Typical Year Rainfall Analysis for Cambridge-Somerville-MWRA Combined Sewer Overflow (CSO) Control Plans

Technical Information in Support of the December 15th Public Meeting:
Development of Future Typical Year of Rainfall
12.2.2022
This presentation provides an **overview of the technical methodology** used to estimate rainfall values for the updated “typical year” that drives the CSO Control Plan Updates being developed by Cambridge, Somerville, and MWRA. This also serves as a technical document to support information provided at the public meeting.

**Who is this presentation for?**
This presentation is intended for any resident, stakeholder, or practitioner who wants to dive deeper into how the “typical year” is being established. The typical year is used to assess how combined sewer system improvements would perform under a series of rainfall events.

**Disclaimer**
*This presentation does not include a comprehensive review of the values and calculations included in the analysis. Further detailed information will be available in a technical report, available at a later date.*
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PRESENTATION OUTLINE

KEY DEFINITIONS & GOALS

OBSERVED RAINFALL ANALYSIS

FUTURE TYPICAL YEAR
**WHAT IS A CSO?**

**Combined sewer systems** are systems that **carry both sanitary flows and stormwater runoff**. During large storm events, these systems sometimes cannot handle the additional volumes, resulting in **discharge into nearest water bodies** to avoid backup into streets, homes, and yards. This discharge or overflow is termed a **combined sewer overflow (CSO)**.

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**Combined Sewer System:**

**Combined Sewer Overflow Event:**

*Dry Weather Conditions in the Combined Sewer System*

*Wet Weather Conditions in the Combined Sewer System*
WHAT IS A CSO CONTROL PLAN?

1. Establishes water quality and CSO discharge requirements.

2. CSO Control Plan Updates
   - Meets compliance
   - Data Driven
   - Actions to achieve water quality goals

A plan to meet water quality and CSO discharge requirements.

Evaluates how well proposed improvements perform under an agreed upon year of storm events (typical year)

EPA & MassDEP Requirements

DRAFT
A Typical Year is a full year of rainfall data that best represents rainfall conditions over a period of time.

As part of the CSO Control Plan Update, a “typical year” needs to be established to assess how planned improvements would perform under a series of rainfall conditions (the “typical year”)

DRAFT
Looking at typical rainfall conditions is important because long-term rainfall variability shows substantial **seasonal/decadal fluctuations** with an overall increasing trend for annual total rainfall. If past is the key to the future, then in order to understand future rainfall patterns, it is important to study long term trend in future rainfall variability.
A typical year is required by EPA’s CSO Control Policy.

The requirements include:

• Analyze rainfall records using statistics and the best available data.

• Test the performance of CSO controls during rain events on an annual average basis.
The typical year is used throughout the CSO control planning process. 
• During Development: To **identify** and test alternatives.
• During Implementation: Sets a **benchmark** to measure and assess progress.

This is an example of measuring CSO reduction over time using the **typical year** as a benchmark.

Figure 1-1. Estimated Treated, Untreated and Total CSO Volume in the Typical Year, 1988-2021.
According to information available at this time, there is no EPA/DEP guidance to incorporate future rainfall projections into developing a typical year for CSO Control Plans.

This CSO Control Plan Update Process is unique because it establishes a typical year considering future climate change projections, including higher intensity rainstorms.
The Future Typical Year is determined by considering **both historic observed and modeled future** rainfall parameters to understand how the **system improvements will perform under the impacts of climate change**. This methodology has been **peer reviewed and vetted by climate science experts**.

This presentation shows the methodology for evaluating the typical year considering both recent observed data **and** future climate change projections.
WHAT IS THE GOAL OF THIS TYPICAL YEAR ANALYSIS?

**Goal**

Determine the “typical” or most average year of rainfall patterns over the past 26 years + under future conditions*

**Purpose**

The “typical” or most average year of rainfall patterns based on modeled future data will be used to evaluate alternatives for the CSO Control Plan Updates considering future climate change

* Identify representative future typical year considering climate change and use observed rainfall pattern from the representative year to assess future CSO control plans.
HOW IS THE TYPICAL YEAR ANALYZED?

OBSERVED RAINFALL

MODELED FUTURE RAINFALL PROJECTIONS

FUTURE TYPICAL YEAR
WHY DO WE NEED TO CONSIDER BOTH OBSERVED DATA AND FUTURE PROJECTIONS TO EVALUATE A FUTURE TYPICAL YEAR?

**Observed data** from rainfall gauges is detailed at 15-min intervals, which is necessary to run Combined Sewer models for assessing system improvements.

Future rainfall projections from climate change models are needed to evaluate a typical year of rainfall in the future. However, future rainfall projections are only available at daily rainfall intervals and not at the 15-min intervals necessary to run Combined Sewer models.

Therefore, the **historical rainfall dataset is used** to identify a year most representative of future rainfall projections to run Combined Sewer models for assessing system improvements.
HOW DO WE CONSIDER BOTH OBSERVED DATA AND FUTURE PROJECTIONS TO EVALUATE A FUTURE TYPICAL YEAR?

- This is a **first of its kind** approach,
- Involves **collaboration with leading climate scientists**, and
- Is **consistent with the Massachusetts Climate Resilience Design Standards and Guidance**.

1. **Identified the Future Period**
   (2040-2069)
2. **Assessed two Greenhouse Gas (GHG) Emissions Scenarios**
3. **Analyzed multiple Global Climate Models (GCMs)**
4. **Compared Results to Observed Rainfall Data**
5. **Identified 2050 Future Typical Year for use in Updated CSO Control Plans**
   (in-progress)

This is a first of its kind approach, involves collaboration with leading climate scientists, and is consistent with the Massachusetts Climate Resilience Design Standards and Guidance.
OBSERVED RAINFALL ANALYSIS
The process for assessing observed data is as follows:

1. Rainfall Gauge Data is Processed in 15 Minute Intervals
2. Various Rainfall Parameters are Assessed
3. Deviation Analysis is Conducted for Two Scenarios
Step 1: The best available rainfall data from the past 26 years was collected and processed from physical rainfall gauges.

Rainfall Gauges

A rain gauge is a meteorological instrument to measure the precipitating rain in a given amount of time over a given area.
Rainfall data was processed from rain gauges maintained by MWRA at the following locations:

- WARD ST: 23 years (1999-2021)
- COLUMBUS PARK: 26 years (1996-2021)
- CHELSEA CREEK: 26 years (1996-2021)
Step 2: Rainfall parameters assessed from each gauge include:
(see next slides for definitions)

These parameters help us understand typical rainfall patterns over the last 26 years.
These parameters help us understand typical rainfall patterns over the last 26 years.
Rainfall parameters deeper dive: What does “Count of Storms Binned by Duration & Depths” mean?

Data on storm depth is “binned”, meaning organized, by storm duration and frequency of occurrence for that duration.

### Count of Storms

(for different durations of 15-min, 1-hr, 6-hr, 24-hr, or 1-day) are binned by design storm* depths for respective durations for the following return periods, based on Atlas -14**

<table>
<thead>
<tr>
<th>Duration</th>
<th>&lt; 3 months (&lt;3M)</th>
<th>3 to 6 months (3M to 6m)</th>
<th>6 months to 1 year (6M to 1Y)</th>
<th>1 year to 2 years (1Y to 2Y)</th>
<th>Greater than 2 years (&gt;2Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>&lt;0.72 in.</td>
<td>0.72-1.19 in.</td>
<td>1.19-1.67 in.</td>
<td>1.67-2.08 in.</td>
<td>&gt;2.08 in.</td>
</tr>
</tbody>
</table>

**Example**

(e.g., for 6-hr duration) are binned using the following 6-hr design storm* depths for the following return periods, based on Atlas -14**

See following page for full data table of one of the rainfall gauges.

*A design storm refers to a hypothetical storm event of a given depth of rainfall over a given duration and distribution that has an annual frequency of occurring

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<td>78</td>
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<td>121</td>
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</tbody>
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*Average values for each rainfall parameter, at each gauge, are used in Step 3: Deviation Analysis*
The figure below shows how Annual Rainfall Depth varies by year.

Example Statistic: Observed Annual Rainfall (Example at Columbus Park Gauge)
As shown by the table below, rainfall analysis results vary not only by year but also **spatially by rainfall gauge location**.

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<td>Ward St</td>
<td>AVG</td>
<td>6</td>
<td>95</td>
<td>46.3</td>
<td>17</td>
<td>&lt;0.23</td>
<td>0.23 - 0.36</td>
<td>0.36 - 0.5</td>
<td>0.5 - 0.62</td>
<td>0.6 - &lt;3M</td>
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<td>0.23</td>
<td>0.36 - 0.5</td>
<td>0.5 - 0.62</td>
<td>0.6 - &gt;2Y</td>
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<tr>
<td>Columbus Park</td>
<td>AVG</td>
<td>6</td>
<td>97</td>
<td>47.1</td>
<td>19</td>
<td>&lt;0.23</td>
<td>0.23 - 0.36</td>
<td>0.36 - 0.5</td>
<td>0.5 - 0.62</td>
<td>0.6 - &lt;3M</td>
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<td>0.36 - 0.5</td>
<td>0.5 - 0.62</td>
<td>0.6 - &gt;2Y</td>
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<tr>
<td>Chelsea Creek</td>
<td>AVG</td>
<td>6</td>
<td>100</td>
<td>44.4</td>
<td>20</td>
<td>&lt;0.23</td>
<td>0.23 - 0.36</td>
<td>0.36 - 0.5</td>
<td>0.5 - 0.62</td>
<td>0.6 - &lt;3M</td>
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<td>0.23</td>
<td>0.36 - 0.5</td>
<td>0.5 - 0.62</td>
<td>0.6 - &gt;2Y</td>
<td></td>
</tr>
</tbody>
</table>

*24-hour depth from NOAA Atlas 14 is divided by a derived factor of 1.13 to convert 24-hour amounts to 1-day depth accumulations*
The figure below shows the Annual Rainfall Depths for the observed years arranged in ascending order for one example gauge. **Years at each gauge within ±10% of the observed annual rainfall depth are pre-selected for deviation analysis at that gauge.**

![Total Rainfall (Columbus Park Gauge): Observed](image-url)

- **Hist01**
- **Hist02**
- **Hist03**
- **Hist04**
- **Hist05**
- **Hist06**
- **Hist07**
- **Hist08**
- **Hist09**
- **Hist10**
- **Hist11**
- **Hist12**
- **Hist13**
- **Hist14**
- **Hist15**
- **Hist16**
- **Hist17**
- **Hist18**
- **Hist19**
- **Hist20**
- **Hist21**
- **Hist22**
- **Hist23**
- **Hist24**
- **Hist25**
- **Hist26**

**Total Annual Rainfall (inches)**

- **47.1: Observed Annual**
Step 3: Deviation analysis determines the **amount that a single measurement (year) differs from the average**. Deviation analysis is used to understand rainfall variation across the 26 years and determine the year with the **least** deviation from the average.

**DEVIATION ANALYSIS STEPS**

A. **Absolute deviation**: difference between an individual year and the average over the period of record. *Difference between dashed averaged line and bar height.*

B. **Relative deviation**: absolute deviation divided by the average over the period of record.

C. **Weighted deviation**: relative deviation times a weighting factor (two scenarios of different weights to rainfall parameters).

**Example of Absolute Deviation**

![Graph showing total annual rainfall with absolute deviation analysis](image-url)
OBSERVED RAINFALL ANALYSIS: Deviation Analysis

Two Scenarios were evaluated for Weighted Deviation Analysis in order to capture the most detailed available data for all steps in the analysis:

Sub-Hourly Data (more detailed) Scenario, considers:
- The most holistic set of climate parameters that contribute to CSOs.
- Available observed 15-min rainfall data, and ideal set of weights to rainfall parameters that seem appropriate for CSOs.

Daily Data (less detailed) Scenario, used to address the availability of only daily rainfall projections in the future (from global climate models).
Two Scenarios were evaluated for Weighted Deviation Analysis:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cons DRY Days</th>
<th># Storms</th>
<th>Total Depth (in)*</th>
<th># Back-Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Hourly Data (more detailed) Scenario</td>
<td>12.0%</td>
<td>4.0%</td>
<td>-</td>
<td>12.0%</td>
</tr>
<tr>
<td>Daily Data (less detailed) Scenario</td>
<td>20.0%</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</table>

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<tbody>
<tr>
<td>&lt;3M**</td>
<td>0.23 - 0.36</td>
<td>0.38 - 0.61</td>
<td>0.85 - 1.06</td>
<td>1.06</td>
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<td>3M to 6M</td>
<td>0.5 - 0.62</td>
<td>0.61 - 0.85</td>
<td>1.19 - 1.67</td>
<td>1.67 - 2.08</td>
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<tr>
<td>6M to 1Y</td>
<td>&gt; 0.62</td>
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<td>&gt; 2.08</td>
<td>&gt; 3.23</td>
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<td>1Y to 2Y</td>
<td>&lt; 0.23</td>
<td>&lt; 0.38</td>
<td>&lt; 0.72</td>
<td>&lt; 1.14</td>
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<td>&gt;2Y</td>
<td>&lt; 0.23</td>
<td>&lt; 0.38</td>
<td>&lt; 0.72</td>
<td>&lt; 1.14</td>
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</table>

*no weights* to annual rainfall depth since these weights will be applied to years that have been *pre-selected* to be within ±10% of the average annual rainfall depth at each gauge.

**no weights** to <3-month storms/<3-month wet days since these storms are less likely to contribute to CSOs in a system that has completed a CSO Control Plan like MWRA.

+ 24-hour depth from NOAA Atlas 14 is divided by a derived factor of 1.13 to convert 24-hour amounts to 1-day depth accumulations.
The following example illustrates the **stepwise methodology** to **calculate the weighted deviation analysis**, using observed data at Columbus Park Gauge, example year 2017, for the annual number of storms parameter.

**A. Absolute deviation:**

\[
\text{Absolute Deviation} = \text{abs(Individual Year } - \text{ Record Average)}
\]

\[
\text{Absolute Deviation} = \text{abs}(94 - 97) = 3
\]

**B. Relative Deviation:**

\[
\text{Relative Deviation} = \frac{\text{Absolute Deviation}}{\text{Record Average}}
\]

\[
\text{Relative Deviation} = \frac{3}{97} = 0.03
\]

**C. Weighted Deviation Using the Sub-Daily Scenario:**

\[
\text{Weighted Deviation} = \text{Relative Deviation } \times \text{Scenario Weighting Factor}
\]

\[
\text{Weighted Deviation} = 0.03 \times 0.04 = 0.0012
\]
The most representative observed year of rainfall is **not simply the one closest** to the observed annual average rainfall depth, but also the one that **most closely matches other rainfall parameters analyzed**.
The years with the **lowest weighted deviations** (least variability from the average) for rainfall parameters considered for the two scenarios are as follows:

**Sub-hourly Data Scenario** (more detailed):
- 2000
- 2017
- 2002
- 2003
- 2009

**Daily Data Scenario** (less detailed):
- 2000
- 2004
- 2002
- 2003
- 2009

Top candidate years that are representative of average rainfall patterns are similar, if we consider both sub-hourly (more detailed) and daily (less detailed) scenarios.
FUTURE TYPICAL YEAR
Rainfall data from climate change projections are only available with daily rainfall totals. Parameters assessed from each gauge, grid, and Global Climate Model (GCM), include:

- Consecutive Dry Days
- Total Annual Rainfall Depth
- Count of Wet Days Binned by Depths

These parameters help us understand future conditions with climate change.
The process for assessing future data is as follows:

1. **Model Future Rainfall Data is Processed for each Gauge in Daily Intervals**

2. **Model Future Data is Bias Corrected**

3. **Deviation Analysis Conducted to Identify Observed Historical Year that is most Representative of Model Future Average**

4. **Typicalization of the Representative Year**
### FUTURE TYPICAL YEAR: Key Terminology

#### Key Components of the Future Typical Year Rainfall Analysis:

<table>
<thead>
<tr>
<th><strong>MACA</strong>*</th>
<th><strong>GAUGE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Future daily global climate model (GCM) projections were obtained from the Multivariate Adaptive Constructed Analogs (MACA) statistically downscaled product</td>
<td>MWRA rain gauge locations were used to download modeled future daily rainfall projections</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>DOWNSCALED</strong></th>
<th><strong>GRID</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical downscaling is the process of converting large scale global climate models into fine spatial scale so that the data is in close agreement with local data and can be used for station level analysis</td>
<td>MACA projections used in the analysis are based on approx. 4-km resolution grids, with modeled future daily rainfall projections available for each grid for each GCM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>GCM</strong></th>
<th><strong>PLANNING HORIZON</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>A global climate model (GCM) is a complex mathematical representation of the major climate system components (atmosphere, land surface, ocean, and sea ice), and their interactions</td>
<td>A length of time in the future for which the plannings are made. For climate analysis, typically a 30 years average is taken. For example, 2050 planning horizon represents an averaging period of 2040-2069</td>
</tr>
</tbody>
</table>

---


**https://www.gfdl.noaa.gov/climate-modeling/
The future planning horizons, Global Climate Models, and Greenhouse Gas Emissions Scenarios used for the future typical year analysis are based on those that have been adopted by Massachusetts Executive Office of Energy and Environmental Affairs, as part of the Statewide Climate Resilience Design Standards and Guidance.
Step 1: To determine the future typical year, modeled daily rainfall data were downloaded for the areas around the rainfall gauges.

MACA grids were identified and 3 grids around each of the 3 existing rainfall gauges were selected:
- Ward St
- Columbus Park
- Chelsea Creek

Multivariate Adaptive Constructed Analogs (MACA) is a statistical method for downloading future climate projection using downscaled Global Climate Models (GCMs)

**https://www.gfdl.noaa.gov/climate-modeling/
Model Future Rainfall Data:
11 Global Climate Models (GCMs)*

Greenhouse Gas (GHG) Emission Scenarios:
Low (RCP4.5) and High (RCP8.5)

Planning Horizons:
Historical (26 years): 1996 – 2021
(model historical to calculate uncertainties from observed dataset)
Future (30 years): 2050 (2040 – 2069)
(forecasted/projected model data to study future change in rainfall patterns)

Future dataset: 11 GCMs for each of the 3 grids for each of the 3 gauges for 30 years for both emission scenarios.

*The 11 Global Climate Models (GCMs) have been selected from a wider set of GCMs as adopted by the Massachusetts Executive Office of Energy and Environmental Affairs for the Statewide Climate Resilience Design Standards and Guidance.
Annual Rainfall Depth variability across the 11 Global Climate Models, for both GHG Emission Scenarios. This figure shows how rainfall projections are likely to vary in the future.

Shaded area represents the spread across 11 models

Dashed lines represent the 330-model year average (11 models over 30 years)
Bias Correction is the process of adjusting the future model data so that it aligns with observed data. Bias correction factor is the difference between the model historical data and the observed historical data and can be either positive or negative. The purpose of the bias correction process is to correct uncertainties in model future dataset based on observed data.

First, find the Bias Correction Factor by comparing observed data with historical model data for each GCM.

Then, apply that Bias Correction Factor to the respective model future data. This will “correct” the future data to best represent future conditions.
Step 2: To evaluate future rainfall parameters, the bias correction factor for each GCM, grid, and gauge must be calculated. This is derived from comparison of observed data to modeled historical data.

The table shows an example of calculating the bias correction factor:

<table>
<thead>
<tr>
<th>CNRM-CM5, GRID 1</th>
<th>Count of Wet Days - 1-Day Depths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Consecutive Dry Days</td>
</tr>
<tr>
<td>Model Hist Avg (1996-2021)</td>
<td>5.9</td>
</tr>
<tr>
<td>Obs. Hist Avg, Columbus Park Gauge (1996-2021)</td>
<td>5.9</td>
</tr>
<tr>
<td>Bias correction (% change)</td>
<td>0%</td>
</tr>
<tr>
<td>Bias correction (additive)</td>
<td></td>
</tr>
</tbody>
</table>

For some parameters, % change was compared, while for others the difference in the two values was compared. This was based on recommendation from climate scientists.
FUTURE TYPICAL YEAR: Model Future Rainfall Depth

The figure below shows how bias corrected Annual Rainfall Depth is projected to vary by year for a sample GCM for a sample gauge.

*RCP 8.5 scenario has been selected by the Massachusetts Executive Office of Energy and Environmental Affairs for the Statewide Climate Resilience Design Standards and Guidance*
Typical statistics from future years are used to identify observed year that **best represents** climate change conditions.
Climate change projections show **higher variability** of future annual rainfall compared to observed years.

Total Annual Rainfall: Observed and Model Future

- **47.1**: Historical Average (1996-2021)
- **49.5**: Model Future Average (2040-2069)
Years at each gauge within ±10% of the observed annual rainfall depth are pre-selected for deviation analysis at that gauge.

Total Annual Rainfall: Observed and Model Future

- **Observed Data** (Results from Sample Columbus Park Gauge)
- **Model Future Data** (Results from Sample Model CNRM-CM5)
- **Observed Years** within 10% Model Future Average
- **Observed Average**
- **Model Future Average**

**Observed Data**
- **Historical Average** (1996-2021) = 47.1 inches
- **Model Future Average** (2040-2069) = 49.5 inches
Step 3: Deviation analysis evaluates the amount that a single measurement (year) differs from the average. Deviation analysis is used to understand rainfall variation across the 26 years under climate change.

**DEVIATION ANALYSIS STEPS**

1. **Absolute deviation**: difference between an individual year and the period of record average.
2. **Relative deviation**: absolute deviation divided by the period of record average.
3. **Weighted deviation**: relative deviation times a weighting factor (two scenarios of different weights).
Daily-Data Scenario was evaluated for Weighted Deviation Analysis:

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>Cons Dry Days</th>
<th>Total Rainfall Depth*</th>
<th>&lt;3M**</th>
<th>3M to 6M</th>
<th>6M to 1Y</th>
<th>1Y to 2Y</th>
<th>&gt;2Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily-Data Scenario</td>
<td>20%</td>
<td>-</td>
<td>-</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

* **No weights** to annual rainfall depth since these weights will be applied to years that have been pre-selected to be within ±10% of the average annual rainfall depth at each gauge.

** No weights** to <3-month storms/<3-month wet days since these storms are less likely to contribute to CSOs in a system that has completed a CSO Control Plan like MWRA.

+ 24-hour depth from NOAA Atlas 14 is divided by a derived factor of 1.13 to convert 24-hour amounts to 1-day depth accumulations.
The observed year that is most representative of future rainfall patterns is **not simply the one closest** to the projected future annual average rainfall depth, but also the one that **most closely matches other rainfall parameters analyzed**.
The rainfall events in the observed year that are most representative of future rainfall patterns are compared with the future Intensity-Duration-Frequency (IDF) curves based on projections that have been adopted by the Massachusetts Executive Office of Energy and Environmental Affairs, as part of the Statewide Climate Resilience Design Standards and Guidance.
### Future Design Storm Projections

<table>
<thead>
<tr>
<th>BINS</th>
<th>PRESENT DAY (NOAA ATLAS 14 DEPTHS (IN.))</th>
<th>2050 (2040-2069) RAINFALL DEPTH PROJECTIONS*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duration</td>
<td>Return Period</td>
</tr>
<tr>
<td></td>
<td>15-minute</td>
<td>3M</td>
</tr>
<tr>
<td></td>
<td>6M</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>1Y</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>2Y</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>1-hour</td>
<td>3M</td>
</tr>
<tr>
<td></td>
<td>6M</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>1Y</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>2Y</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>6-hour</td>
<td>3M</td>
</tr>
<tr>
<td></td>
<td>6M</td>
<td>1.19</td>
</tr>
<tr>
<td></td>
<td>1Y</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td>2Y</td>
<td>2.08</td>
</tr>
<tr>
<td></td>
<td>24-hour</td>
<td>3M</td>
</tr>
<tr>
<td></td>
<td>6M</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td>1Y</td>
<td>2.60</td>
</tr>
<tr>
<td></td>
<td>2Y</td>
<td>3.23</td>
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<tr>
<td></td>
<td>1-day</td>
<td>3M</td>
</tr>
<tr>
<td></td>
<td>6M</td>
<td>1.64</td>
</tr>
<tr>
<td></td>
<td>1Y</td>
<td>2.30</td>
</tr>
<tr>
<td></td>
<td>2Y</td>
<td>2.86</td>
</tr>
</tbody>
</table>

The future rainfall projections used are best available projections from Cornell University, developed as part of the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) Climate and Hydrologic Risk Project and adopted by the State’s Climate Resilience Design Standards Tool.

*Using RCP 8.5 scenario, which has been selected by the Massachusetts Executive Office of Energy and Environmental Affairs for the Statewide Climate Resilience Design Standards and Guidance [https://resilientma.mass.gov/rmat_home/designstandards/](https://resilientma.mass.gov/rmat_home/designstandards/)
FUTURE TYPICAL YEAR – Future Rainfall Projections

**Observed (1996-2021)**

*Average annual rainfall: 47.1”*

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**Future (2040-2069), RCP8.5***

*Average annual rainfall: 49.5”*

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*Using RCP 8.5 scenario, which has been selected by the Massachusetts Executive Office of Energy and Environmental Affairs for the Statewide Climate Resilience Design Standards and Guidance [https://resilientma.mass.gov/rmat_home/designstandards/](https://resilientma.mass.gov/rmat_home/designstandards/)*

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**From a Sample Gauge**

Today’s 2-year storm is likely to be comparable to 2050’s 1-year storm

Today’s 1-year storm is likely to be comparable to 2050’s 6-month storm
Comparing Representative Year Against Future Sub-Hourly Bins

Substituting alternative events from other historical years of record would be targeted to add events with higher intensities over short durations and reduce the largest event.

<table>
<thead>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;3M*</td>
<td>&lt;3M*</td>
<td>&lt;3M*</td>
<td>&lt;3M*</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.46 - 0.50</td>
<td>0.76</td>
<td>1.54 - 1.71</td>
<td>2.37 - 2.63</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.50 - 0.61</td>
<td>0.87 - 1.06</td>
<td>1.71 - 2.08</td>
<td>2.63 - 3.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.61 - 0.76</td>
<td>1.06 - 1.31</td>
<td>2.08 - 2.57</td>
<td>3.22 - 4.0</td>
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<td></td>
<td>&gt; 0.76</td>
<td>&gt; 1.31</td>
<td>&gt; 2.57</td>
<td>&gt; 4.0</td>
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<td></td>
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<td>&lt; 0.46</td>
<td>&lt; 0.76</td>
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<td>&lt; 1.06</td>
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<td>&lt; 1.31</td>
<td>&lt; 2.57</td>
<td>&lt; 3.22</td>
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<td>&lt; 4.0</td>
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<td>&lt; 4.0</td>
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</tr>
<tr>
<td>1992 TYP</td>
<td>94</td>
<td>46.83</td>
<td>94</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Representative 2050 (Observed)</td>
<td>98</td>
<td>50.07</td>
<td>97</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2050 Typical Year (Targets)</td>
<td>+/ - 98</td>
<td>+/ - 50</td>
<td>+/ - 97</td>
<td>~4 events</td>
<td>0</td>
<td>+/- 98</td>
</tr>
</tbody>
</table>
NEXT STEPS

- Finalize the Future Typical Year
- Finalize technical report related to development of Future Typical Year
THANK YOU

Written comments to this Technical Information can be submitted by January 5\textsuperscript{th} (include "CSO Control Typical Year" in the subject) to:

Cambridge: Catherine Woodbury, cwoodbury@cambridgema.gov