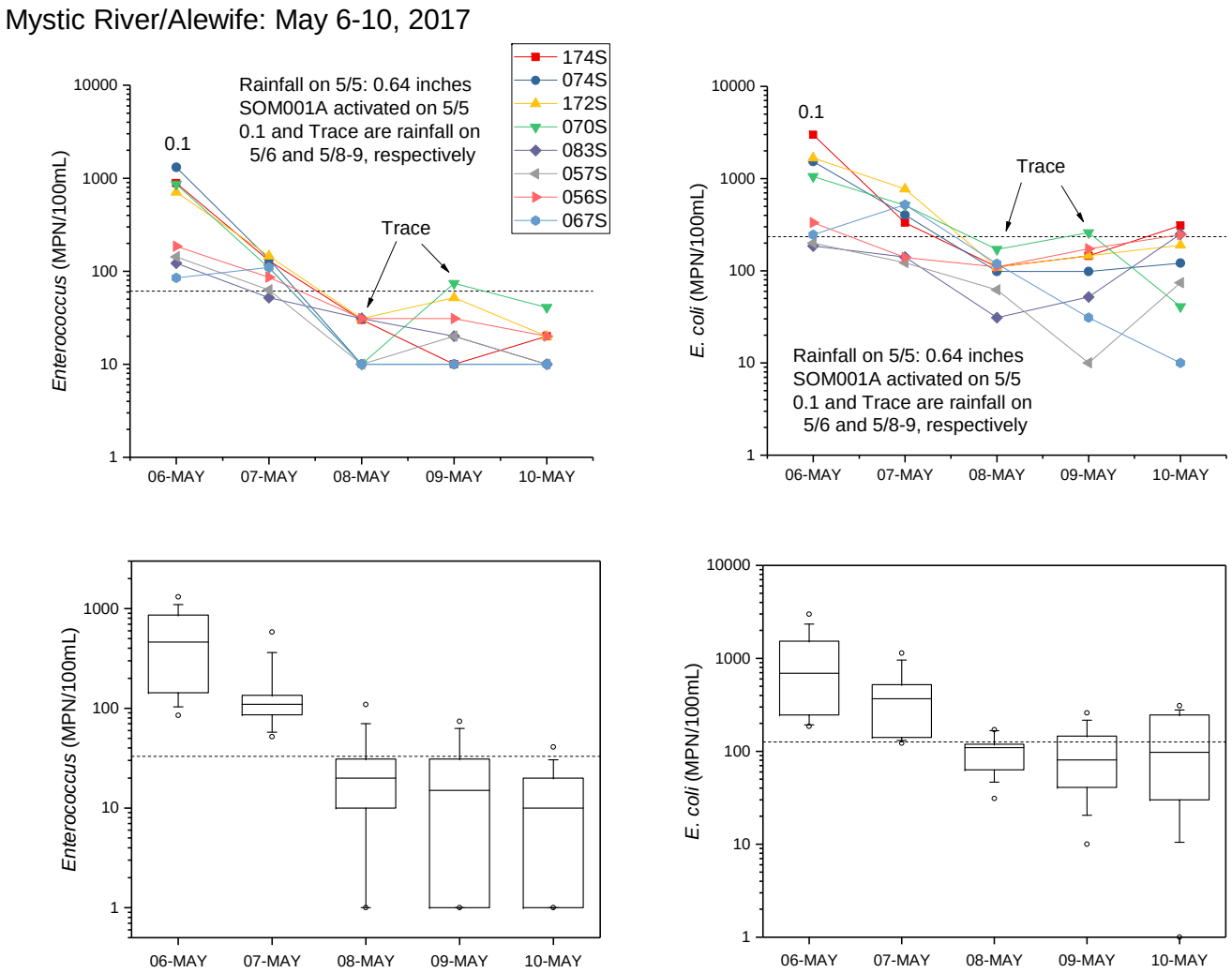
[10] According to the City of Somerville CSO web page (https://www.somervillema.gov/cso).

Figure 3. Charles River results from July 13-18, 2017



No known CSO

Figure 4. Mystic River and Alewife Brook results from May 6-10, 2017



SOM001A discharged on 5/5 (070S is the closest downstream monitoring station).

APPENDIX 5. References

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