CSO Annual Report – January 1 to December 31, 2022:
CSO Discharge Estimates and Rainfall Analyses

April 28, 2023 ***(Revised May 17, 2023)***

Delivering a better world

Table of Contents

Figures

Tables

1. Introduction

On December 30, 2021, the Massachusetts Water Resources Authority (MWRA) submitted the Final Combined Sewer Overflow *Post Construction Monitoring Program and Performance Assessment Report ("December 2021 CSO Report")* to the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (MassDEP) documenting the results of the four-year study to measure the performance of its Long Term Control Plan (LTCP). Until the Schedule was amended in February 2022, this was the final court scheduled milestone in Boston Harbor Litigation (U*nited States v. Metro. Distr. Comm'n.*, et al, No. 85-0489 RGS). From 1987 through 2015, MWRA addressed 182 CSO-related court schedule milestones, including completing the construction of the 35 wastewater system projects that comprised the LTCP by December 2015. MWRA's obligations for CSO control under the Court Order are defined in the March 15, 2006, *Second Stipulation of the United States and the Massachusetts Water Resources Authority on Responsibility and Legal Liability for Combined Sewer Overflow Control*, as amended on April 30, 2008 (the "Second Stipulation").

This report is the second of three Annual Reports as required by the Court's compliance order which extends until December 2024 to complete the time for, among other things, identified projects and further evaluating alternatives to further reduce CSOs at the sixteen outfalls that did not meet the LTCP goals by December 31, 2021. As part of this extension, MWRA is required to provide estimates of combined sewer overflow (CSO) discharges in its service area during calendar year 2022. For more information about MWRA's federal court obligations for CSO control, including the LTCP levels of control, see Section 1.3.5 in Semiannual CSO Discharge Report No. 2, May 3, 2019.

Pursuant to the Court's Schedule Seven, as amended, MWRA reports herewith its estimates using hydraulic modeling of calendar year 2022 CSO activation frequency and total discharge volume from each of the CSO outfalls addressed in MWRA's approved LTCP, including but not limited to the outfalls discharging to the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin. In addition, MWRA also provides estimates of CSO activation frequency and volume at each of the outfalls calculated using meter data. MWRA has also provided this information to its member communities with CSOs, including Boston Water and Sewer Commission (BWSC) and the cities of Cambridge, Chelsea, and Somerville as well as watershed groups and other stakeholders.

For the MWRA outfalls in the variance waters (Charles River, Alewife Brook, and Upper Mystic River) the activations, volumes, and durations are provided in accordance with the reporting requirements in the Variance Extensions for the Alewife/Upper Mystic River and the Lower Charles River/Charles Basin, issued by MassDEP in 2019 pursuant to the Massachusetts Surface Water Quality Standards at 314 CMR 4.00. The Variances authorize limited CSO discharges to the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin in conjunction with National Pollution Discharge Elimination System (NPDES) permits MA0103284, MA0101982 and MA0101974 issued to MWRA, the City of Cambridge and the City of Somerville, respectively.

This report is organized into the following chapters:

Chapter 1: Introduction

Chapter 2: Summary of 2022 Meter[1] Data and Comparison to Model Results. Presents the following:

- a summary of the model changes incorporated into the 2022 system conditions model
- a summary analysis of the 2022 rainfall in comparison to the Typical Year[2]
- a table with the metered CSO activation frequency, duration, and volume for each of the MWRA outfalls tributary to the variance waters for 2022 to meet the reporting requirement as described in section D.4.b.iv of the 2019 Alewife Brook Variance and as described in section D.3.b.iv of the 2019 Charles River Variance
- the estimated CSO activations and discharge volume during calendar year 2022 using the MWRA collection system model, configured to represent system conditions in 2022
- the estimated CSO activations and discharge volumes calculated from monitoring data from MWRA and the CSO community meters

Chapter 3: Updated System Performance Assessment and Comparison with LTCP Levels of Control. Presents the following:

- a comparison of the CSO activations and discharge volumes for the Typical Year for Q4-2022 (end of 2022) system conditions to the activation frequency and volume goals established for each outfall under the Second Stipulation. Also presented are previously-modeled Typical Year CSO activations and volumes for 1992 system conditions
- a table with the percent capture of combined sewage for the Typical Year for Q4-2022 system conditions.
- a summary of the status of further evaluations of outfalls that did not meet the LTCP goals for activation frequency and/or volume as of the end of 2022.

Appendix A: Rainfall Data Collection and Analyses January 1 – December 31, 2022. Provides a summary of the rainfall data collected for 2022, characterizes the return period for each storm, and provides a comparison to the Typical Year rainfall.

2. Summary of 2022 Model Results and Comparison to Meter Data

MWRA developed estimated CSO activation frequency and discharge volume at each CSO outfall during calendar year 2022 using the MWRA's Integrated Catchment Model (ICM) of the collection system. The model simulated each of the rainfall events in 2022 with system conditions existing at the time of each storm. In support of these simulations, MWRA updated the model to account for new information and known changes to the system, including system improvements that were completed during the year, new meter data, and results of field inspections. Each system change was incorporated into the 2022 Typical Year simulation, which represents end-of-year conditions. The model updates for 2022 are summarized in section 2.1 and the rainfall analysis is summarized in section 2.2. Section 2.3 presents the meter estimates of MWRA CSO discharges to the variance waters for 2022 and Section 2.4 presents the comparison of meter and modeled estimates of all CSO discharges for the January 1, 2022 – December 31, 2022 period.

[1] Metered data are estimates of outfall discharge calculated using data from sensors, taking into account physical configurations and constraints.

[2] Typical Year Rainfall or Typical Year: The performance objectives of MWRA's approved Long-Term CSO Control Plan include annual frequency and volume of CSO discharge at each outfall based on "Typical Year" rainfall from 40 years of rainfall records at Logan Airport, 1949-1987 plus 1992. The Typical Year was a specifically constructed rainfall series that was based primarily on a single year (1992) that was close to the 40-year average in total rainfall and distribution of rainfall events of different sizes. The rainfall series was adjusted by adding and subtracting certain storms to make the series closer to the actual averages in annual precipitation, number of storms within different ranges of depth and storm intensities. The development of the Typical Year is described in MWRA's System Master Plan Baseline Assessment, June 15, 1994. The Typical Year consists of 93 storms with a total precipitation of 46.8 inches.

2.1 Hydraulic Model Updates

Updates to MWRA's hydraulic model are necessary to estimate CSO discharges as improvements are made to the MWRA and community sewer systems; to compare model predictions against meter data; and to update Typical Year CSO performance for comparison with the LTCP activation and volume goals. The MWRA's Q4-2022 model was updated with the changes listed in Table 2-1 below. The table provides the **Location** of the part of the model that was modified. The **Summary of Change** provides information on what was changed in the model. **Supporting Information** provides additional context on the justification/source of information about the modification that was made to the model. The Q4-2022 system conditions model was used to predict CSO discharges during the storms that occurred in the period of January 1, 2022 through December 31, 2022 and to assess the Typical Year CSO performance for current system conditions.

Table 2-1. Model Changes to reflect Q4-2022 System Conditions

Location	Summary of Change	Supporting Information
CSO Facilities	Updated the Real Time Control (RTC) to include the storm-by-storm operation of the facilities based on facility operation data provided by MWRA.	The updated RTC was added for the January 1 – December 31, 2022 period based on MWRA and BWSC-provided data.
BOS046, Boston Gate House #1	The model RTC was updated to reflect the actual gate conditions at Gate House #1 during the January 1, 2022 – December 31, 2022 period (the Typical Year version of the model will open the gates in accordance with BWSC's updated SOP's).	BWSC opens the gates in Gate House #1 for individual storms based on operator discretion and if the storm is predicted to exceed 80% of a 2-year recurrence interval depth. According to BWSC, the gates were not opened between January 1 to December 31, 2022.
East Boston BOS005	Closed regulator RE005-1 (outfall BOS005).	Regulator was closed as part of the Contract 2 Sewer Separation Work on September 6, 2022. Outfall BOS005 is now permanently closed as a CSO outfall but remains open discharging stormwater only.
East Boston BOS014	Updated the model to include a new dry weather flow connection at BOS014.	BWSC provided record drawings documenting the new dry weather flow connection. Work was completed on January 26, 2022.
East Boston RE003-2	Closed RE003-2 (discharged to outfall BOS003).	BWSC closed RE003-2 as part of the Contract 3 Sewer Separation work. BWSC completed the work to close the regulator in May of 2022.
East Boston RE003-7	Closed RE003-7 (discharged to outfall BOS003).	BWSC closed RE003-7 as part of the Contract 3 Sewer Separation work. BWSC completed the work to close the regulator in May of 2022.
East Boston RE003-12	Updated the configuration of the restricted interceptor connection at RE003-12 by replacing the existing dry weather flow (DWF) connection with 24-inch line and removing a manhole.	BWSC updated the configuration of the restricted interceptor connection at Regulator RE003-12 as part of the Contract 3 Sewer Separation work. BWSC completed the work to construct the new DWF connection in May of 2022.
Roxbury Canal Sewer (RCS)	BWSC piping configuration for the RCS connection was imported to better represent existing conditions. See below for further detail.	BWSC provided record drawings to MWRA of the RCS showing a connection that directs brook flow and additional stormwater flows to Fort Point Channel during dry weather away from downstream CSOs. This work was part of Roxbury Sewer Separation Phase I 15-309-011 completed on October 22, 2021.
MWR018-019-020 Tributary Area	The MWRA's model was updated to include georeferenced subcatchments in the Back Bay and trunk sewers in the Old Stony Brook system to enable further alternative analysis. See below for further detail.	BWSC's model was provided to MWRA and was used to implement this update because it included a more detailed representation of the subcatchments and piping configuration in the Back Bay and Stony Brook systems.

As described in the table above, updates were made to the MWRA's model to the Roxbury Canal Sewer (RCS) and area tributary to MWR018-019-020. These updates were made to support alternative investigations being conducted in an effort to achieve LTCP compliance at MWR018-019-020 where Typical Year CSO activation and/or volume exceed the LTCP goals. The following sections provide additional detail on these updates.

<u>Roxbury Canal Sewer</u>

As part of the alternative investigations MWRA has been working with BWSC to identify separated stormwater areas in the area tributary to outfalls MWR018-019-020. BWSC completed two phases of sewer separation projects in the Roxbury area which contribute flow to the Old Stony Brook Conduit (OSBC). Roxbury Sewer Separation Contract 1 was completed October 22, 2021, and Contract 2 was completed December 11, 2020[3]. To account for the separation work, MWRA's model was updated to add the RCS and associated pipes. Located near Nubian Square, the RCS is comprised of an existing 72-inch stormwater line that enters an overflow structure where the preferred path conveys brook flow and stormwater to Fort Point Channel through a 24-inch pipe and a flap gate to prevent backflow into the overflow structure. During wet weather, a side outlet weir in the overflow structure diverts stormwater to the OSBC (Figure 2-1). The previous configuration in MWRA's model directed all of the brook flow and stormwater towards the Boston Main Interceptor (BMI), Ward Street Headworks, and the OSBC system. Flow changes to the Ward Street Headworks can impact discharge volumes at the Cottage Farm CSO Facility which is sensitive to the backwater condition created upstream of the headworks during large storms. Additionally, downstream outfalls directly connected to the OSBC and Boston Marginal Conduit (BMC) such as BOS046, MWR018, MWR019, and MWR020 are influenced by flow changes to the OSBC. The Prison Point CSO Facility is also influenced by changes in flow to the BMC. To better reflect existing conditions, the piping configuration and upstream hydrology was imported from the BWSC model. Figure 2-2 shows the extent of new piping incorporated into the model for the RCS update.

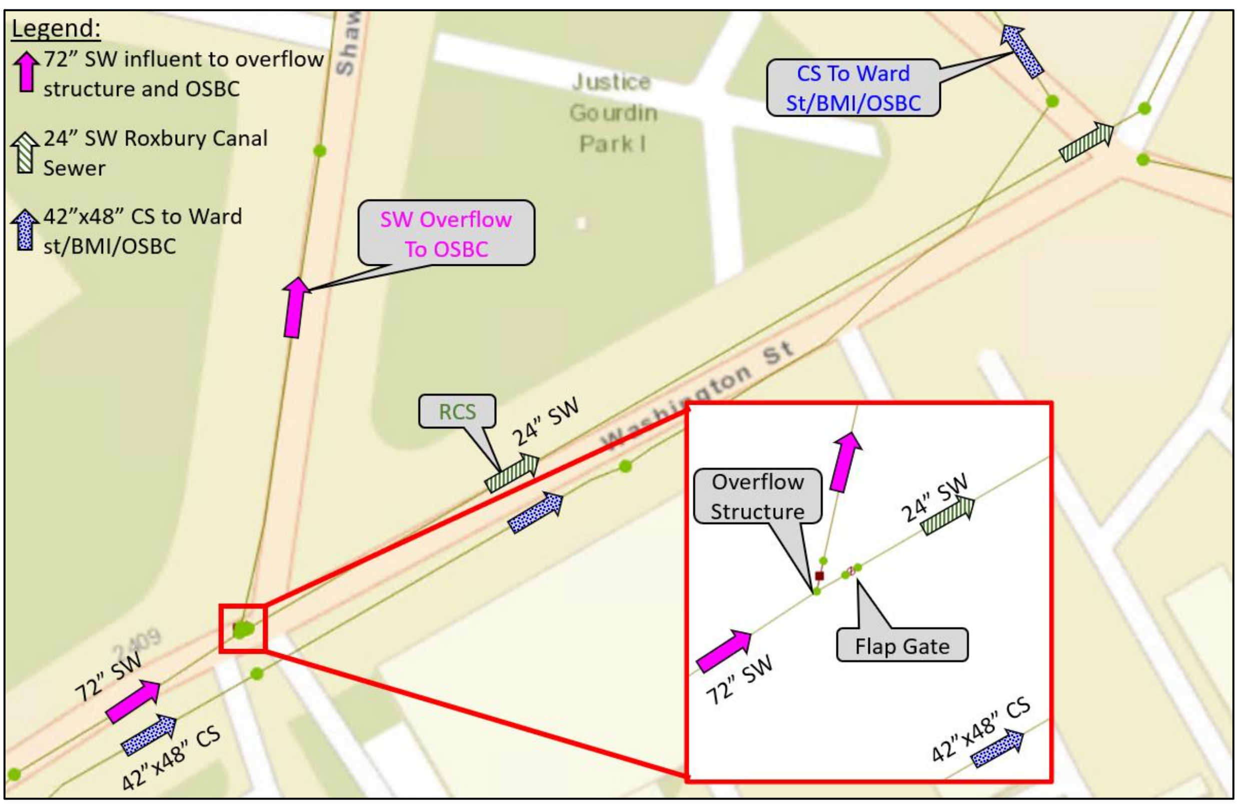

Figure 2-1. Roxbury Canal Sewer Record Drawings & Model Configuration

[3] According to BWSC Roxbury Sewer Separation Contract 1 was completed ono October 22, 2021 which was after Roxbury Sewer Separation Contract No. 2 which was completed on December 11, 2020.

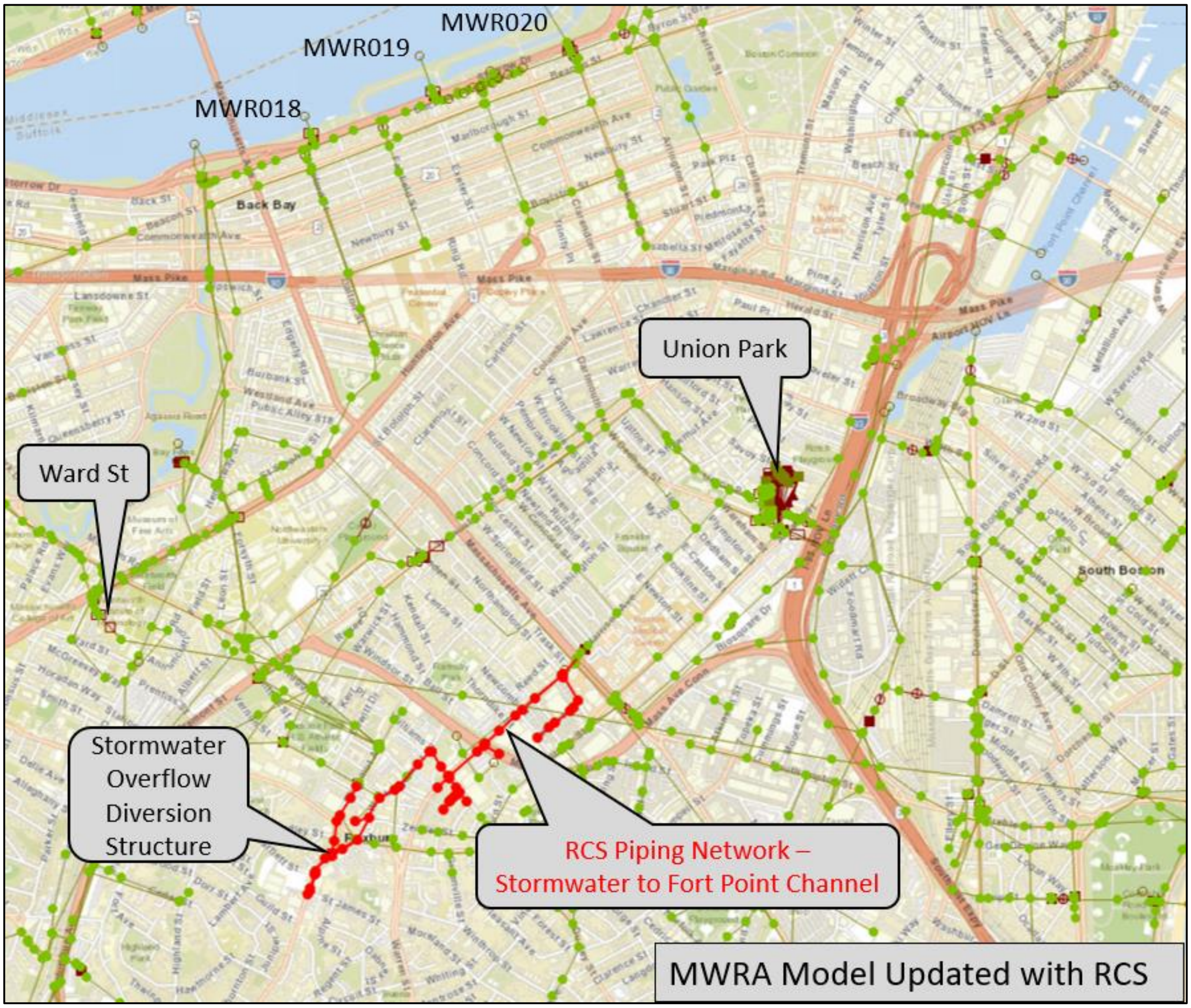

Figure 2-2. Roxbury Canal Sewer Model Update

The revision of the RCS configuration in MWRA's model reduced the total flow to the OSBC and the hydraulically-connected interceptor systems while improving the correlation between meter and model results. The reduction in flow to the OSBC and related interceptors was due in part to the flow being conveyed to Fort Point Channel through the RCS connection, and in part to the incorporation of the updated runoff areas from the BWSC's model. The updated delineations from BWSC had much less tributary connected impervious area than the previous versions of the model. The Prison Point CSO Facility, Cottage Farm CSO Facility, MWR018-019-020, and BOS070 systems are hydraulically influenced by this model update. Table 2-2 presents the meter vs model annual discharge volume results for 2021 and 2022 at these locations for the Q4-2021 version of the model as presented in the previous Annual Report and an interim version of the Q4-2022 version of the model that includes the RCS connection but not the Stony Brook and Back Bay model refinements described in the following section.

Table 2-2. Roxbury Canal Sewer 2021 and 2022 Meter vs Model Results

Location	2021 Volume (MG)			2022 Volume (MG)	
	Meter (3)	Q4-2021 Model	Q4-2022 Model (1)	Meter (3)	Q4-2022 Model (1)
Prison Point CSO Facility	444.14	474.36	452.95	70.70	66.40
Cottage Farm CSO Facility	88.10	72.73	77.52	0	0
MWR018-019-020 (2)	5.45	23.51	21.97	0	0
BOS070/DBC	39.99	44.45	43.23	1.09	0.17

1. The results represent an interim version of the Q4-2022 model without the model refinements in the Back Bay and Stony Brook area.
2. Represents the total discharge volume from the three outfalls.
3. Metered data are estimates of outfall discharge calculated using data from sensors, taking into account physical configurations and constraints.

The following is a summary of the observations at the key locations:

- At the Prison Point CSO Facility, the 2021 metered discharge volume was 444.14 MG. With the RCS update implemented, the discharge volume predicted by the model was 452.95 MG, which is closer to the metered volume than before the RCS update was implemented. The model predicted discharge volume in 2022 was slightly lower than the metered volume. However, the 2021 modeled volume was slightly higher than the meter data.
- At the Cottage Farm CSO Facility, the 2021 metered discharge volume was 88.10 MG. With the RCS update implemented, the discharge volume predicted by the model was 77.52 MG, which is closer to the metered volume than before the RCS update was implemented. In 2022, the Cottage Farm CSO Facility did not have a metered or modeled activation.
- At MWR018-019-020, the 2021 metered discharge volume was 5.45 MG. With the RCS update implemented, the discharge volume predicted by the model was 21.97 MG, which is closer to the metered volume than before the RCS update was implemented. In 2022, MWR018-019-020 did not have a metered or modeled activation.
- At BOS070/DBC, the 2021 metered discharge volume was 39.99 MG. With the RCS update implemented, the discharge volume predicted by the model was 43.23 MG, which is closer to the metered volume than before the RCS update was implemented. In 2022, BOS070 discharge is under-predicted by the model with a metered discharge of 1.09 MG and the volume predicted by the model of 0.17 MG.

A review of the meter and model data in the overall MWRA system showed that this model refinement did not substantially impact the model predictions beyond the locations noted above. Overall, the addition of the RCS model update allowed the model to predict results that are close to the meter data for 2021 and 2022.

Stony Brook Model Update

As part of the effort to identify alternatives that could further reduce activations and volumes at MWR018-019-020 towards the LTCP goals, MWRA has further refined its model in the tributary areas to these outfalls. MWRA's model was updated to include georeferenced subcatchments in the Back Bay and trunk sewers in the OSBC system. In this area, the Q4-2022 version of the model contains four times the number of nodes, four times the number of conduits, and 1.5 times the number of subcatchments compared to the Q4-2021 model. Figure 2-3 shows the baseline MWRA model and the updated model configurations of the OSBC and Back Bay systems highlighted in red. Figure 2-4 shows the subcatchments in the baseline MWRA model and the georeferenced subcatchments in the updated model. This additional detail will allow for evaluation of redirecting upstream separate storm drains away from the combined sewer system.

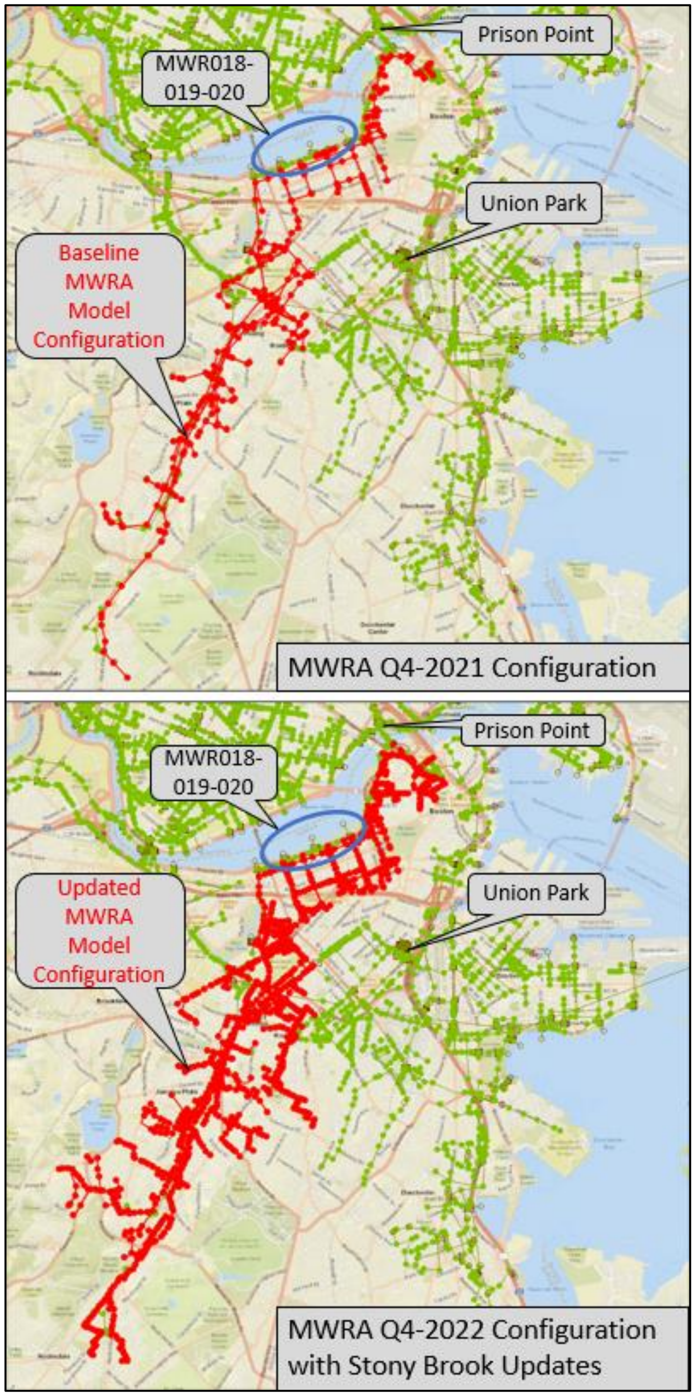

Figure 2-3. Baseline MWRA Model and the Updated Model Configurations of the Old Stony Brook and Back Bay Systems

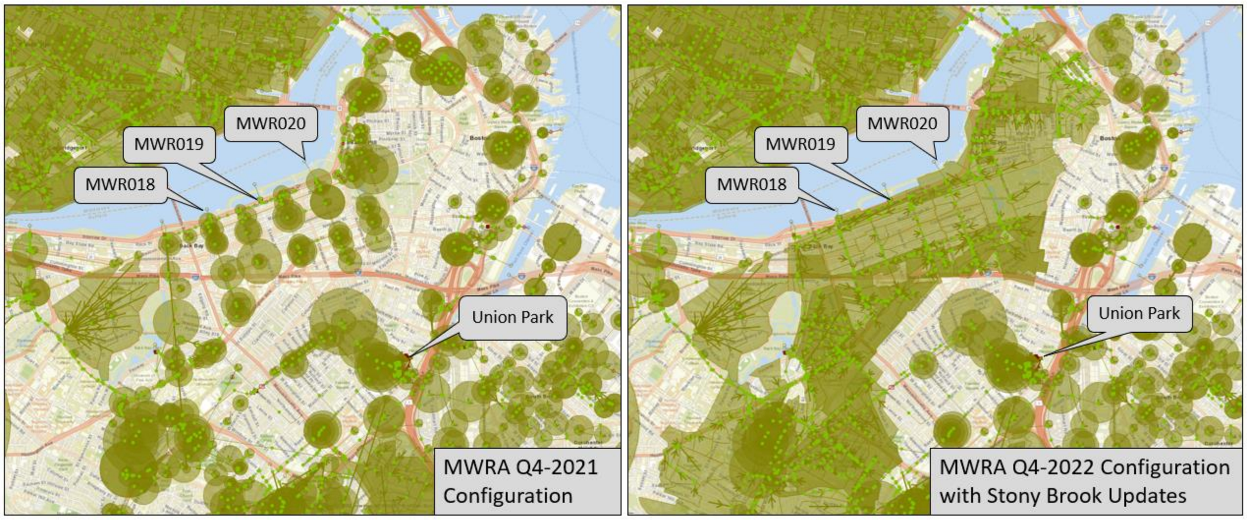

Figure 2-4. Baseline MWRA Model Subcatchments and the Updated Model Georeferenced Subcatchments

The updated model was run for 2021 and 2022 periods and the results were compared to the corresponding metered discharges to check that the model predictions were still close to the meter results. Prison Point CSO Facility, Cottage Farm CSO Facility, and MWR018-019-020 have large tributary areas that are directly connected to the refined area. Table 2-3 presents the meter vs model annual discharge volume results for 2021 and 2022 at these locations for the Q4-2021 version of the model as presented in the previous Annual Report and the Q4-2022 version of the model that includes the RCS connection described above. A review of the meter and model data in the overall MWRA system showed that this additional model refinement did not substantially impact the model predictions.

Table 2-3. Stony Brook & Back Bay Model Refinement 2021 & 2022 Meter vs Model Results

Location	2021 Volume (MG)			2022 Volume (MG)	
	Meter	Q4-2021 Model	Q4-2022 Model (1)	Meter	Q4-2022 Model (1)
Prison Point CSO Facility	444.14	474.36	462.17	70.70	69.29
Cottage Farm CSO Facility	88.10	72.73	68.98	0	0
MWR018-019-020	5.45	23.51	18.52	0	0

1. The Q4-2022 version of MWRA's model includes the model refinements in the Back Bay, Stony Brook Systems, and the RCS.

The following is a summary of the observations at the key locations:

- At the Prison Point CSO Facility, the 2021 metered discharge volume was 444.14 MG. With the Stony Brook and RCS updates implemented, the discharge volume predicted by the model was 462.17 MG, which is closer to the metered volume than before the Stony Brook and RCS updates were implemented. The model predicted discharge volume in 2022 was slightly lower than the metered volume. However, the 2021 modeled volume was higher than the meter data.
- At the Cottage Farm CSO Facility, the 2021 metered discharge volume was 88.10 MG. With the Stony Brook and RCS updates implemented, the discharge volume predicted by the model was 68.98 MG, which is similar to the model result before the Stony Brook and RCS updates were implemented. In 2022, the Cottage Farm CSO Facility did not have a metered or modeled activation.
- At MWR018-019-020, the 2021 metered discharge volume was 5.45 MG. With the Stony Brook and RCS updates implemented, the discharge volume predicted by the model was 18.52 MG, which is closer to the metered volume than before the Stony Brook and RCS updates were implemented. In 2022, MWR018-019-020 did not have a metered or modeled activation.

Table 2-4 presents the Typical Year results for the Q4-2021 system conditions vs. Q4-2022 model conditions. At the Prison Point CSO Facility, Cottage Farm CSO Facility, and outfalls MWR018-019-020, the RCS and Stony Brook and Back Bay model refinements brought the model results closer to the meter data while reducing the Typical Year overflow volumes.

Table 2-4. Stony Brook & Back Bay Model Refinement Typical Year Model Results

Location	Q4-2021 Model		Q4-2022 Model(1)		Long Term Control Plan	
	Act. Freq.	Volume (MG)	Act. Freq.	Volume (MG)	Act. Freq.	Volume (MG)
Prison Point CSO Facility	17	248.33	17	245.01	17	243
Cottage Farm CSO Facility	2	9.09	2	7.81	2	6.30
MWR018-019-020	2	2.04	2	0.63	0	0

1. The Q4-2022 version of MWRA's model includes the model refinements in the Back Bay, Stony Brook Systems, and the RCS.

2.2 Rainfall Analyses

Rainfall is a driving factor in the analysis of CSOs, as the occurrence of overflows within the MWRA sewer system is dependent on rainfall intensity and/or depth. The rainfall for the period of January 1, 2022 to December 31, 2022 was analyzed to help support the understanding of the modeled performance for 2022 conditions with respect to the measured activations and volumes at each outfall for the 2022 period, and with respect to the LTCP targets for performance for the Typical Year. As described in the *CSO Annual Report: Discharge Estimates and Rainfall Analyses report for Calendar Year 2021*[4], the MWRA's rainfall recurrence interval calculation methodology was updated from *Technical Paper 40* (TP-40)[5] to *Atlas-14*[6].

Values for Atlas 14 for Boston were extracted from NOAA's data server[7] on April 12, 2022. The Atlas 14 partial duration curves were used to assign the recurrence intervals. The smallest storm the partial duration curves addresses is the 1-year storm, so the partial duration intensity-duration-frequency (IDF) curves for the 3-month and 6-month frequencies were extrapolated. All of the storm recurrence intervals identified in the text and sections below and in Appendix A are based on the 2019 edition of Atlas 14 referenced above.

Appendix A includes the following tables that were prepared in support of this analysis:

- Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2022 to December 31, 2022
- Table A-5. Frequency of Events within Selected Ranges of Total Rainfall for January 1, 2022 to December 31, 2022
- Table A-6. Comparison of Storms Between January 1, 2022 and December 31, 2022 and Typical Year with Greater Than 2 Inches of Total Rainfall
- Table A-7. Comparison of Storms Between January 1, 2022 and December 31, 2022 and the Typical Year with Peak Intensities Greater than 0.40 inches/hour

The findings from those tables are summarized below.

In 2022, Metropolitan Boston experienced significantly less volume of rain, fewer high intensity storm events, and fewer large storms in terms of depth compared to the Typical Year. The Typical Year total rainfall depth of 46.80 inches was 13.17 inches higher than that of the average depth across the

[4] CSO Annual Report April 29, 2022: CSO Discharge Estimates and Rainfall Analyses for Calendar Year 2021 https://www.mwra.com/cso/pcmpa-reports/042922-annualcso.pdf
[5] TP 40: https://reduceflooding.com/wp-content/uploads/2018/09/TechnicalPaper_No40.pdf
[6] Atlas 14 Volume 10 report : https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume10.pdf
[7] NOAA's Data server for MA: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma

collection system's rain gauges in 2022 of 33.63 inches. The impact of the lower rainfall (in terms of total rainfall, as well as peak intensity), is evident in the 2022 vs. Typical Year rainfall comparisons in the rainfall summary tables, and in comparing the modeled CSO discharge estimates for the Typical Year and 2022. For example, Prison Point is predicted to discharge 234.81 MG in the Typical Year; in 2022, Prison Point's modeled discharge volume was 62.47 MG, a 172.34 MG difference.

In terms of comparing the 2022 rainfall to the Typical Year, the following observations are noted:

- 2022 averaged 93 storm events with an average annual rainfall depth of 33.63 inches, compared to 93 storm events with an average annual rainfall depth of 46.80 inches for the Typical Year (Table A-5).
- In general, the breakdown of numbers of storms by rainfall depth categories for 2022 skewed towards the smaller storms compared to the Typical Year. The 2022 period had nine more storms with depths less than 0.5 inches and nine fewer storms with depths greater than 0.5 inches. (Table A-5).
- In terms of larger storms, for the four gauges shown in Table A-6 the average number of storms with greater than 2 inches of total rainfall in 2022 ranged from zero to two, less than in the Typical Year count of six storms. In 2022 only two storm events were recorded to have a depth greater than 2 inches at Columbus Park (BO-DI-2), while no storms above 2-inches were recorded at Ward Street (BO-DI-1) or USGS Fresh Pond. The largest storm in 2022 had a depth of 2.14 inches at Columbus Park, compared to the largest storm in the Typical Year, which has a depth of 3.89 inches (Table A-6).
- For the four gauges shown in Table A-7, the number of storms with peak intensities greater than 0.40 inches per hour ranged from three to four, compared to nine for the Typical Year. The evaluated gauges had a peak intensity of 0.71 inches per hour. In comparison, the Typical Year peak had one storm with intensity of 1.08 inches per hour with the remaining eight storms having peak intensities between 0.75 and 0.42 inches per hour (Table A-7).

Appendix A presents the rainfall data measured during the period of January 1, 2022 through December 31, 2022. It also describes the analysis of the rainfall data used to characterize the return period of each storm event and a comparison of measured rainfall for the 2022 period to the rainfall included in the Typical Year. Further detail regarding the rainfall data collection and processing can be found in Chapter 9 of the *December 2021 CSO Report.*

2.3 Meter Estimates of CSO Discharges to Variance Waters for 2022

Under the CSO Variances for the Alewife/Upper Mystic River and the Lower Charles River/Charles Basin, MWRA, Cambridge, and Somerville must provide public notification of CSO activations within four hours and estimate volumes within five business days. In addition, the variances require MWRA, Cambridge and Somerville to report the annual CSO volumes and overflow durations no later than April 30th of each year. MWRA and the CSO communities have been collecting meter data used to report the CSO discharges at each of the outfalls tributary to the variance waters as part of the CSO Notification Program.

Table 2-5 below presents the estimated activation frequency, duration, and volume of CSO to the variance waters for MWRA-owned outfalls based on meter data. The data were collected by MWRA, supplemented by BWSC monitoring of regulators tributary to both outfalls MWR023 and BOS046. Refer to the Cambridge and Somerville annual reports for additional discussion regarding community metering data.

Table 2-5. 2022 MWRA Metered CSO Discharges to Variance Waters

Outfall/Waterbody	MWRA Metered(1) CSO Discharge Estimates(2)		
	Activation Frequency	Volume (MG)	Duration (hr)
Alewife Brook			
MWR003	0	0	0
Upper Mystic			
SOM007A/MWR205A	4	3.12	5.81
Lower Charles			
MWR010	0	0	0
MWR018	0	0	0
MWR019	0	0	0
MWR020	0	0	0
MWR201 (Cottage Farm) (treated)	0	0	0
MWR023	1	0.01	0.25

(1) Metered data are estimates of outfall discharge calculated using data from sensors, taking into account physical configurations and constraints.

(2) This table of metered CSO activation frequency, duration, and volume for each of the MWRA outfalls tributary to the variance waters for 2022 is provided to meet the reporting requirement as described in section D.4.b.iv of the 2019 Alewife Brook Variance and as described in section D.3.b.iv of the 2019 Charles River Variance.

2.4 Meter and Modeled Estimates of 2022 System Wide CSO Discharges

The Q4-2022 system conditions model was used to simulate the storm events from January 1, 2022 to December 31, 2022. MWRA and the CSO communities have been collecting meter data at each of the outfalls listed in the LTCP as part of the CSO Notification Program. These meter data were used to tabulate the CSO activation frequency and volume for the January 1, 2022 to December 31, 2022 period.

The estimates of CSO activations and volumes based on meter data for non-MWRA-owned outfalls were made available from BWSC Cambridge, Chelsea and Somerville. Each of the communities utilizes a professional metering firm for the installation and maintenance of flow metering equipment and the assessment of CSO activations, volumes and durations based on the meter data. MWRA has not reviewed the meter configurations or the methodologies for computing the CSO activations and volumes based on meter data at these locations. Calculating CSO discharges from meter data for the purpose of developing volume estimates, whether by MWRA or by the communities, is inherently difficult and can be inaccurate given complex hydraulics, difficultly in proper calibration given normal dry conditions, etc.

Summary of 2022 Modeled and Metered CSO Discharges

Table 2-6 presents the comparison of metered estimates and modeled CSO discharges from January 1, 2022 to December 31, 2022.

As indicated in Table 2-6, the model was able to replicate the storm responses for the majority of storm events in the 2022 period. However, it was not possible to match all of the modeled and metered activations for every meter and storm event. These differences may be attributed to various conditions or combination of conditions, including rainfall data quality and rainfall spatial variation, unknown transient conditions in the collection system, and the accuracy of overflow metering data (see Section 4.2 of Semiannual Report No. 5 *Model Calibration and Factors Affecting Model Results*).

Table 2-7 provides a list of the locations with notable differences between metered and modeled CSO discharges for the January 1 – December 31, 2022 period.

Table 2-6. Summary of 2022 Modeled and Metered CSO Discharges

Outfall	January 1 – Dec 31, 2022			
	Meter(1) (2)		Model	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
Alewife Brook				
CAM001	0	0.00	0	0.00
CAM002	0	0.00	0	0.00
MWR003	0	0.00	0	0.00
CAM401A	10	0.47	1	0.06
CAM401B	0	0.00	0	0.00
SOM001A	1	0.03	1	0.10
TOTAL	**10**	**0.50**	**1**	**0.16**
Upper Mystic River				
SOM007A/MWR205A(3)	4	3.12	4	5.00
Mystic/Chelsea Confluence				
MWR205 (Somerville Marginal Facility)	18	34.56	18	39.65
BOS013	0	0.00	3	0.06
BOS014	1	0.00	0	0.00
BOS017	0	0.00	0	0.00
CHE003	0	0.00	0	0.00
CHE004	0	0.00	0	0.00
CHE008	3	0.19	2	0.38
TOTAL	**18**	**34.75**	**18**	**40.09**
Upper Inner Harbor				
BOS009	8	0.06	5	0.21
BOS010	0	0.00	0	0.00
BOS012	0	0.00	0	0.00
BOS019	1	0.06	0	0
BOS057	0	0.00	0	0.00
BOS060	0	0.00	2	0.02

Table 2-6. Summary of 2022 Modeled and Metered CSO Discharges

Outfall	January 1 – Dec 31, 2022			
	Meter(1) (2)		Model	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
MWR203 (Prison Point)	9	70.70	9	69.29
TOTAL	**9**	**70.82**	**9**	**69.52**
Lower Inner Harbor				
BOS003	7	0.27	0	0.00
BOS004	0	0.00	0	0.00
BOS005	Closed	Closed	0	0.00
TOTAL	**7**	**0.27**	**0**	**0.00**
Fort Point Channel				
BOS062	0	0.00	0	0.00
BOS064	0	0.00	0	0.00
BOS065	1	0.00	0	0.00
BOS068	0	0.00	0	0.00
BOS070/DBC	6	1.09	3	0.17
MWR215 (Union Park)	0	0.00	2	4.21
BOS070/RCC	0	0.00	1	0.02
BOS073	0	0.00	0	0.00
TOTAL	**7**	**1.09**	**3**	**4.40**
Reserved Channel				
BOS076	0	0.00	0	0.00
BOS078	0	0.00	0	0.00
BOS079	0	0.00	0	0.00
BOS080	0	0.00	0	0.00
TOTAL	**0**	**0.00**	**0**	**0.00**
Upper Charles				
CAM005	4	0.16	2	0.05
CAM007	0	0.00	0	0.00
TOTAL	**4**	**0.16**	**2**	**0.05**
Lower Charles				
CAM017	0	0.00	0	0.00
MWR010	0	0.00	0	0.00
MWR018	0	0.00	0	0.00
MWR019	0	0.00	0	0.00
MWR020	0	0.00	0	0.00
MWR201	0	0.00	0	0.00
MWR023(3)	1	0.01	1	0.12
TOTAL	**1**	**0.01**	**1**	**0.12**
Back Bay Fens				
BOS046(3)(4)	0	0.00	0	0.00
TOTAL	0	0.00	0	0.00

Table 2-6. Summary of 2022 Modeled and Metered CSO Discharges

Outfall	January 1 – Dec 31, 2022			
	Meter[(1) (2)]		Model	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
TOTAL UNTREATED		**2.34**		**1.19**
TOTAL TREATED		**105.26**		**113.15**
GRAND TOTAL		**107.60**		**114.34**

(1) Metered data are estimates of outfall discharge calculated using data from sensors, taking into account physical configurations and constraints.
(2) Meter volume reported is calculated from MWRA, Cambridge, Somerville, Chelsea, and BWSC community meters.
(3) Outfall SOM007A/MWR205A is a side-outlet relief off of outfall MWR205, downstream of the Somerville Marginal Facility. This outfall can activate and discharge treated flow during storm events when high tides restrict the discharge from outfall MWR205. The SOM007A/MWR205A volume includes a fraction of the flow treated at Somerville Marginal facility plus separate stormwater that enters the Somerville Marginal Conduit (outfall) downstream of the facility. The volume presented is therefore not included in the total treated flow calculated below as the treated CSO fraction of the volume at SOM007A/MWR205A is counted in the volume presented for MWR205.
(4) BOS046 (Gatehouse 1) is primarily a stormwater discharge but may discharge CSO if the upstream regulators overflow. The upstream regulators are monitored by BWSC. The gatehouse is normally closed but may be opened for flood mitigation. Flow can discharge at Gatehouse 1 if the gate is opened or if water overtops the closed gate. Based on model tracer studies, when a discharge occurs during model simulations at BOS046 and one or more of the upstream regulators in the Stony Brook system are predicted to activate, it was estimated that 25% of the CSO from the upstream regulators discharges at the MWR023 outfall (Charles River) and 75% discharges at BOS046 (Back Bay Fens). According to BWSC, the gate was not opened in 2022 therefore the CSO discharge that occurred was not subject to the split defined in the tracer study.
(5) BOS046 (Gatehouse 2) contains a gate which may also be overtopped in larger storm events; this gate was added to the model after the Q1-2021 system conditions model run per new field information. Meter data at for Boston Gatehouse 2 indicated that the gate was not overtopped during 2022.

Table 2-7. Notable Differences Between Metered and Modeled CSO Discharges, January 1 – December 31, 2022

Location	Meter	Model	Comment
CAM401A	10 discharges 0.47 MG	1 discharge 0.06 MG	• The meter data included six activations with volumes less than 0.01 MG. MWRA and the CSO communities are working together to resolve and further understand observed differences. Possible explanations being evaluated include meter configuration/accuracy, modeled hydrology and hydraulic accuracy, and returning sediment deposition in the downstream system.
BOS009	8 discharges 0.06 MG	5 discharges 0.21 MG	• The meter data included seven activations with volumes less than 0.01 MG.
BOS003	7 discharges 0.27 MG	0 discharges 0 MG	• The model was updated to reflect record drawings for work included in Contract III of the BWSC work in East Boston. This work included closing regulators RE003-2 and RE003-7. In addition, modifications were made to regulator RE003-12. 2 activations (each <0.01 MG) occurred before the new DWF connection at RE003-12 was complete. One of the 5 activations that occurred after the DWF connection was complete had a volume <0.01 MG. MWRA continues to work with BWSC to check that the model is accurately representing constructed field conditions.
BOS070 DBC	6 discharges 1.09 MG (total)	3 discharges 0.17 MG	• The meter data included one activation with a volume less than 0.01 MG.
Union Park Pump Station	0 discharges 0 MG	2 discharges 4.21 MG	• The modeled activations occurred on 10/13 and 12/16. On 10/13 facility storage tanks filled twice but did not discharge and on 12/16 the UP tanks were filled but did not discharge.

3. Updated System Performance Assessment and Comparison with LTCP Levels of Control

3.1 Performance Assessment

This section summarizes the system performance under Typical Year rainfall based on the Q4-2022 system conditions model, representing conditions as of the end of 2022. As set forth in further detail below, with the completion of the Post Construction Monitoring Program and Performance Assessment and additional work completed at certain outfalls MWRA has demonstrated that 72 of the 86 outfalls listed in Exhibit B of the Second Stipulation have achieved or materially achieved LTCP goals as of the end of 2022, which is two more than reported at the end of 2021. MWRA continues to focus on the 14 (formerly 16) outfalls not yet forecasted to meet LTCP goals. Of the remaining 14 outfalls, eight have projects to meet the LTCP goals that are in design or construction and are expected to be completed by 2024. The six outfalls that remain are particularly challenging and no clear alternatives commensurate to the minimal receiving water quality benefits have been identified. Investigations continue for these six challenging outfalls.

Hydraulic modeling has historically served as the basis for evaluating performance of the MWRA's CSO system. Table 3-1 presents a full accounting of the status and Typical Year overflow activity as of Q4-2022 System Conditions for all discharge locations addressed by MWRA's CSO planning efforts and projects since MWRA assumed responsibility for system-wide CSO control in the mid-1980s. Table 3-1 also presents previously-modeled CSO discharge levels for 1992 system conditions for the Typical Year, and the LTCP goals for Typical Year levels of control as defined in the Second Stipulation. In Table 3-1, Q4-2022 System Conditions activations or volumes that are greater than (i.e. do not achieve) the LTCP goals are shaded in grey, and each CSO outfall is color-coded based on status of attainment with the LTCP goals, as follows:

- Dark blue indicates outfalls that achieve the LTCP goals under the Q4-2022 conditions.
- Light blue indicates outfalls that are forecast to achieve the LTCP goals after December 2021.
- No color indicates outfalls that are particularly challenging with no clear plan yet established to achieve the LTCP goals.

Table 3-1. Typical Year Performance: Baseline 1992, Q4-2022 Conditions and LTCP Goals

Outfall currently achieves LTCP activation and volume goals.			Outfall is forecast to achieve LTCP goals after Dec 2021.			
Outfall investigations continue for forecast of LTCP attainment potential.			Model prediction is greater than LTCP value.			
OUTFALL	1992 SYSTEM CONDITIONS (1)		Q4-2022 SYSTEM CONDITIONS		LONG TERM CONTROL PLAN (2)	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
ALEWIFE BROOK						
CAM001	5	0.15	1	0.02	5	0.19
CAM002	11	2.73	0	0.00	4	0.69
MWR003	6	0.67	3	0.61	5	0.98
CAM004	20	8.19	Closed	N/A	Closed	N/A
CAM400	13	0.93	Closed	N/A	Closed	N/A
CAM401A	18	2.12	5	0.66	5	1.61
CAM401B			4	0.50	7	2.15
SOM001A(9)	10	11.93	8	4.47	3	1.67
SOM001	0	0.00	Closed	N/A	Closed	N/A
SOM002	0	0.00	Closed	N/A	N/I(3)	N/I(3)
SOM002A	0	0.00	Closed	N/A	Closed	N/A
SOM003	0	0.00	Closed	N/A	Closed	N/A
SOM004	5	0.09	Closed	N/A	Closed	N/A
TOTAL		**26.81**		**6.26**		**7.29**
UPPER MYSTIC RIVER						
SOM007A/MWR205A(7) (8)	9	7.61	5	4.50	3	3.48
SOM006	0	0.00	Closed	N/A	N/I(3)	N/I(3)
SOM007	3	0.06	Closed	N/A	Closed	N/A
TOTAL		**7.67**		**4.50**		**3.48**
MYSTIC/CHELSEA CONFLUENCE						
MWR205(7) (Somerville-Marginal CSO Facility)	33	120.37	30	100.38	39	60.58
BOS013*	36	4.40	8	0.27	4	0.54
BOS014	20	4.91	0	0	0	0.00
BOS015	76	2.76	Closed	N/A	Closed	N/A
BOS017(7)	49	7.16	6	0.34	1	0.02
CHE002	49	2.51	Closed	N/A	4	0.22
CHE003	39	3.39	0	0.00	3	0.04
CHE004	44	18.11	2	0.08	3	0.32
CHE008(7)	35	22.35	6	1.94	0	0.00
TOTAL		**185.96**		**103.01**		**61.72**
UPPER INNER HARBOR						
BOS009(7)	34	3.60	10	0.73	5	0.59
BOS010	48	11.83	1	0.06	4	0.72
BOS012	41	7.90	0	0.00	5	0.72
BOS019	107	4.48	1	0.07	2	0.58
BOS050	No Data		Closed	N/A	Closed	N/A
BOS052	0	0.00	Closed	N/A	Closed	N/A
BOS057*	33	14.71	2	0.60	1	0.43
BOS058	17	0.29	Closed	N/A	Closed	N/A
BOS060*	64	2.90	2	0.44	0	0.00
MWR203 (Prison Point Facility)*	28	261.85	17	245.01	17	243.00
TOTAL		**307.56**		**246.91**		**246.04**

Table 3-1. Typical Year Performance: Baseline 1992, Q4-2022 Conditions and LTCP Goals

OUTFALL	1992 SYSTEM CONDITIONS (1)		Q4-2022 SYSTEM CONDITIONS		LONG TERM CONTROL PLAN (2)	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
LOWER INNER HARBOR						
BOS003	28	18.09	4	1.15	4	2.87
BOS004	34	3.43	4	0.29	5	1.84
BOS005	4	10.23	Closed	Closed	1	0.01
BOS006	17	1.21	Closed	N/A	4	0.24
BOS007	34	3.93	Closed	N/A	6	1.05
TOTAL		**36.89**		**1.44**		**6.01**
CONSTITUTION BEACH						
MWR207	24	4.00	Closed	N/A	Closed	N/A
TOTAL		4.00		N/A		N/A
FORT POINT CHANNEL						
BOS062(7)	8	4.15	5	1.24	1	0.01
BOS064	14	0.99	0	0.00	0	0.00
BOS065(7)	11	3.08	1	0.50	1	0.06
BOS068	4	0.62	0	0.00	0	0.00
BOS070/DBC(7)	4	281.62	7	4.88	3	2.19
MWR215 (Union Park Facility)			9	22.19	17	71.37
BOS070/RCC			0	0.00	2	0.26
BOS072	21	3.62	Closed	N/A	0	0.00
BOS073	23	4.73	0	0.00	0	0.00
TOTAL		**298.81**		**28.81**		**73.89**
RESERVED CHANNEL						
BOS076	65	65.94	1	0.10	3	0.91
BOS078	41	14.84	0	0.00	3	0.28
BOS079	18	2.10	0	0.00	1	0.04
BOS080	33	6.21	0	0.00	3	0.25
TOTAL		**89.09**		**0.10**		**1.48**
NORTHERN DORCHESTER BAY						
BOS081	13	0.32	0 / 25 year(10)	N/A	0 / 25 year(10)	N/A
BOS082	28	3.75	0 / 25 year(10)	N/A	0 / 25 year(10)	N/A
BOS083	14	1.05	Closed	N/A	0 / 25 year(10)	N/A
BOS084	15	3.22	0 / 25 year(10)	N/A	0 / 25 year(10)	N/A
BOS085	12	1.31	0 / 25 year(10)	N/A	0 / 25 year(10)	N/A
BOS086	80	3.31	0 / 25 year(10)	N/A	0 / 25 year(10)	N/A
BOS087	9	1.27	Closed	N/A	0 / 25 year (10)	N/A
TOTAL		**14.23**		**0.00**		**0.00**
SOUTHERN DORCHESTER BAY						
BOS088	0	0.00	Closed	N/A	Closed	N/A
BOS089 (Fox Pt.)	31	87.11	Closed	N/A	Closed	N/A
BOS090 (Commercial Pt.)	19	10.16	Closed	N/A	Closed	N/A
TOTAL		**97.27**		**0.00**		**0.00**
UPPER CHARLES						
BOS032	4	3.17	Closed	N/A	Closed	N/A
BOS033	7	0.26	Closed	N/A	Closed	N/A
CAM005(9)	6	41.56	8	0.75	3	0.84
CAM007*	1	0.81	2	0.48	1	0.03
CAM009(4)	19	0.19	Closed	N/A	2	0.01
CAM011(4)	1	0.07	Closed	N/A	0	0.00
TOTAL		**46.06**		**1.23**		**0.88**

Table 3-1. Typical Year Performance: Baseline 1992, Q4-2022 Conditions and LTCP Goals

OUTFALL	1992 SYSTEM CONDITIONS (1)		Q4-2022 SYSTEM CONDITIONS		LONG TERM CONTROL PLAN (2)	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
LOWER CHARLES						
BOS028	4	0.02	Closed	N/A	Closed	N/A
BOS042	0	0.00	Closed	N/A	Closed	N/A
BOS049	1	0.01	Closed	N/A	Closed	N/A
CAM017	6	4.72	0	0.00	1	0.45
MWR010	16	0.08	0	0.00	0	0.00
MWR018(9)	2	3.18	2	0.42	0	0.00
MWR019(9)	2	1.32	2	0.16	0	0.00
MWR020(9)	2	0.64	2	0.05	0	0.00
MWR021	2	0.50	Closed	N/A	Closed	N/A
MWR022	2	0.43	Closed	N/A	Closed	N/A
MWR201(9) (Cottage Farm Facility)	18	214.10	2	7.81	2	6.30
MWR023(5)	39	114.60	2	0.09	2	0.13
SOM010	18	3.38	Closed	N/A	Closed	N/A
TOTAL		**342.98**		**8.53**		**6.88**
NEPONSET RIVER						
BOS093	72	1.61	Closed	N/A	Closed	N/A
BOS095	11	5.37	Closed	N/A	Closed	N/A
TOTAL		**6.98**		**0.00**		**0.00**
BACK BAY FENS						
BOS046 – Boston GH1(5)	2	5.25	2	0.26	2	5.38
BOS046 – Boston GH2(6)			0	0.00		
TOTAL		**5.25**		**0.26**		**5.38**
Total Treated		**698**		**375**		**381**
Total Untreated		**759**		**21**		**23**
GRAND TOTAL		**1457**		**396**		**404**

Notes:

* Model predicted activation and volume for Q4-2022 System Conditions has decreased since 1992 levels to a level believed to achieve anticipated water quality improvements. The inability to precisely meet activation and/or volume goals at these locations is considered immaterial.

(1) 1992 System Conditions include completion of Deer Island Fast-Track Improvements, upgrades to headworks, and new Caruso and DeLauri pumping stations. Estimated 1988 Grand Total Typical Year CSO volume (prior to these improvements) was 3,300 million gallons.
(2) From Exhibit B to Second Stipulation of the United States and the Massachusetts Water Resources Authority on Responsibility and Legal Liability for Combined Sewer Overflows, as amended by the Federal District Court on May 7, 2008 (the "Second CSO Stipulation").
(3) N/I: Outfall is not included in Exhibit B to the Second CSO Stipulation.
(4) Tentatively closed pending additional hydraulic evaluation by City of Cambridge.
(5) BOS046 (Gatehouse 1) is primarily a stormwater discharge but may contain CSO if the upstream regulators overflow. The upstream regulators are monitored directly. Gatehouse 1 is normally closed but may be opened for flood mitigation. Flow can discharge at the Gatehouse if either the gate is opened or if water overtops the gate. Based on model tracer studies, when a discharge occurs it is estimated that 25% of the CSO from the upstream regulators discharges at outfall MWR023 (Charles River) and 75% discharges at outfall BOS046 (Back Bay Fens).
(6) BOS046 (Gatehouse 2) contains a gate which may also be overtopped in extreme wet weather; this gate was added to the model after the Q1-2021 system conditions model run per new field information.
(7) See Table 3-3 below for outfalls forecast to attain LTCP goals by 2024.
(8) The SOM007A/MWR205A volume includes a fraction of the flow treated at Somerville Marginal facility plus separate stormwater that enters the Somerville Marginal Conduit (outfall) downstream of the facility. The volume presented is therefore not included in the total treated flow calculated below as the treated CSO fraction of the volume at SOM007A/MWR205A is counted in the volume presented for MWR205.
(9) See Table 3-4 below for site-specific investigations underway where no additional system improvement has yet been recommended to attain LTCP goals.
(10) The outfalls do not discharge in a 25-year storm as defined at the time the LTCP was approved.

As indicated in Table 3-1, of the 46 outfalls that remain active (i.e. are not physically closed or associated with the North Dorchester Bay CSO Storage Tunnel), 32 outfalls meet or materially meet the LTCP goals as of Q4-2022 conditions[8]. As of the 2021 annual report, 16 outfalls were not predicted to meet LTCP goals. As of 2022, two of those 16 outfalls are now meeting LTCP goals (BOS014 and BOS003). Of the remaining 14 outfalls, eight have projects predicted to meet the LTCP goals that are in design or construction and are expected to be completed by 2024. Progress continues to be made to identify alternatives to move the six outfalls that remain closer towards their individual LTCP goals. Additional detail is provided below in Section 3.3. The total treated and untreated CSO volume of 396 MG is below the LTCP goal of 404 MG and as noted above a number of projects are underway that will further reduce the total volume by 2024.

3.1.1 Percent Capture of Combined Sewage

Table 3-2 presents the computed percent capture of combined sewage for the Typical Year for Q4-2022 system conditions. The percent capture was computed by dividing the tributary wet weather volume conveyed to Deer Island and the MWRA's CSO treatment facilities by the total tributary wet weather volume. The total tributary wet weather volume, in turn, was defined as the volume of runoff collected into the combined sewer system, plus sanitary/base flow from the combined sewer areas that occurred for the duration of rain events. Wet weather volume from areas where complete sewer separation has been implemented (such as Dorchester, Constitution Beach, and the former CAM004 area) was not counted, nor was wet weather flow from separate systems outside of the CSO communities of Boston, Cambridge, Somerville and Chelsea. Wet weather volume from partially-separated areas (i.e. areas where active CSOs remain) was counted.

In Table 3-2, the percent capture is presented in terms of the wet weather volume tributary to Deer Island, the wet weather volume tributary to Deer Island, Cottage Farm, Prison Point and Union Park, and the wet weather volume at Deer Island, Cottage Farm, Prison Point, Union Park and Somerville Marginal. Table 3-2 shows that the percent capture at Deer Island is 93.5%, the percent capture with Deer Island, Cottage Farm, Prison Point, and Union Park is 98.0%, and the percent capture at Deer Island, Cottage Farm, Prison Point, Union Park, and Somerville Marginal is 99.7%.

Table 3-2. Percent Capture of Combined Sewage for the Typical Year for Q4-2022 System Conditions

	Typical Year Q4-2022
(A) Total Tributary Wet Weather Volume[(1)] (MG)	6,073
(B) Total volume discharged at untreated CSOs or at CSO Facilities (MG)	396
(C) = (A - B) Total Wet Weather Volume Captured at Deer Island (MG)	5,677
(D) = (C)/(A) Percent Capture at Deer Island	93.5%
(E) Total volume discharged at untreated CSOs or at Somerville Marginal Screening/Disinfection Facility (MG)	122
(F) = (A - E) Total Wet Weather Volume Captured at Deer Island, Cottage Farm, Prison Point and Union Park (MG)	5,951
(G) = (F)/(A) Percent Capture at Deer Island, Cottage Farm, Prison Point and Union Park	98.0%
(H) Total volume discharged at untreated CSOs (MG)	21
(I) = (A - H) Total Wet Weather Volume Captured at Deer Island, Cottage Farm, Prison Point, Union Park and Somerville Marginal (MG)	6,052
(J) = (I)/(A) Percent Capture at Deer Island, Cottage Farm, Prison Point, Union Park and Somerville Marginal	99.7%

Notes:
1. Wet weather volume defined as volume of runoff collected into the combined sewer system, plus sanitary/base flow that occurs for the duration of rain events. Includes wet weather volume from combined or partially-combined areas in Boston, Cambridge, Chelsea and Somerville.

[8] Outfall BOS005 was closed as part of the East Boston Contract 2 Sewer Separation Work on September 6, 2022 but it had been meeting the LTCP goal prior to closure. This outfall is therefore included in the total count of 46 outfalls and the total number of outfalls meeting LTCP goals of 32.

3.2 Outfalls Forecast to Attain LTCP Activation and Volume Goals by December 2024

Table 3-3 presents 10 outfalls that did not meet the LTCP goals as of December 2021 but are forecast to meet the LTCP goals by December 2024. Six of these outfalls were originally presented in Table 2-3 of the December 2021 CSO Report. Table 3-3 has been updated to include outfalls BOS062, BOS065, BOS017 and BOS070/DBC, which are now forecast to meet LTCP goals by December 2024. Table 3-3 (below) presents the same information from Table 2-3 of the *December 2021 CSO Report* with updated information provided in bold text. For each outfall, Table 3-3 presents a description and updated status of the system improvement(s) intended to result in attainment of the LTCP goals by 2024, as well as the entity implementing the work and the tentative schedule for completion. As noted above the construction projects at the regulators tributary to BOS003 and BOS014 are now complete, and these locations are predicted to meet LTCP goals as of the end of 2022, however, the Contract 3 sewer separation project is still in progress and will be completed by the end of 2023.

Table 3-3. Outfalls Forecast to Attain LTCP Goals by 2024

OUTFALL	LOCATION	SYSTEM IMPROVEMENT(S)*	TO BE IMPLEMENTED BY	TENTATIVE SCHEDULED COMPLETION
MWR205	Somerville Marginal CSO Facility	Construct new connection from the facility influent conduit to the interceptor and replace tide gate. **Project is currently in the design phase. The project is being coordinated with several other MassDOT projects in the area. The project is scheduled to bid in fall 2023, completed in Fall 2024.**	MWRA	2024
SOM007A/ MWR205A				
BOS003	East Boston	Complete BWSC Sewer Separation Contract 3, including upgrade of interceptor connection at regulator RE003-12. **Construction began in August 2021 and is ongoing. As of March 1, 2023, separation is complete for approximately 92% of the area to be separated. Regulators RE003-2 and RE003-7 were closed in May of 2022. The reconstruction of the restricted interceptor connection at regulator RE003-12 was completed in May of 2022. Remaining separation work is expected to be completed in Winter of 2023.**	BWSC	2023
BOS009				
BOS014		Construct new interceptor connection as part of BWSC Sewer Separation Contract 3. **New connection has been completed and was brought online January 24, 2022.**		
CHE008	Chelsea Creek	Replace/upgrade interceptor connection. **Final design is complete and the construction contract was awarded in December 2022. Construction is scheduled to begin in April 2023 and be completed in Summer of 2023.**	MWRA	2023
BOS017	Mystic/Chelsea Confluence	**Modify existing siphon structure. Design is in progress. Construction is estimated to be completed in 2024.**	BWSC	2024
BOS062	Fort Point Channel	**Modify existing regulator structure. Design is in progress. Construction is estimated to be completed in 2024.**	BWSC	2024
BOS065		**Modify existing regulator structure. Design is in progress. Construction is estimated to be completed in 2024.**	BWSC	2024
BOS070		**Construct a new relief pipe parallel to the BMI. Design is in progress. Construction is estimated to be completed in 2024.**	BWSC	2024

***Bold** text indicates update to the table since it was originally presented in the December 2021 CSO Report.

3.3 Outfalls Currently Not Forecast to Attain LTCP Activation and/or Volume Goal

Six locations remain where Typical Year CSO activation and/or volume exceed the LTCP goals and no additional system improvement has yet been recommended. MWRA has continued to track CSO performance at these locations and assess the causes of higher overflow activity. In Table 2-4 of the December 2021 CSO Report, MWRA identified candidate projects or system adjustments that may further mitigate CSO discharges to bring activations and volumes to, or closer to, the LTCP goals. In Chapter 4 of that report, additional information was provided regarding the alternatives being evaluated for these outfalls. The following section presents updates for the remaining six outfalls that present significant challenges and for which evaluations will continue.

3.3.1 SOM001A

SOM001A is located on the Alewife Brook Conduit in the Alewife Brook System. This outfall is not meeting the LTCP goals for activation frequency or volume as shown in Table 3-4. A schematic of the Alewife Brook system including SOM001A is presented in Table 3-4.

Table 3-4. SOM001A Q4-2022 Conditions and LTCP Goal

OUTFALL	TYPICAL YEAR			
	Q4-2022 SYSTEM CONDITIONS MODEL		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
ALEWIFE BROOK				
SOM001A	8	4.47	3	1.67

Investigations into alternatives that could reduce the activation frequency and volume at outfall SOM001A have included:

- raising the weir in the SOM001A regulator;
- increasing the capacity of flow conveyance between the SOM001A regulator and the interceptor system;
- diverting upstream flows away from the Tannery Brook Drain, towards regulator SOM009 and the Prison Point system; and
- utilizing in-system storage within the Tannery Brook Drain to attenuate peak flows to the regulator.
- Managing already separated stormwater tributary to the Tannery Brook Drain.

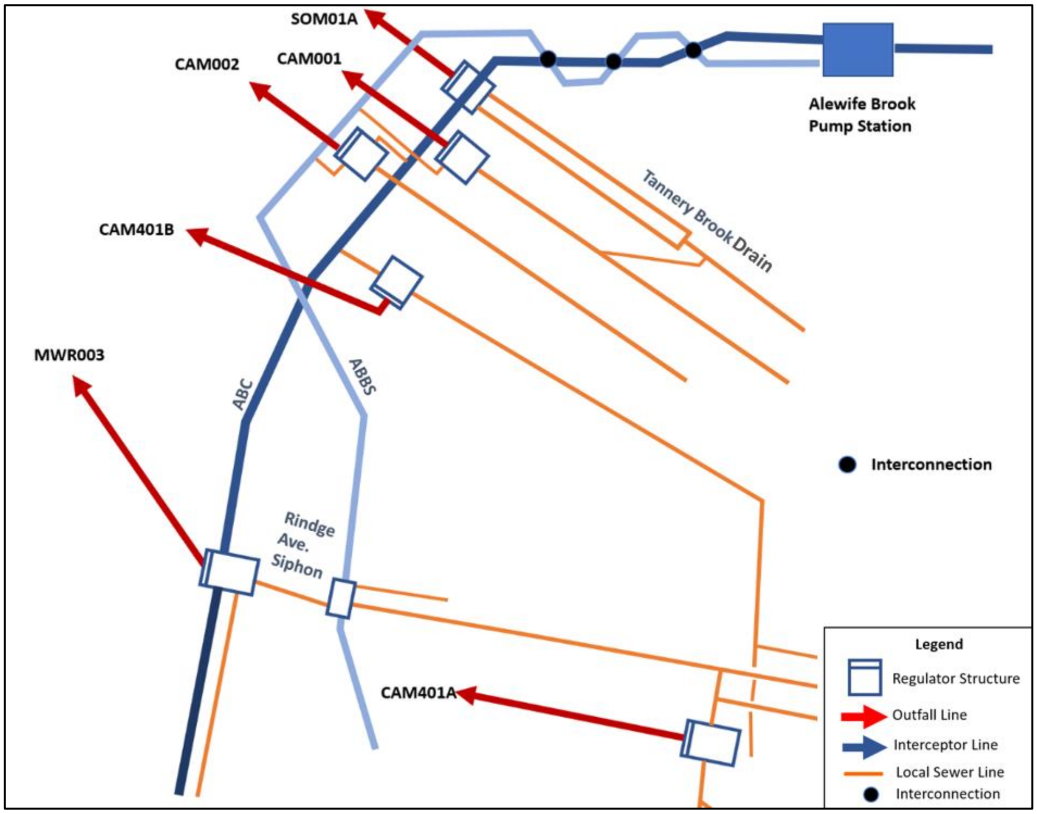

Figure 3-1. Schematic of Alewife Sub-System

After evaluating many different variations of the alternatives listed above, an alternative was identified that results in a prediction that SOM001A would meet the LTCP goals at in the Typical Year. This alternative included:

- raising the weir in the SOM001A regulator 3 inches;
- increasing the size of the orifice connection to the Alewife Brook Conduit (ABC) from 32x32-inch to 56x32-inch with a modulating gate to restrict the opening during large storms; and
- relining the ABC and Alewife Brook Branch Sewer (ABBS) from approximately the location of SOM001A to the Alewife Brook Pump Station to slightly increase the conveyance capacity.

Model results indicate that while the alternative identified above allows SOM001A to achieve LTCP compliance, it would increase the volume at outfall MWR003, located upstream along the ABC, by 0.4 MG. This increase at MWR003 would push that outfall out of compliance with its LTCP goal of 0.98 MG by 0.11 MG (the activation frequency at MWR003 would still be in compliance). Without the modulating gate at the dry weather flow (DWF) orifice, adverse hydraulic grade line impacts during the 5-year, 24-hour storm event were predicted in a low-lying area along the ABC downstream of the regulator. The intent would be that the gate would be closed during storms larger than the Typical Year storms to limit the DWF connection to its current capacity.

MWRA is currently working with the City of Somerville to evaluate whether flood mitigation efforts that the city is currently investigating will reduce and/or attenuate the stormwater tributary to SOM001A and mitigate the adverse impacts noted for the alternative described above in the 5-year storm and at MWR003 for the Typical Year. The City of Somerville is also working to evaluate whether these potential flood mitigation efforts may have an overall benefit on CSO control. MWRA and the City of Somerville continue to work together to identify and investigate alternatives as well as the appropriate combination of flood mitigation and system modifications for CSO control that will meet the dual objectives, considering overall cost, constructability, and overall receiving water benefits.

The next step will be to prepare preliminary estimates of construction costs for this alternative.

3.3.2 Cottage Farm

The Cottage Farm CSO Facility is a CSO treatment facility that detains and treats CSO before it is discharged to the Charles River. The facility provides relief to the North Charles Metropolitan Sewer/Relief Sewer and to the South Charles Relief Sewer. This outfall is not meeting the LTCP goal for annual volume as shown in Table 3-5. A schematic of the interceptor system in the vicinity of the Cottage Farm Facility is presented in Figure 3-2.

Table 3-5. Cottage Farm Q4-2022 Conditions and LTCP Goal

OUTFALL	TYPICAL YEAR			
	Q4-2022 SYSTEM CONDITIONS MODEL		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
CHARLES RIVER				
MWR201 (Cottage Farm)	2	7.81	2	6.30

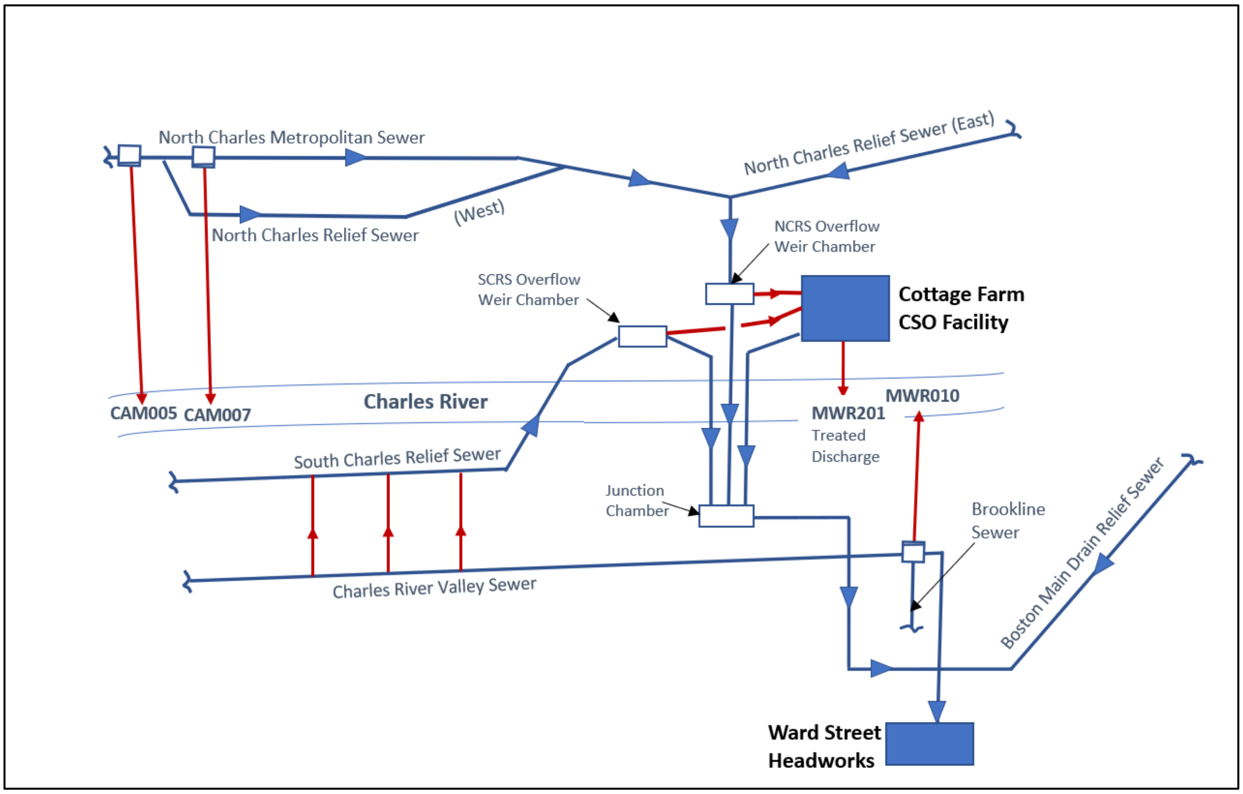

Figure 3-2. Schematic of the Charles River/Cottage Farm Sub-System

Investigations into alternatives that could reduce the volume at the Cottage Farm CSO Facility have included:

- upstream sewer separation and targeted groundwater infiltration removal;
- facility operation optimization; and
- CSO storage

Separation of the area tributary to outfall CAM011 was predicted to reduce the annual discharge volume at Cottage Farm, but not quite to the level of the LTCP goal. Removing a portion of the groundwater inflow from the upstream South Charles Relief Sewer system was predicted by the model to provide the incremental volume reduction needed for Cottage Farm to meet the LTCP volume goal in conjunction with the CAM011 separation. However, the specific activities needed to achieve the additional groundwater inflow removal and the actual efficacy of those activities are unknown. Facility optimization was evaluated, but no further optimization measures were identified.

Layouts and costs are currently being developed for potential additional storage needed at Cottage Farm to reduce the Typical Year discharge volume to the LTCP goal of 6.3 MG.

3.3.3 CAM005

CAM005 is located on Mount Auburn Street at Longfellow Road at the entrance to Mount Auburn Hospital and discharges to the Charles River. This outfall is not meeting the LTCP goal for activation frequency as shown in Table 3-6. CAM005 is shown in the schematic for Cottage Farm in Figure 3-2. above.

Table 3-6. CAM005 Q4-2022 Conditions and LTCP Goal

OUTFALL	Q4-2022 SYSTEM CONDITIONS MODEL		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
CHARLES RIVER				
CAM005	8	0.75	3	0.84

Investigations into alternatives that could reduce the activation frequency at outfall CAM005 continue to be evaluated. The City of Cambridge is currently removing the sediment from the CAM005 outfall pipe. Investigations into alternatives that could reduce the activation frequency at CAM005 (assuming a cleaned outfall) include :

- sewer separation;
- raising and lengthening the CAM005 weir (see the Task 8.2 – 8.3: Alewife Brook and Charles River System Optimization Evaluations issued on December 28, 2022); and
- implementing upstream green infrastructure;

Model results indicated that raising and lengthening the CAM005 weir brings the outfall closer to meeting the LTCP goal for activations. However, additional measures will be required to achieve the LTCP goal. MWRA is continuing to evaluate green infrastructure and sewer separation in combination with raising and lengthening the CAM005 weir.

Following the selection of an alternative to reach the LTCP goal at CAM005, a preliminary construction cost will be developed. Currently, additional information is being gathered on the regulator structure by Cambridge through a laser scan. Then, a construction feasibility analysis will be undertaken to identify the optimal configuration and materials of construction for the raised and lengthened weir.

3.3.4 MWR018/019/020

The regulator structures associated with outfalls MWR018, MWR019 and MWR020, which all discharge to the Charles River, provide relief to the Boston Marginal Conduit along the Esplanade in Boston. . These three outfalls are not meeting the LTCP goals for activation frequency or volume as shown in Table 3-7. A schematic of the system associated with outfalls MWR018, MWR019 and MWR020 is presented in Figure 3-3.

Table 3-7. MWR018/019/020 Q4-2022 Conditions and LTCP Goal

OUTFALL	Q4-2022 SYSTEM CONDITIONS MODEL		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
MWR018	2	0.42	0	0.00
MWR019	2	0.16	0	0.00
MWR020	2	0.05	0	0.00

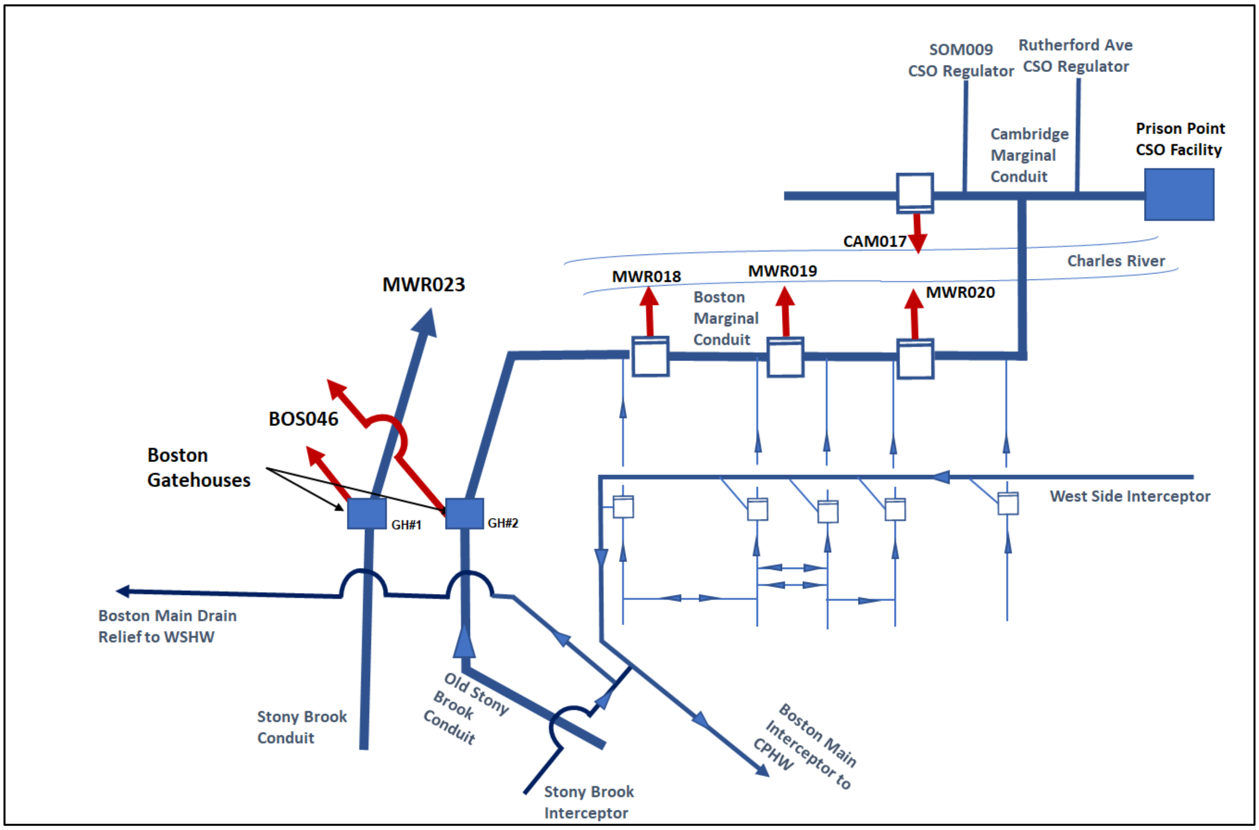

Figure 3-3. Schematic of Charles River/Prison Point Sub-System

Investigations into alternatives that could reduce the activation frequency and volume at outfalls MWR018/019/020 have included:

- raising the weirs;
- green infrastructure/subsurface stormwater infiltration;

- sewer separation;
- separate stormwater removal from the collection system; and
- CSO storage

Initial model assessments indicated that raising weirs at MWR018/019/020 would adversely affect the hydraulic grade line with minimal reduction to CSO discharges to the Charles River. Conceptual storage layouts were developed, but the storage alternatives are likely to be infeasible to implement due to siting issues along the Esplanade. In order to evaluate sewer separation, stormwater removal, and green infrastructure/subsurface stormwater infiltration alternatives, it was necessary to increase the level of detail in the model in the areas upstream of the BMC. MWRA's model was accordingly updated to include geo-referenced subcatchments in the Back Bay and trunk sewers in the OSBC system. The subcatchments are being further refined to isolate areas and street segments served by separate storm drains that tie back into the combined system. These areas will be targeted for stormwater relocation and green infrastructure/subsurface stormwater infiltration alternatives. Refer to Section 2 Hydraulic Model Updates for further detail.

Currently, alternatives consisting of a combination of sewer separation, stormwater removal, and green infrastructure/subsurface stormwater infiltration are being evaluated. Following the selection of an alternative to reach the LTCP goal at MWR018/019/020, preliminary layouts and preliminary estimates of construction costs will be developed.

3.4 Summary

As noted in the introduction, the Court extended the time until December 2024 for the MWRA to complete identified projects and further evaluate alternatives to further reduce CSOs at the sixteen outfalls that did not meet the LTCP goals by December 31, 2021. As described above, of the 46 outfalls that remain active (i.e., are not physically closed or associated with the North Dorchester Bay CSO Storage Tunnel), 32 outfalls meet or materially meet the LTCP goals as of Q4-2022 conditions. Of the remaining 14 outfalls, eight have projects in design or construction to meet the LTCP goals. These projects are expected to be completed by 2024. For the six remaining challenging outfalls, no clear alternatives commensurate to the minimal receiving water quality benefits have been identified. Investigations continue for these six outfalls. It is also noted that the total treated and untreated CSO volume of 396 MG is below the LTCP goal of 404 MG and as noted above a number of projects are underway that will further reduce the total volume by 2024. In addition, the CSO communities continue to pursue work that will also reduce CSO discharges.

Appendix A Rainfall Processing and Analyses January 1, 2022 – December 31, 2022

A.1 Rainfall Analyses

This section presents the rainfall data measured from 20 gauges within the MWRA wastewater service area during the period of January 1, 2022 through December 31, 2022. It also describes the analysis of the rainfall data used to characterize the return period of each storm event and a comparison of measured rainfall for the 2022 period to the rainfall included in the Typical Year. As described in the *CSO Annual Report: Discharge Estimates and Rainfall Analyses report for Calendar Year 2021*, the MWRA's rainfall recurrence interval calculation methodology was updated from *Technical Paper 40* (TP-40) to *Atlas-14*.

Values for Atlas 14 for Boston were extracted from NOAA's data server on April 12, 2022. The Atlas 14 partial duration curves were used to assign the recurrence intervals. The smallest storm the partial duration curves addresses is the 1-year storm, so the partial duration intensity-duration-frequency (IDF) curves for the 3-month and 6-month frequencies were extrapolated. All of the storm recurrence intervals identified in the text and sections below and in Appendix A are based on the 2019 edition of Atlas 14 referenced above.

A.1.1 Rainfall Data Collection and Processing

Rainfall was quantified for this analysis using 15-minute rainfall data collected at rain gauges distributed over the MWRA system. The rain gauges are listed in Table A-1 and the locations are shown in Figure A-1.

Table A-1. Rain Gauges

Gauge Code	Name	Owner	Gauge Code	Name	Owner
BO-DI-1	Ward St.	MWRA	BWSC006	Dorchester -Talbot	BWSC
BO-DI-2	Columbus Park	MWRA	Rox	Roxbury	BWSC
BWSC001	Union Park Pump Sta.	BWSC	CH-BO-1	Chelsea Ck.	MWRA
BWSC002	Roslindale	BWSC	FRESH_POND	USGS Fresh Pond	USGS
BWSC003	Dorchester Adams St.	BWSC	HF-1C	Hanscom AFB	MWRA
BWSC004	Allston	BWSC	RG-WF-1	Hayes Pump Sta.	MWRA
BWSC007	Charlestown	BWSC	SOM	Somerville Remote	MWRA
EB	East Boston	BWSC	Lex	Lexington Farm	Project (1)
BWSC008	Longwood Medical	BWSC	SP	Spot Pond	Project (1)
BWSC005	Hyde Park	BWSC	WF	Waltham Farm	Project (1)

(1) Project gauges were removed as of July 1, 2020. Project gauge data has been replaced with the nearest rain gauge, following the QA/QC procedures and closest rain gauges substitution table.

Quality assurance and quality control were provided by reviewing the data based on geographic location, comparing total rainfall depth and rainfall intensity values by month and for individual storm events. The shape of rainfall hyetographs was reviewed for irregularities. Rain gauges with significantly higher or lower total rainfall depths than other gauges, and unusual hyetograph shapes, were flagged as suspect and further reviewed.

Suspect or missing rain gauge data were replaced with data from the rain gauge in closest linear proximity. If the closest gauge also had suspect data, the second closest rain gauge was used. Table A-2 identifies the two closest rain gauges to each of the rain gauges. Replacement of suspect data was recorded in Table A-3.

Additional information on the methodologies for rainfall data collection and processing can be found in Semiannual Reports 1 and 2.

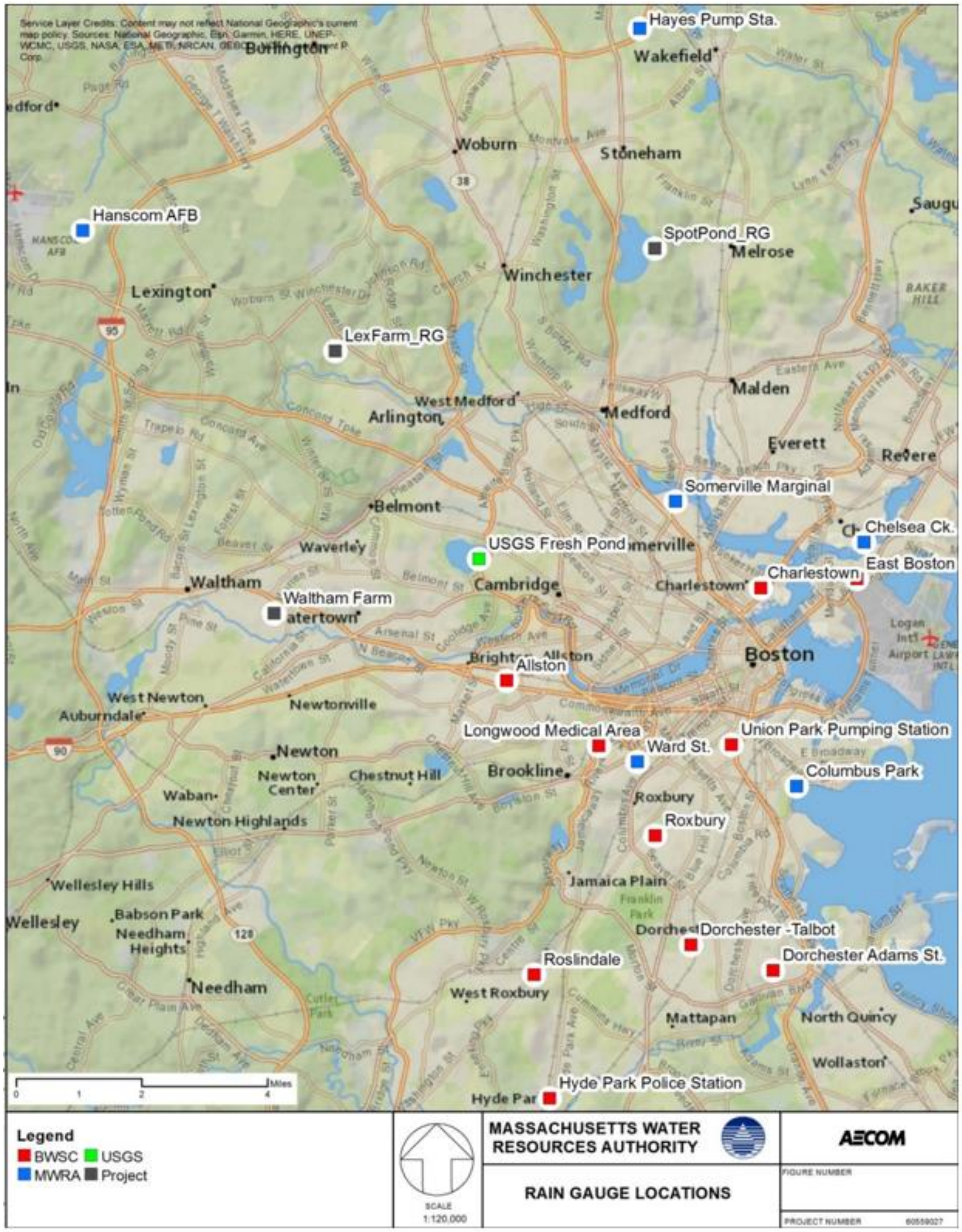

Figure A-1. Rain Gauge Location Plan

Table A-2. Closest Rain Gauges for Data Substitution

Origin Gauge		Closest Gauge		Second Closest Gauge	
Gauge Name	**Gauge Code**	**Gauge Code**	**Distance (mi)**	**Gauge Code**	**Distance (mi)**
Ward Street	BO-DI-1	BWSC008	0.66	Rox	1.23
Columbus Park	BO-DI-2	BWSC001	1.24	Rox	2.39
Union Park Pumping Station	BWSC001	BO-DI-2	1.24	BO-DI-1	1.52
Roslindale	BWSC002	BWSC005	2.02	BWSC006	2.54
Dorchester Adams St.	BWSC003	BWSC006	1.37	Rox	2.88
Allston	BWSC004	BWSC008	1.81	FRESH_POND	2.03
Hyde Park Police Station	BWSC005	BWSC002	2.02	BWSC006	3.36
Dorchester -Talbot	BWSC006	BWSC003	1.37	Rox	1.86
Charlestown	BWSC007	EB	1.53	CH-BO-1	1.80
Longwood Medical Area	BWSC008	BO-DI-1	0.67	Roxbury	1.71
Chelsea Creek	CH-BO-1	EB	0.60	BWSC007	1.80
East Boston	EB	CH-BO-1	0.60	BWSC007	1.53
USGS Fresh Pond	FRESH_POND	BWSC004	2.21	SOM	3.26
Hanscom AFB	HF-1C	Lex	4.47	WF	6.92
Lexington Farm	Lex	FRESH_POND	4.08	WF	4.37
Hayes Pump Sta.	RG-WF-1	SP	3.58	Lex	7.13
Roxbury	Rox	BO-DI-1	1.23	BWSC008	1.71
Somerville	SOM	BWSC007	1.95	CH-BO-1	3.07
Spot Pond	SP	SOM	4.12	Lex	5.34
Waltham Farm	WF	FRESH_POND	3.37	BWSC004	3.86

Table A-3. Summary of Rainfall Data Replacement, January 2022-December 2022

Rain Gauge	Replacement Data Start Time	Replacement Data End Time	Replacement Rain Gauge
Union Park (BWSC001)	1/1/2022 00:00	10/1/2022 19:30	Columbus Park (BO-DI-2)
Spot Pond (SP)	1/1/2022 00:00	1/1/2023 23:45	Somerville (SOM)
Longwood (BWSC008)	1/1/2022 00:00	10/1/2022 19:30	Ward Street (BO-DI-1)
Charlestown (BWSC007)	1/1/2022 00:00	10/1/2022 19:30	East Boston (EB)
Dorchester-Adams (BWSC003)	1/1/2022 00:00	10/1/2022 19:30	Dorchester-Talbot (BWSC006)
Lexington Farm (Lex)	1/1/2022 00:00	1/1/2023 23:45	USGS Fresh Pond (FRESH_POND)
Roxbury (Rox)	1/1/2022 00:00	10/1/2022 19:30	Ward Street (BO-DI-1)
Waltham Farm (WF)	1/1/2022 00:00	1/1/2023 23:45	USGS Fresh Pond (FRESH_POND)
USGS Fresh Pond (FRESH_POND)	6/13/2022 00:30	6/14/2022 16:45	Allston (BWSC004)
Hanscom AFB (HF-1C)	1/1/2022 00:00	1/1/2023 23:45	USGS Fresh Pond (FRESH_POND)
Chelsea Creek (CH-BO-1)	2/3/2022 15:15	2/4/2022 8:30	East Boston (EB)
	2/7/2022 10:15	2/18/2022 8:00	East Boston (EB)
	6/9/2022 5:45	6/9/2022 8:30	East Boston (EB)
	6/17/2022 00:00	9/14/2022 23:45	East Boston (EB)
Somerville (SOM)	1/17/2022 2:00	1/17/2022 11:00	Charlestown (BWSC007)
	10/24/2022 10:30	10/26/2022 9:15	Charlestown (BWSC007)

A.1.2 Monitored Storms and Comparison with Typical Year

For the period of January 1, 2022 to December 31, 2022, the rainfall data at each rain gauge were analyzed and summarized, providing the date and time, duration, volume, average intensity, peak 1-hour, 24-hour, and 48-hour intensities and storm recurrence intervals for each storm. The storm recurrence intervals were assigned values of <3 months, 3 months, 3-6 months, 6 months, 1 year, 1-2 year, or the nearest year for recurrence intervals greater than 2 year, based on comparison to the IDF values from Atlas 14. Table A-4 presents the summary of storm events for Ward Street Headworks for the period of January 1, 2022 to December 31, 2022. These data show that 94 storm events occurred in the year long period at the Ward Street Headworks rain gauge (BO-DI-1). The majority of events had less than 3-month recurrence intervals at 1-hour or 24-hour durations.

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2022 to December 31, 2022

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr	Peak 48-hr Intensity (in/hr)	Storm Recurrence Interval (1)		
								1-hr	24-hr	48-hr
1	1/1/22 11:00	30.5	0.38	0.01	0.09	0.02	0.01	<3m	<3m	<3m
2	1/5/22 13:00	5.5	0.07	0.01	0.03	0.00	0.00	<3m	<3m	N/A
3	1/7/22 4:00	14.75	0.45	0.03	0.07	0.02	0.01	<3m	<3m	N/A
4	1/9/22 10:00	1.25	0.07	0.06	0.06	0.00	0.00	<3m	<3m	N/A
5	1/17/22 2:15	12.25	1.02	0.08	0.23	0.04	0.02	<3m	3m	N/A
6	1/20/22 5:00	5	0.15	0.03	0.06	0.01	0.00	<3m	<3m	N/A
7	1/25/22 9:30	0.75	0.06	0.08	0.06	0.00	0.00	<3m	<3m	N/A
8	1/30/22 9:45	4.5	0.08	0.02	0.03	0.00	0.00	<3m	<3m	N/A
9	1/31/22 11:45	3.75	0.11	0.03	0.04	0.00	0.00	<3m	<3m	N/A
10	2/2/22 9:45	1.5	0.12	0.08	0.09	0.00	0.00	<3m	<3m	N/A
11	2/3/22 14:30	19.75	1.15	0.06	0.27	0.05	0.02	<3m	3m	N/A
12	2/5/22 14:00	1	0.04	0.04	0.04	0.00	0.00	<3m	<3m	N/A
13	2/6/22 10:15	3.75	0.12	0.03	0.06	0.00	0.00	<3m	<3m	N/A
14	2/7/22 10:30	22.5	1.16	0.05	0.20	0.05	0.02	<3m	3m	N/A
15	2/16/22 12:30	3	0.21	0.07	0.09	0.01	0.00	<3m	<3m	N/A
16	2/17/22 23:30	9.75	0.47	0.05	0.11	0.02	0.01	<3m	<3m	N/A
17	2/22/22 14:45	8.75	0.52	0.06	0.11	0.02	0.01	<3m	<3m	N/A
18	2/25/22 13:45	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
19	2/26/22 14:00	2.75	0.23	0.08	0.15	0.01	0.00	<3m	<3m	N/A
20	2/27/22 11:00	8	0.22	0.03	0.05	0.01	0.00	<3m	<3m	N/A
21	2/28/22 12:15	1	0.02	0.02	0.02	0.00	0.00	<3m	<3m	N/A
22	3/1/22 12:45	12	0.23	0.02	0.07	0.01	0.00	<3m	<3m	N/A
23	3/3/22 2:45	1.75	0.18	0.10	0.13	0.01	0.00	<3m	<3m	N/A

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2022 to December 31, 2022

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr	Peak 48-hr Intensity (in/hr)	Storm Recurrence Interval (1)		
								1-hr	24-hr	48-hr
24	3/7/22 17:45	5.25	0.42	0.08	0.39	0.02	0.01	3m	<3m	N/A
25	3/9/22 15:30	6.5	0.25	0.04	0.07	0.01	0.01	<3m	<3m	N/A
26	3/12/22 2:15	15.25	0.48	0.03	0.29	0.02	0.01	<3m	<3m	N/A
27	3/15/22 23:15	10.75	0.04	0.00	0.03	0.00	0.00	<3m	<3m	N/A
28	3/17/22 13:30	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
29	3/19/22 9:15	16.25	0.18	0.01	0.07	0.01	0.00	<3m	<3m	N/A
30	3/24/22 2:15	25	1.23	0.05	0.24	0.05	0.03	<3m	3m	3m
31	3/26/22 15:45	3.75	0.20	0.05	0.11	0.01	0.00	<3m	<3m	N/A
32	3/31/22 22:15	10.25	0.53	0.05	0.22	0.02	0.01	<3m	<3m	N/A
33	4/6/22 8:15	4	0.12	0.03	0.05	0.00	0.00	<3m	<3m	N/A
34	4/7/22 22:00	9.5	0.37	0.04	0.17	0.02	0.01	<3m	<3m	N/A
35	4/9/22 9:30	7	0.10	0.01	0.05	0.00	0.00	<3m	<3m	N/A
36	4/12/22 10:30	0.5	0.03	0.06	0.03	0.00	0.00	<3m	<3m	N/A
37	4/14/22 19:45	3.5	0.24	0.07	0.16	0.01	0.00	<3m	<3m	N/A
38	4/16/22 19:15	5	0.48	0.10	0.16	0.02	0.01	<3m	<3m	N/A
39	4/19/22 1:15	4.75	1.07	0.23	0.39	0.04	0.02	3m	3m	N/A
40	4/26/22 16:45	9.25	0.28	0.03	0.06	0.01	0.01	<3m	<3m	N/A
41	5/2/22 16:30	11	0.23	0.02	0.09	0.01	0.00	<3m	<3m	N/A
42	5/4/22 8:15	8	0.12	0.01	0.07	0.00	0.00	<3m	<3m	N/A
43	5/6/22 12:00	0.25	0.12	0.48	0.12	0.00	0.00	<3m	<3m	N/A
44	5/15/22 1:15	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
45	5/16/22 20:00	1.25	0.14	0.11	0.13	0.01	0.00	<3m	<3m	N/A
46	5/20/22 9:30	0.25	0.11	0.44	0.11	0.00	0.00	<3m	<3m	N/A

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2022 to December 31, 2022

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr	Peak 48-hr Intensity (in/hr)	Storm Recurrence Interval [(1)]		
								1-hr	24-hr	48-hr
47	5/21/22 1:15	5	0.04	0.01	0.02	0.00	0.00	<3m	<3m	N/A
48	5/25/22 12:15	0.25	0.12	0.48	0.12	0.00	0.00	<3m	<3m	N/A
49	5/28/22 1:45	14.5	0.61	0.04	0.27	0.03	0.01	<3m	<3m	N/A
50	6/1/22 13:30	1.75	0.20	0.11	0.17	0.01	0.00	<3m	<3m	N/A
51	6/2/22 5:45	0.5	0.02	0.04	0.02	0.00	0.00	<3m	<3m	N/A
52	6/8/22 0:15	10.5	0.27	0.03	0.16	0.01	0.01	<3m	<3m	N/A
53	6/9/22 5:30	3.25	0.70	0.22	0.32	0.03	0.01	3m	<3m	N/A
54	6/13/22 2:45	2.75	0.09	0.03	0.06	0.00	0.00	<3m	<3m	N/A
55	6/19/22 1:15	5.5	0.24	0.04	0.10	0.01	0.00	<3m	<3m	N/A
56	6/23/22 21:30	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
57	6/27/22 10:30	8.75	0.72	0.08	0.22	0.03	0.01	<3m	<3m	N/A
58	7/2/22 3:15	1.5	0.13	0.09	0.10	0.01	0.00	<3m	<3m	N/A
59	7/5/22 21:15	3.5	0.06	0.02	0.03	0.00	0.00	<3m	<3m	N/A
60	7/14/22 0:45	2.75	0.31	0.11	0.23	0.01	0.01	<3m	<3m	N/A
61	7/18/22 15:00	9.5	0.22	0.02	0.17	0.01	0.00	<3m	<3m	N/A
62	7/25/22 21:45	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
63	7/28/22 20:45	1.25	0.03	0.02	0.02	0.00	0.00	<3m	<3m	N/A
64	8/1/22 4:15	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
65	8/5/22 15:15	0.75	0.44	0.59	0.44	0.02	0.01	3m-6m	<3m	N/A
66	8/7/22 19:30	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
67	8/9/22 13:30	1.25	0.13	0.10	0.12	0.01	0.00	<3m	<3m	N/A
68	8/22/22 10:45	8.75	0.91	0.10	0.58	0.04	0.02	6m	3m	N/A
69	8/26/22 15:15	2	0.75	0.37	0.71	0.03	0.02	6m-1y	<3m	N/A

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2022 to December 31, 2022

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr	Peak 48-hr Intensity (in/hr)	Storm Recurrence Interval [(1)]		
								1-hr	24-hr	48-hr
70	8/31/22 4:30	0.75	0.06	0.08	0.06	0.00	0.00	<3m	<3m	N/A
71	9/5/22 10:30	32.25	1.32	0.04	0.14	0.05	0.03	<3m	3m	3m
72	9/13/22 9:00	1.25	0.05	0.04	0.04	0.00	0.00	<3m	<3m	N/A
73	9/18/22 20:30	1	0.11	0.11	0.11	0.00	0.00	<3m	<3m	N/A
74	9/19/22 19:30	2	0.40	0.20	0.37	0.02	0.01	3m	<3m	N/A
75	9/26/22 4:00	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
76	9/26/22 19:00	7.5	0.29	0.04	0.25	0.01	0.01	<3m	<3m	N/A
77	10/4/22 16:30	40.75	1.14	0.03	0.18	0.04	0.02	<3m	3m	3m
78	10/13/22 17:30	16.25	1.83	0.11	0.42	0.08	0.04	3m	6m	N/A
79	10/17/22 13:45	15.25	0.38	0.02	0.12	0.02	0.01	<3m	<3m	N/A
80	10/19/22 10:00	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
81	10/23/22 15:45	31	0.25	0.01	0.12	0.01	0.01	<3m	<3m	<3m
82	10/25/22 13:15	26	0.67	0.03	0.21	0.03	0.01	<3m	<3m	<3m
83	11/1/22 5:00	0.75	0.04	0.05	0.04	0.00	0.00	<3m	<3m	N/A
84	11/11/22 19:30	13.75	0.54	0.04	0.31	0.02	0.01	3m	<3m	N/A
85	11/13/22 6:15	7.5	0.19	0.03	0.09	0.01	0.00	<3m	<3m	N/A
86	11/15/22 23:45	13.25	0.99	0.07	0.23	0.04	0.02	<3m	3m	N/A
87	11/27/22 15:30	7.25	0.61	0.08	0.26	0.03	0.01	<3m	<3m	N/A
88	11/30/22 14:45	7	0.86	0.12	0.36	0.04	0.02	3m	<3m	N/A
89	12/3/22 11:45	8.25	0.21	0.03	0.11	0.01	0.00	<3m	<3m	N/A
90	12/6/22 18:45	22	0.93	0.04	0.23	0.04	0.02	<3m	3m	N/A
91	12/11/22 19:45	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
92	12/15/22 12:00	48	1.93	0.04	0.19	0.07	0.04	<3m	6m	6m

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2022 to December 31, 2022

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr	Peak 48-hr Intensity (in/hr)	Storm Recurrence Interval [(1)]		
								1-hr	24-hr	48-hr
93	12/22/22 18:30	21.75	1.84	0.08	0.31	0.08	0.04	3m	6m	N/A
94	12/31/22 8:45	17	0.41	0.02	0.10	0.02	0.01	<3m	<3m	N/A

(1) Recurrence intervals given in ranges of less than 3 months (<3m), 3-months, (3m), 3-6 months (3-6m), 6 months (6m), 6 months-1year (6m-1y), 1 year (1y), 1 to 2 year (1y-2y) or the nearest year for recurrence intervals >2 year, based on Atlas 14.

The characteristics of the rain events that occurred in the January 1 through December 31, 2022 monitoring period were compared to rainfall characteristics from the Typical Year to help interpret the measured CSO activations and volumes in comparison to Typical Year performance.

The total rainfall and number of storms at each rain gauge were identified for the period of January 1, 2022 through December 31, 2022, and the number of storms by depth. These values were then compared to the values from the Typical Year. Table A-5 presents this comparison. As indicated in Table A-5, during 2022 the rain gauges measured an average total rainfall volume of 33.63 inches, compared with 46.8 inches in the Typical Year, a 13.17-inch decrease in precipitation compared to the Typical Year. While the average number of storms in 2022 matches the Typical Year with 93 events, the number of storms within the depth categories in Table A-5 skewed towards the smaller storms compared to the Typical Year. The 2022 period had a nine more storms with depths less than 0.5 inches and nine fewer storms with depths greater than 0.5 inches.

Storms with greater than 2 inches of total rainfall at the Ward Street, Columbus Park, Chelsea Creek Headworks, and USGS Fresh Pond rain gauges were identified and compared to storms with greater than 2 inches of total rainfall in the full Typical Year (Table A-6). Experience has shown that large storms often account for a disproportionate volume of CSO. Also, within the Typical Year, the storms with greater than 2 inches of rainfall were separated from each other by a period of at least one month.

Table A-5. Frequency of Events within Selected Ranges of Total Rainfall for January 1, 2022 to December 31, 2022

Rain Gauge	Total Rainfall (inches)	Total Number of Storms	Number of Storms by Depth				
			Depth	Depth	Depth	Depth	Depth
			< 0.25	0.25 to 0.5	0.5 to 1.0	1.0 to 2.0	≥2.0
			inches	inches	inches	inches	inches
Typical Year	46.80	93	49	14	16	8	6
January - December 2022 Metering Data							
Average of Rain Gauges							
Average	33.63	93	53	19	13	7	1
MWRA Rain Gauges							
Ward Street	34.94	94	56	15	13	10	0
Columbus Park	34.89	100	59	19	15	5	2
Chelsea Creek	30.16	92	54	19	12	6	1
Hanscom AFB	30.53	82	42	20	13	7	0
Hayes PS	31.12	94	55	23	8	8	0
BWSC Rain Gauges							
Allston	33.46	88	48	18	12	7	3
Charlestown	32.66	94	54	19	13	7	1
Dorchester-Adams	37.98	100	56	17	16	9	2
Dorchester-Talbot	37.98	100	56	17	16	9	2
Hyde Park	38.59	97	53	18	15	8	3
East Boston	32.66	94	54	19	13	7	1
Longwood	34.94	94	56	15	13	10	0
Roslindale	42.58	102	53	21	16	8	4
Roxbury	34.94	94	56	15	13	10	0
Union Park	34.89	100	59	19	15	5	2
USGS Rain Gauge							
Fresh Pond	30.53	82	42	20	13	7	0
MWRA Rain Gauges							
Lexington Farm	30.53	82	42	20	13	7	0
Spot Pond	29.32	94	57	18	13	6	0
Somerville	29.32	94	57	18	13	6	0
Waltham Farm	30.53	82	42	20	13	7	0

Table A-6. Comparison of Storms Between January 1, 2022 and December 31, 2022 and Typical Year with Greater Than 2 Inches of Total Rainfall

Rain gauge	Date	Duration (hr)	Total Rainfall (inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)	Storm Recurrence Interval (24-hr)(1)
Typical Year	12/11/92	50	3.89	0.08	0.2	1y-2y
	8/15/92	72	2.91	0.04	0.66	6m
	9/22/92	23	2.76	0.12	0.65	1y-2y
	11/21/92	84	2.39	0.03	0.31	6m
	5/31/92	30	2.24	0.07	0.37	6m-1y
	10/9/92	65	2.04	0.03	0.42	<3m
January - December 2022 Rain Gauge Data						
Columbus Park Headworks (BO-DI-2)	10/13/2022	17.75	2.14	0.12	0.48	6m-1y
	12/15/2022	47.5	2.01	0.04	0.20	6m
Chelsea Creek (CH-BO-1)	10/13/2022	18.75	2.11	0.11	0.45	6m-1y
Ward Street Headworks (BO-DI-1)	Zero storms with depths greater than 2 inches recorded in 2022					
Fresh Pond (USGS)	Zero storms with depths greater than 2 inches recorded in 2022					

The largest storm event of the period was recorded at Columbus Park Headworks on October 13, 2022, with 2.14 inches of rainfall over 17.75 hours, which equates to a 6m-1y 24-hour duration recurrence interval.

Storms with peak rainfall intensities greater than 0.40 in/hr at the Ward Street, Columbus Park, Chelsea Creek Headworks, and USGS Fresh Pond rain gauges were identified and compared to storms with greater than 0.40 in/hr of peak intensity in the Typical Year (Table A-7). Storms with intensities greater than 0.40 in/hr are of importance because higher intensity storms have been found to produce more CSO activations and volumes than lower intensity storms. The full Typical Year has nine storm events with intensities greater than 0.40 inches per hour. For the four gauges shown in Table A-7, the number of storms with peak intensities greater than 0.40 inches per hour was three to four.

For storms with peak rainfall intensities greater than 0.4 in/hr at Ward Street Headworks, Columbus Park Headworks, and Chelsea Creek Headworks rain gauges, hyetographs were developed. These hyetographs show the 15-minute rainfall intensities and show the distribution of rainfall during the storm. Rainfall distribution during a storm can impact the behavior of system hydraulics due to soil saturation. For example, a storm where the peak rainfall occurs towards the end of the event will generally create more CSO than a storm with similar total rainfall and peak intensity, where the peak occurs at the beginning of the storm. An example hyetograph for the October 13, 2022 at the Ward Street gauge is shown in Figure A-2. This hyetograph is a clear example of the peak of the storm occurring towards the end of the event, which could compound the impact of this event (1.83 inches total rainfall at the Ward Street gauge) on CSO volumes.

Table A-7. Comparison of Storms Between January 1, 2022 and December 31, 2022 and the Typical Year with Peak Intensities Greater than 0.40 inches/hour

Rain gauge	Date	Duration (hr)	Total Rainfall (inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)	Storm Recurrence Interval (1-hr)(1)
Typical Year	10/23/1992	4	1.18	0.29	1.08	2y
	8/11/1992	11	0.87	0.08	0.75	6m-1y
	8/15/1992	72	2.91	0.04	0.66	6m-1y
	9/22/1992	23	2.76	0.12	0.65	6m-1y
	5/2/1992	7	1.14	0.16	0.63	6m
	9/9/1992	1	0.57	0.57	0.57	6m
	9/3/1992	13	1.19	0.09	0.51	3m-6m
	6/5/1992	18	1.34	0.07	0.44	3m
	10/9/1992	65	2.04	0.03	0.42	3m
January - December 2022 Rain Gauge Data						
Ward Street Headworks (BO-DI-)	8/5/2022	0.75	0.44	0.59	0.44	3m-6m
	8/22/2022	8.75	0.91	0.10	0.58	6m
	8/26/2022	2	0.75	0.37	0.71	6m-1y
	10/13/2022	16.25	1.83	0.11	0.42	3m
Columbus Park Headworks (BO-DI-2)	8/5/2022	1.75	0.48	0.27	0.47	3m-6m
	8/26/2022	2	0.55	0.28	0.51	3m-6m
	10/13/2022	17.75	2.14	0.12	0.48	3m-6m
Chelsea Creek (CH-BO-1)	6/27/2022	8.75	0.98	0.11	0.48	3m-6m
	8/9/2022	5.25	0.61	0.12	0.52	3m-6m
	10/13/2022	18.75	2.11	0.11	0.45	3m-6m
Fresh Pond (USGS)	4/19/2022	4.5	1.02	0.23	0.40	3m
	5/28/2022	14.5	0.71	0.05	0.42	3m
	8/26/2022	2.25	0.50	0.22	0.47	3m-6m
	10/13/2022	16.25	1.83	0.11	0.54	6m

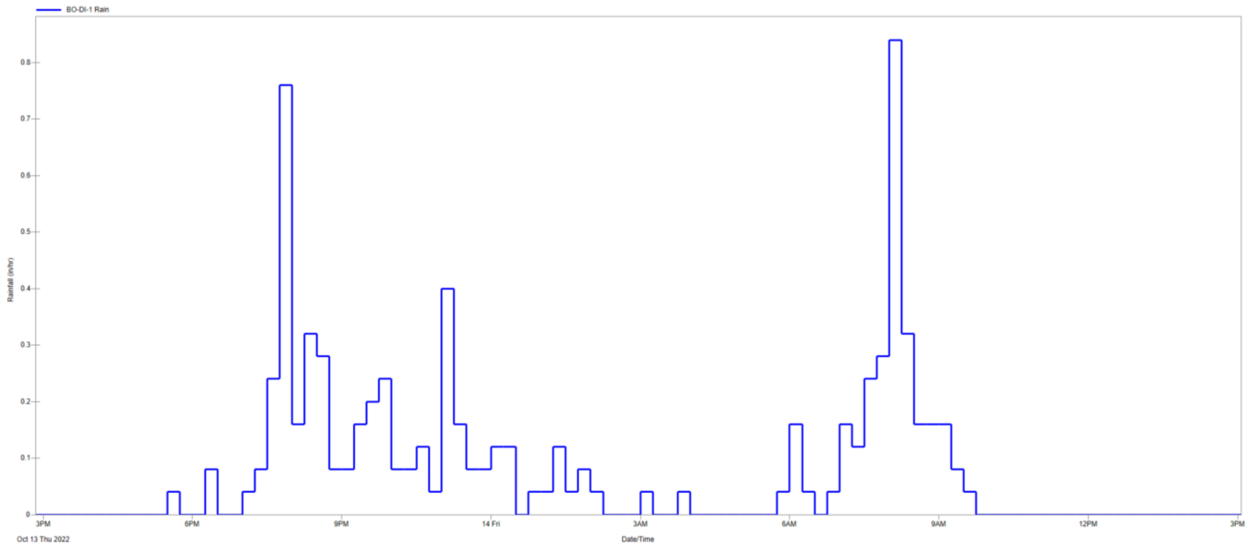

Figure A-2. Hyetograph from the Ward Street Headworks Gauge for October 13, 2022

The following is a summary of the rainfall comparison of January 1, 2022 to December 31, 2022 to the Typical Year:

- 2022 averaged 93 storm events with an average annual rainfall depth of 33.63 inches, compared to 93 storm events with an average annual rainfall depth of 46.80 inches for the Typical Year (Table A-5).
- In general, the breakdown of numbers of storms by rainfall depth categories for 2022 were skewed towards the smaller storms compared to the Typical Year. The 2022 period had nine more storms with depths less than 0.5 inches and nine fewer storms with depths greater than 0.5 inches (Table A-5).
- In terms of larger storms, for the four gauges shown in Table A-6 the average number of storms with greater than 2 inches of total rainfall in 2022 ranged from zero to two, less than the Typical Year count of six storms. In 2022 only two storm events were recorded to have a depth greater than 2 inches at Columbus Park (BO-DI-2), while no storms above 2 inches were recorded at Ward Street (BO-DI-1) or USGS Fresh Pond. The largest storm in 2022 had a depth of 2.14 inches, compared to the largest storm in the Typical Year which has a depth of 3.89 inches (Table A-6).
- For the four gauges shown in Table A-7, the number of storms with peak intensities greater than 0.40 inches per hour ranged from three to four, compared to nine for the Typical Year. The evaluated gauges had a peak intensity of 0.71 inches per hour. In comparison, the Typical Year peak had one storm with intensity of 1.08 inches per hour with the remaining eight storms having peak intensities between 0.75 and 0.42 inches per hour (Table A-7).

In 2022, Metropolitan Boston experienced significantly less volume of rain, fewer high intensity storm events, and fewer large storms in terms of depth compared to the Typical Year. The Typical Year total rainfall depth of 46.80 inches was 13.17 inches higher than the average depth across the collection system's rain gauges in 2022 of 33.63 inches. The impact of the lower rainfall (in terms of total rainfall, as well as peak intensity), is evident in the 2022 vs. Typical Year rainfall comparisons in the rainfall summary tables, and in comparing the modeled CSO discharge estimates for the Typical Year and 2022. For example, in the Typical Year Prison Point is predicted to discharge 234.81 MG, compared to the 2022 Prison Point modeled discharge volume of 62.47 MG, a 172.34 MG difference.