Massachusetts Ambient Air Monitoring Network Assessment

2020

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I. SUMMARY

Introduction

The Massachusetts Department of Environmental Protection (MassDEP) has prepared this 2020 Ambient Air Monitoring Network Assessment pursuant to 40 CFR 58.10(d). The Federal Clean Air Act established a joint Federal-State partnership for protecting the quality of our nation's air. A key component of this partnership is the national system of ambient air quality monitors. State and local air pollution control agencies maintain a network of air monitoring stations that measure ambient concentrations of pollutants for which the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS). Those pollutants, which are known as "criteria pollutants," include ozone (O_3), particulate matter smaller than 10 microns (PM_{10}), particulate matter smaller than 2.5 microns ($PM_{2.5}$), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and lead (Pb). The monitoring network is designed to determine if air quality meets the NAAQS as well as to provide data needed to identify, understand, and address ambient air quality problems. EPA promulgates regulations that define minimum monitoring requirements as well as monitoring techniques and procedures.

Monitoring networks are designed to achieve, with limited resources, the best possible scientific data to inform the protection of public health, the environment and public welfare. The number, location, and types of monitors needed to achieve this goal depends on a myriad of factors including demographics, pollution levels, air quality standards, monitoring technology, budgets, and scientific understanding. These factors all change over time. In accordance with EPA monitoring regulations, state and local air pollution control agencies must conduct an assessment of their monitoring networks every 5 years in order to determine:

- if the network meets the monitoring objectives defined in Appendix D of 40 CFR 58.10,
- whether new monitoring sites are needed,
- whether existing sites are no longer needed and can be discontinued, and
- whether new technologies are appropriate for the ambient air monitoring network.

The network assessment must consider the ability of existing and proposed monitoring sites to provide relevant data for air quality characterization for areas with relatively high populations of susceptible individuals (e.g., children with asthma). The assessment also must show the impacts of proposals to discontinue any sites on data users other than the agency itself, such as nearby states and tribes or organizations conducting health effects studies. For the criteria pollutant $PM_{2.5}$, the assessment also must identify needed changes to population-oriented sites.

MassDEP's Air Assessment Branch maintains an ambient air quality monitoring network that consists of 22 monitoring stations located in 18 cities and towns and monitors ambient concentrations of all criteria pollutants. The Wampanoag Tribe of Gay Head (Aquinnah) operates an additional air monitoring station on Martha's Vineyard. MassDEP also monitors meteorological conditions, ambient levels of toxic air pollutants as part of the National Air Toxics Trends Sites (NATTS) network and ozone precursors as part of the Photochemical Assessment

Monitoring Stations (PAMS) network. Ozone precursors are substances that react in the atmosphere to form ground-level ozone.

MassDEP's air monitoring network places an emphasis on monitoring ozone and $PM_{2.5}$ levels. In the past, Massachusetts air quality has been in nonattainment of the ozone standard and has been close to the $PM_{2.5}$ standard. Today, Massachusetts is designated in attainment of all standards, although the Commonwealth still experiences days with elevated levels of ozone, making ozone monitoring a continued priority. The ozone monitoring network is designed to measure concentrations of ozone and its precursors in-state, as well as provide insight into ozone formation and ozone transport. MassDEP also continues to place priority on monitoring $PM_{2.5}$ concentrations due to the significant health effects posed by $PM_{2.5}$ exposure.

Figure 2-1 shows the location of monitoring stations. All these sites have been approved by EPA as meeting applicable siting criteria, as specified in Subpart B of 40 CFR Part 58. As required by EPA, all criteria pollutants are monitored using Federal Reference Methods (FRMs) or Federal Equivalent Methods (FEMs) and monitors are operated according to the procedures specified in Quality Assurance Project Plans (QAPPs) that have been approved by EPA. MassDEP's monitors meet EPA guidelines and requirements for characterizing micro-scale (up to 100 square meters), middle-scale (a few city blocks), neighborhood (up to 4 square kilometer), urban (a city), and regional (up to hundreds of square kilometers) air quality and for measuring the greatest population exposures, highest exposures and regional transport.

Update on 2015 Network Assessment

MassDEP prepared its second Network Assessment in 2015. The 2015 Assessment noted that MassDEP was working to establish a second NO_2 near-road site in the Boston Area and an ozone and consolidated $PM_{2.5}$ site in the Pittsfield area. In 2018, MassDEP established a second near-road NO_2 monitoring station in Chelmsford (Manning Road), adding to the existing near-road monitoring station in Boston (Von Hillern Street). In 2018, MassDEP also established an ozone monitoring station in Pittsfield (Silver Lake Boulevard, 25-003-0008). MassDEP included $PM_{2.5}$ monitoring at the new station, and in doing so was able to consolidate two former sites in Pittsfield (Center Street and South Street) into a single monitoring station.

EPA's 2015 ozone monitoring regulations reduced the number of required Photochemical Assessment Monitoring Station (PAMS) sites in Massachusetts from four to one. In 2017, MassDEP closed the Newburyport monitoring station, which was originally established as a PAMS site. MassDEP also discontinued PAMS monitoring at the Chicopee and Ware monitoring stations, although MassDEP continues to monitor ozone and other criteria pollutants these sites. MassDEP continues to implement PAMS monitoring at its Lynn monitoring station, which EPA approved as MassDEP's PAMS network site.

MassDEP made several other changes to its monitoring Network since the 2015 Assessment:

- In 2016, MassDEP discontinued filter-based $PM_{2.5}$ monitors at Lawrence and Worcester (Washington Street) as part of trend of relying more on continuous $PM_{2.5}$ monitors.

- In 2017, MassDEP established a site in North Adams to monitor continuous $PM_{2.5}$ and black carbon as a way to monitor wood smoke in the Greylock Valley area.

- In 2018, MassDEP closed the $PM_{2.5}$ monitoring station at Boston – North Street due to a loss of access to the site.

- In 2020, MassDEP established a temporary monitoring station in Weymouth near a natural gas compressor station that is under construction. The station includes a continuous $PM_{2.5}$ monitor, volatile organic compounds (VOCs) sampler and a carbonyl sampler. MassDEP is working to establish a permanent monitoring station in Weymouth, which also will monitor ozone and NO_2.

2020 Network Assessment Results

MassDEP's review of the Massachusetts monitoring network indicates that the network meets or exceeds EPA's minimum monitoring requirements, that the network is well designed and operated, and adequately characterizes air quality in Massachusetts. While Massachusetts is designated in attainment of the 2015 8-hour ozone NAAQS, MassDEP continues to make ozone monitoring a priority to confirm the overall downward trend in ozone concentrations and to alert the public on days when ozone is elevated. MassDEP also continues to operate a robust $PM_{2.5}$ monitoring network due to the significant health effects posed by $PM_{2.5}$.

MassDEP has reviewed changes in population and pollutant emissions and determined that MassDEP's existing monitoring network is properly designed. Massachusetts population centers remain the same geographically, although overall population has increased (see Figure 3-2); there has been little change in the distribution of vehicle miles travelled across the state (see Figure 4-3); and pollutant emissions have declined fairly uniformly across the state (see Figure 4-4). The absence of major shifts in these factors indicates that adjustment of the basic design of the air monitoring network is unnecessary.

In addition, review of the distribution of sensitive populations (such as children) and of the incidence of various diseases associated with air pollution (such as asthma, respiratory disease, lung cancer, and circulatory diseases), as well as Environmental Justice populations, indicates that the existing network of monitoring sites adequately supports air quality characterization in areas with sensitive populations. However, given the health impacts of $PM_{2.5}$, MassDEP is evaluating opportunities to enhance $PM_{2.5}$ monitoring in Environmental Justice communities.

MassDEP used an analytical tool provided by EPA (NetAssess2020) to evaluate whether any sites are redundant and could be removed and whether any new sites are needed in the monitoring network. The tools evaluates correlations between existing site measurements; distance between sites; the likelihood of the site exceeding a standard; the correlation between site measurements; removal bias (i.e., the difference between the measured concentrations at a site and those that would be estimated for that site based on data from surrounding sites); and create maps that show the coverage area of each monitor.

MassDEP continues to evaluate opportunities to optimize the monitoring network and provides updates for EPA review and approval through annual Network Plans. MassDEP has taken advantage of opportunities to streamline operations by optimizing travel routes, maintenance schedules, and relying more on automated continuous monitors for most parameters. Two measures implemented since the 2015 Network Assessment include relying more on continuous Federal Equivalent Method (FEM) $PM_{2.5}$ monitors and reducing the workload associated with monitoring PAMS parameters.

II. NETWORK PURPOSE AND DESCRIPTION

The Massachusetts ambient air quality monitoring network serves several purposes:

- **Provide information about air quality to the public.** MassDEP's website provides near real-time data from continuous monitoring sites, explanations of the health effects of pollution, information about the NAAQS, and the ability to chart historical air quality monitoring data and air quality trends. The network also supports MassDEP's daily air quality forecast and alert system. Both data and forecasts are posted at MassAir at www.mass.gov/air.

- **Verify compliance with National Ambient Air Quality Standards (NAAQS).** EPA specifies the minimum number of monitors that must be located in Massachusetts to demonstrate whether the state is in attainment of each of the criteria pollutants.

- **Assess the effectiveness of current air pollution control regulations and initiatives / support development of policies and regulations aimed at reducing air pollution.** MassDEP uses air monitoring data to develop and track progress of State Implementation Plans (SIPs) that specify the air pollution controls and strategies to attain and maintain the NAAQS and meet Regional Haze requirements.

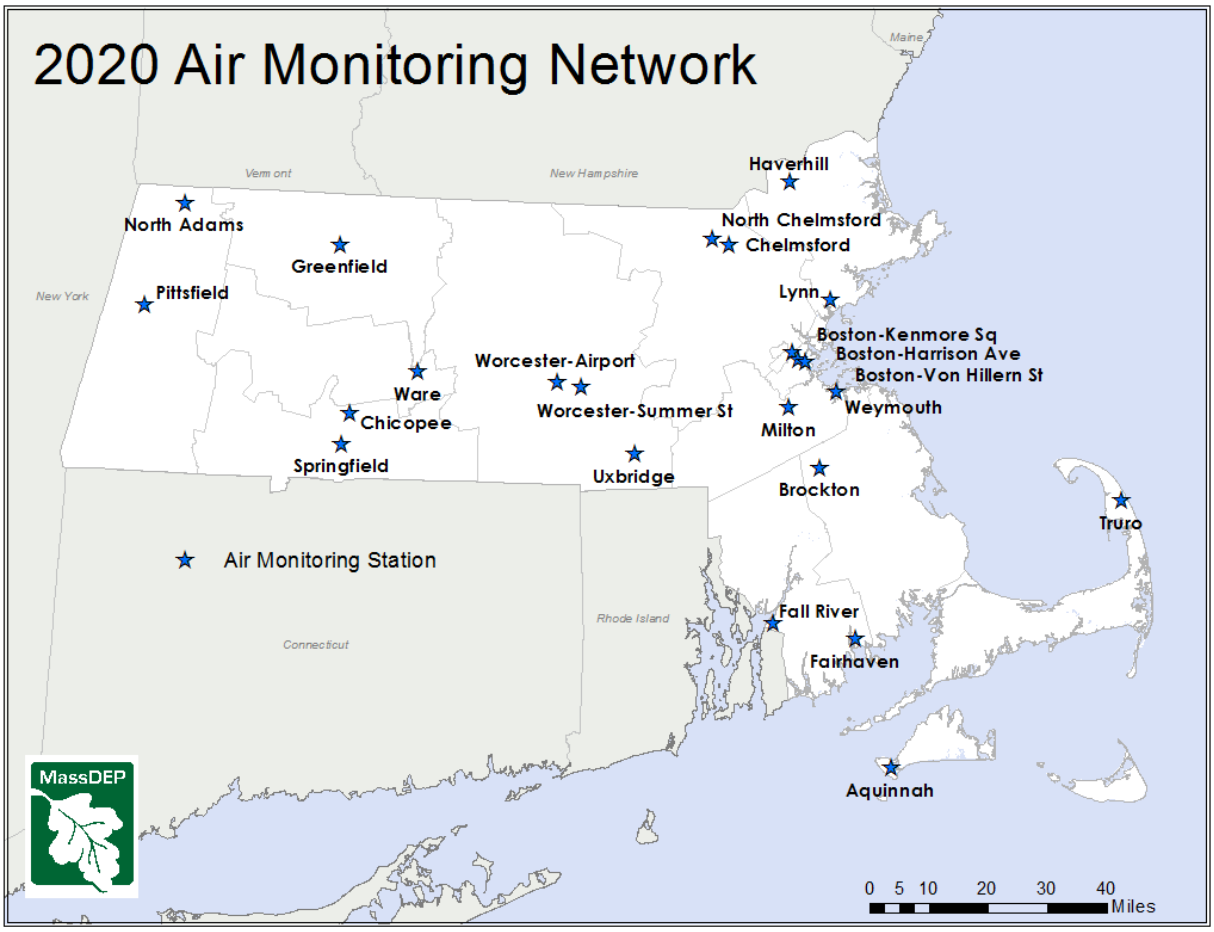
- **Ambient monitoring data are used in conjunction with modeling to characterize the extent of air pollution problems, including transport into and out of the state, as well as to evaluate the impacts of alternative control strategies.** MassDEP's monitoring data are important to regional air pollution control planning efforts. Massachusetts is a member of three interstate regional organizations that coordinate the development of air pollution control plans - Ozone Transport Commission (OTC), Mid-Atlantic/Northeast Visibility Union (MANE-VU), and Northeast States for Coordinated Air Use Management (NESCAUM).

- **Site-specific permitting.** MassDEP staff and consultants use ambient air quality and meteorological monitoring data to make site-specific permitting decisions that ensure that emissions from new or modified facilities do not cause or contribute to violations of NAAQS or consume Prevention of Significant Deterioration increments. In addition, meteorological and toxic chemical monitoring information is used in conjunction with models to estimate if emissions are likely to result in exceedances of MassDEP's Ambient Air Limits (AALs) for toxic pollutants.

- **Research.** Environmental and medical academics, the Massachusetts Department of Public Health, the World Health Organization, conservation groups, environmental advocates, and consultants use ambient air monitoring data to evaluate the public health and environmental impacts of air pollution and to develop and "ground truth" ambient air quality models. Air quality data also are used to better characterize the behavior of contaminants in the atmosphere.

MassDEP operates 22 monitoring stations located in 18 cities and towns. The Wampanoag Tribe of Gay Head (Aquinnah) operates an air monitoring station on Martha's Vineyard. Figure 2-1 shows the location of monitoring stations.

Figure 2-1
Massachusetts Air Monitoring Stations in 2020



MassDEP operates "continuous" and "intermittent" monitors. Continuous monitors sample and measure the air 24 hours per day and generally report out hourly averages. Intermittent monitors take discrete samples for a specific time period, usually 24 hours, at predetermined intervals, usually every third day or every sixth day. Data is averaged in blocks of 1, 3, or 24 hours, depending on the regulatory requirement.

Some monitors, typically those measuring gaseous pollutants, perform the entire analysis automatically on-site. Others, such as the filter-based samples for lead, particulate matter ≤ 10 microns (PM_{10}), particulate matter ≤ 2.5 microns ($PM_{2.5}$), and volatile organic compounds (VOCs) and toxics, require laboratory analysis.

Monitor Descriptions

MassDEP operates "continuous" and "intermittent" monitors. Continuous monitors perform complete, automated analysis on-site, measure air quality 24 hours per day, and report the data as hourly means. These are typically used for gaseous pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and ozone (O_3). Some continuous monitors

perform analyses after an hourly sample has been collected, such as Photochemical Assessment Monitoring Station (PAMS) automated gas chromatographs (AutoGC) and $PM_{2.5}$ Beta Attenuation Monitors (BAMs).

Intermittent monitors obtain discrete samples that are collected by staff and brought to the laboratory for analysis; examples include VOC canisters, carbonyl cartridges and $PM_{2.5}$ filter samples. Depending on the regulatory or analytical requirements, samples may be obtained every day, every third day, every sixth day, or on some other prescribed schedule. The data are averaged in 3- or 24-hour intervals based on EPA requirements for the specific pollutant.

MassDEP is moving toward greater reliance on automated methods such as continuous $PM_{2.5}$ monitors and automated gas chromatographs for VOCs where possible. Advantages of automated analysis in the field include near real-time reporting of ambient air quality data to the public using data loggers and telemetry systems, a continuous record of air quality data 24 hours per day, and fewer labor hours spent retrieving and analyzing samples. However, continuous monitors are expensive, usually require climate-controlled shelters (unlike intermittent samplers that can be placed on rooftops or compact spaces), and can break (requiring back-up equipment).

The Massachusetts network contains the following monitors for criteria pollutants:

- CO: 3 continuous monitors
- NO_x: 10 continuous monitors
- O_3: 17 continuous monitors (including Aquinnah tribal site)
- SO_2: 6 continuous monitors
- $PM_{2.5}$: 16 hourly Federal Equivalent Monitors (FEMs) $PM_{2.5}$ monitors and 11 intermittent Federal Reference Method (FRM) monitors (including collocated units)
- PM_{10}: 4 intermittent monitors (including collocated units)

The Massachusetts network contains the following monitors for other pollutants:

- Black carbon (BC): 7 continuous monitors
- Ozone precursors at one PAMS station:
  - Total reactive oxidized nitrogen (NO_y): 1 continuous monitor
  - VOCs: 1 continuous automated gas chromatograph (GC) and 1 intermittent monitor
  - Carbonyls: 1 intermittent monitor
- NATTS Toxics:
  - VOCs: 1 intermittent monitor
  - Carbonyls: 1 intermittent monitor
  - Polycyclic aromatic hydrocarbons (PAHs): 1 intermittent monitor
  - Metals (including lead): 2 collocated intermittent monitors
- Speciation of $PM_{2.5}$: 2 intermittent monitors measure the individual constituents of $PM_{2.5}$ including elements, sulfates/nitrates, and organic carbon
- NO_y: 2 continuous monitors (in addition to PAMS NO_y)
- VOCs: 1 intermittent monitor (in addition to PAMS and NATTS VOCs)
- Carbonyls: 1 intermittent monitor (in addition to PAMS and NATTS carbonyls)

- IMPROVE: The National Park Service and Wampanoag Tribe operate two IMPROVE monitors

Meteorological monitors measuring atmospheric conditions that influence air pollution levels:

- Wind speed and direction (WS/WD): 13 monitors
- Relative humidity (RH): 13 monitors
- Precipitation: 2 monitors
- Atmospheric pressure (i.e., barometric pressure): 13 monitors
- Solar radiation: 13 monitors
- Ambient temperature: 13 monitors

The Boston – Harrison Avenue site is the Massachusetts NCore site and was designated a National Air Toxics Trends Station (NATTS) in 2003. The NATTS program specifies the measurement of certain non-criteria air pollutants at trace levels, mostly on an intermittent (every sixth day) basis. The following parameters are measured in association with NATTS monitoring:

- Volatile organic compounds (VOCs)
- Carbonyls (formaldehyde and acetaldehyde)
- Polyaromatic hydrocarbons (PAHs)
- Metals
- Black carbon (BC)

Quality Control and Quality Assurance

Whether measurements are continuous or intermittent, all analyzers must be tested to ensure data validity, accuracy and precision, and to ensure that the analyzer is operating properly and can be expected to continue to operate in an acceptable manner. A large portion of MassDEP monitoring staff time is spent calibrating equipment, challenging equipment performance in the field, and reviewing the quality of air monitoring data.

MassDEP's Air Assessment Branch has an active, independent Quality Assurance Section ensuring that proper data collection and analysis procedures are followed, equipment is maintained appropriately, and equipment is calibrated properly using the appropriate test gases. This QA Section performs periodic performance and systems audits at air monitoring sites throughout the network. This is essential to operating the monitoring network, analyzing samples, and producing air quality of sufficient quality to satisfy the needs of users.

Monitor Siting

Appendix D of 40 CFR Part 58 defines spatial monitoring scales that are useful in describing the purpose of individual monitors at specific locations:

- **Micro scale** – Concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 meters. An example is the Boston – Kenmore NO_x located near major roadways and within street canyons, where the influence of the emissions is not expected to spread much beyond the immediate area.
- **Middle scale** – Concentrations typical of areas up to several city blocks in size with dimensions ranging from about 100 meters to 0.5 kilometers. Monitors at this scale characterize local conditions, similar to micro scale, but for a larger surrounding area. Examples include urban PM_{10} monitors.
- **Neighborhood scale –** Concentrations within some extended area of the city that has relatively uniform land use with dimensions in the 0.5 to 4.0 kilometers range. This might be an urban area influenced by a major point source or area sources or the air quality surrounding a defined area of similar conditions. Boston – Harrison Avenue is an example of an urban neighborhood.
- **Urban scale –** Overall, citywide conditions with dimensions on the order of 4 to 50 kilometers. This scale would usually require more than one monitoring site. Ozone networks around Boston, Worcester and Springfield are partially laid out on an urban scale.
- **Regional** – Usually a rural area of reasonably homogeneous geography that extends from tens to hundreds of kilometers. Examples include monitors in Fairhaven, Uxbridge and Truro.

In general, Massachusetts air monitoring stations are sited to characterize one of the following:

- highest expected concentration in an area
- general background levels
- general population exposure
- welfare impacts
- pollutant transport

Most MassDEP monitoring activities are mandated by EPA regulations and guidelines, and MassDEP works very closely with EPA to make sure that Federal air monitoring initiatives are implemented in Massachusetts.

Monitoring Site Details

A full list of the Massachusetts monitor locations, when they were established, their purpose, what they measure, and the equipment used are presented in Figures 2-2 through 2-5.

Figure 2-2: Air Monitoring Site Locations

Site ID	Site Name	County	Address	City
25-025-0002	Boston - Kenmore	Suffolk	Kenmore Square	Boston
25-025-0042	Boston - Harrison Ave	Suffolk	1159 Harrison Avenue	Boston
25-025-0044	Boston - Von Hillern	Suffolk	19 Von Hillern Street	Boston
25-023-0005	Brockton	Plymouth	170 Clinton Street	Brockton
25-017-0009	Chelmsford - EPA	Middlesex	11 Technology Drive	Chelmsford
25-017-0010	Chelmsford - Near Road	Middlesex	Manning Road	Chelmsford
25-013-0008	Chicopee	Hampden	Anderson Road	Chicopee
25-005-1006	Fairhaven	Bristol	30 School Street	Fairhaven
25-005-1004	Fall River	Bristol	659 Globe Street	Fall River
25-011-2005	Greenfield	Franklin	16 Barr Avenue	Greenfield
25-009-5005	Haverhill	Essex	685 Washington Street	Haverhill
25-009-2006	Lynn	Essex	390 Parkland	Lynn
25-021-3003	Milton - Blue Hill	Norfolk	1904 Canton Avenue	Milton
25-003-6001	North Adams	Berkshire	86 Holden Street	North Adams
25-003-0008	Pittsfield	Berkshire	25 Silver Lake Drive	Pittsfield
25-013-0018	Springfield	Hampden	600 Liberty Street	Springfield
25-001-0002	Truro	Barnstable	6 Collins Road	Truro
25-027-0024	Uxbridge	Worcester	366 E. Hartford Avenue	Uxbridge
25-015-4002	Ware	Hampshire	Quabbin Hill Road	Ware
25-021-2004	Weymouth	Norfolk	6 Bridge Street	Weymouth
25-027-0015	Worcester - Airport	Worcester	375 Airport Drive	Worcester
25-027-0023	Worcester - Summer St	Worcester	260 Asylum Street	Worcester
25-007-0001	Aquinnah	Dukes	1 Herring Creek Road	Martha's Vineyard

Figure 2-3: Air Monitoring Site Descriptions

Site ID	Site Name	Scale	Reason for Monitor	Date Established	MSA / MiSA
25-025-0002	Boston - Kenmore	Neighborhood/Micro	Highest Concentration; Population Exposure	1/1/1965	Boston-Cambridge-Newton MSA
25-025-0042	Boston - Harrison Ave	Neighborhood	Population Exposure	12/15/1998	Boston-Cambridge-Newton MSA
25-025-0044	Boston - Von Hillern	Middle	Population Exposure; Highest Concentration	6/15/2013	Boston-Cambridge-Newton MSA
25-023-0005	Brockton	Urban/Neighborhood	Population Exposure	6/30/2013	Boston-Cambridge-Newton MSA
25-017-0009	Chelmsford - EPA	Neighborhood	Population Exposure	4/1/2005	Boston-Cambridge-Newton MSA
25-017-0010	Chelmsford - Near Road	Middle	Population Exposure	7/1/2018	Boston-Cambridge-Newton MSA
25-013-0008	Chicopee	Urban	Population Exposure	1/1/1983	Springfield MSA
25-005-1006	Fairhaven	Regional	Population Exposure	6/30/2013	Providence-Warwick MSA
25-005-1004	Fall River	Neighborhood	Population Exposure	2/1/1975	Providence-Warwick MSA
25-011-2005	Greenfield	Regional/Neighborhood	Population Exposure	1/1/2014	Greenfield Town MiSA
25-009-5005	Haverhill	Regional/Neighborhood	Population Exposure	7/19/1994	Boston-Cambridge-Newton MSA
25-009-2006	Lynn	Urban/Neighborhood	PAMS - Max Precursor O_3; Population Exposure	1/1/1992	Boston-Cambridge-Newton MSA
25-021-3003	Milton - Blue Hill	Regional	Upwind Background $PM_{2.5}$; Highest O_3	4/2/2002	Boston-Cambridge-Newton MSA
25-003-6001	North Adams	Neighborhood	Population Exposure	7/1/2017	Pittsfield MSA
25-003-0008	Pittsfield	Regional/Neighborhood	Population Exposure	7/1/2018	Pittsfield MSA
25-013-0018	Springfield	Urban	Highest Concentration; Population Exposure	5/1/2018	Springfield MSA
25-001-0002	Truro	Regional	General Background	4/1/1987	Barnstable Town MSA
25-027-0024	Uxbridge	Regional	Ozone Transport; Population Exposure	11/1/2008	Worcester MSA
25-015-4002	Ware	Urban	Maximum O_3; Background other pollutants	6/1/1985	Springfield MSA
25-021-2004	Weymouth	Micro/Neighborhood	Source Impact	2/4/2020	Boston-Cambridge-Newton MSA
25-027-0015	Worcester - Airport	Urban	Population Exposure	5/7/1979	Worcester MSA
25-027-0023	Worcester - Summer St	Urban/Middle	Population Exposure	1/1/2004	Worcester MSA
25-007-0001	Aquinnah	Regional	Regional	4/1/2004	Vineyard Haven MiSA

MSA = Metropolitan Statistical Area
MiSA = Micropolitan Statistical Area

Figure 2-4: Site Parameters

Site ID	Site Name	Meteorological	Pollutants
25-025-0002	Boston - Kenmore	None	SO_2, NO_2, $PM_{2.5}$
25-025-0042	Boston - Harrison Ave	WS/WD, TEMP, RH, BP, SOLAR	O_3, SO_2, NO_2, NOy, CO, PM_{10}, $PM_{2.5}$, PM_{Coarse}, $PM_{2.5}$Speciation, Black Carbon, VOCs, Carbonyls
25-025-0044	Boston - Von Hillern	WS/WD, TEMP, RH, BP, SOLAR	NO_2, CO, $PM_{2.5}$, Black Carbon
25-023-0005	Brockton	None	O_3, $PM_{2.5}$
25-017-0009	Chelmsford - EPA	None	O_3
25-017-0010	Chelmsford - Near Road	None	O_3, NO_2, $PM_{2.5}$, Black Carbon
25-013-0008	Chicopee	WS/WD, TEMP, RH, BP, SOLAR	O_3, NO_2, $PM_{2.5}$, $PM_{2.5}$Speciation
25-005-1006	Fairhaven	WS/WD, TEMP, RH, BP, SOLAR	O_3
25-005-1004	Fall River	None	O_3, SO_2, $PM_{2.5}$
25-011-2005	Greenfield	WS/WD, TEMP, RH, BP, SOLAR	O_3, $PM_{2.5}$, Black Carbon
25-009-5005	Haverhill	WS/WD, TEMP, RH, BP, SOLAR	O_3, $PM_{2.5}$
25-009-2006	Lynn	WS/WD, TEMP, RH, BP, SOLAR, PRECIP	O_3, NO_2, $PM_{2.5}$, VOCs, Carbonyls
25-021-3003	Milton - Blue Hill	WS/WD, TEMP, RH, BP, SOLAR	O_3, NO_2
25-003-6001	North Adams	None	$PM_{2.5}$, Black Carbon
25-003-0008	Pittsfield	WS/WD, TEMP, RH, BP, SOLAR	O_3, $PM_{2.5}$, Black Carbon
25-013-0018	Springfield	None	SO_2, NO_2, $PM_{2.5}$, Black Carbon
25-001-0002	Truro	WS/WD, TEMP, RH, BP, SOLAR	O_3
25-027-0024	Uxbridge	WS/WD, TEMP, RH, BP, SOLAR	O_3
25-015-4002	Ware	WS/WD, TEMP, RH, BP, SOLAR, PRECIP	O_3, SO_2, NO_2, PM_{10}, $PM_{2.5}$, NOy
25-021-2004	Weymouth	None	$PM_{2.5}$, VOCs, Carbonyls
25-027-0015	Worcester - Airport	WS/WD, TEMP, RH, BP, SOLAR	O_3
25-027-0023	Worcester - Summer St	None	SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$
25-007-0001	Aquinnah	None	O_3

Figure 2-5: Sampling and Analytical Methods

Parameter	Sample Method	Analytical Method	Sample Frequency	Comments
O_3	Continuous monitor	UV Light Photometry	Continuous / Hourly	
CO	Continuous monitor	GFC; NDIR Detection	Continuous / Hourly	
SO_2	Continuous monitor	UV Fluorescence	Continuous / Hourly	
$NO/NO_2/NOx$	Continuous monitor	Chemiluminescence	Continuous / Hourly	
$NO/NO_2/NOx$	Continuous monitor	CAPS Spectroscopy	Continuous / Hourly	PAMS
NOy	Continuous monitor	Chemiluminescence	Continuous / Hourly	
Lead	Low Volume PM_{10}	ICP/MS x-ray fluorescence	One 24-hr sample every 6 days	NATTS
PM_{10}	Size Selective, Low Volume	Gravimetric	One 24-hr sample every 6 days	
$PM_{2.5}$	Size Selective, Low Volume	Gravimetric	One 24-hr sample every 3 to 6 days	FRM
$PM_{2.5}$	Continuous monitor	Beta Attenuation	Hourly	FEM
$PM_{2.5}$Speciation	Low Volume; Size Selective	ICP/MS x-ray fluorescence, Ion chromatography	One 24-hr sample every 3 days	NCore
$PM_{2.5}$Speciation	Low Volume; Size Selective	IMPROVE Protocol	One 24-hr sample every 6 days	IMPROVE
Black Carbon	Continuous monitor	Optical Transmittance	Continuous / Hourly	
Metals	Low Volume PM_{10}	ICP/MS x-ray fluorescence	One 24-hr sample every 6 days	NATTS
PAHs	Quartz Filter, PUF Cartridge	GC/MS	One 24-hr sample every 6 days	NATTS
VOCs	Sub-ambient trapping	Auto GC	Hourly	PAMS
VOCs	Passivated Canister	GC/MS	One 24-hr sample every 6 days	NATTS/PAMS
Carbonyls	DNPH on Silica Gel Traps	HPLC	One 24-hr sample every 6 days	NATTS
Carbonyls	DNPH on Silica Gel Traps	HPLC	Eight 3-hr samples every 3rd day	PAMS
Wind Speed/Direction	Continuous monitor	Ultrasonic Sensors	Hourly	
Solar	Continuous monitor	Pyranometer	Hourly	
Relative Humidity	Continuous monitor	Electronic Sensor	Hourly	
Ambient Temperature	Continuous monitor	Electronic Thermistor	Hourly	
Barometric Pressure	Continuous monitor	Electronic Sensor	Hourly	
Precipitation	Continuous monitor	Tipping Bucket	Hourly	

O_3 = Ozone
UV = Ultraviolet
CO = Carbon Monoxide
GFC = Gas Filter Correlation
NDIR = Non-Dispersive Infrared
SO_2 = Sulfur Dioxide
$NO/NO_2/NOx$ = Nitric Oxide/Nitrogen Dioxide/Nitrogen Oxides CAPS = Cavity Attenuated Phase Shift
PAMS = Photochemical Assessment Monitoring Stations
NOy = Total Reactive Oxidized Nitrogen
ICP = Inductively Coupled Plasma
MS = Mass Spectrometry
VOCs = Volatile Organic Compounds Auto
GC = Automated Gas Chromatography
PAHs = Polycyclic Aromatic Hydrocarbons
PUF = Polyurethane Foam
GC/MS = Gas Chromatography Mass Spectrometry
NATTS = National Air Toxics Trends Station
DNPH = Dinitrophenylhydrazine
HPLC = High Performance Liquid Chromatography

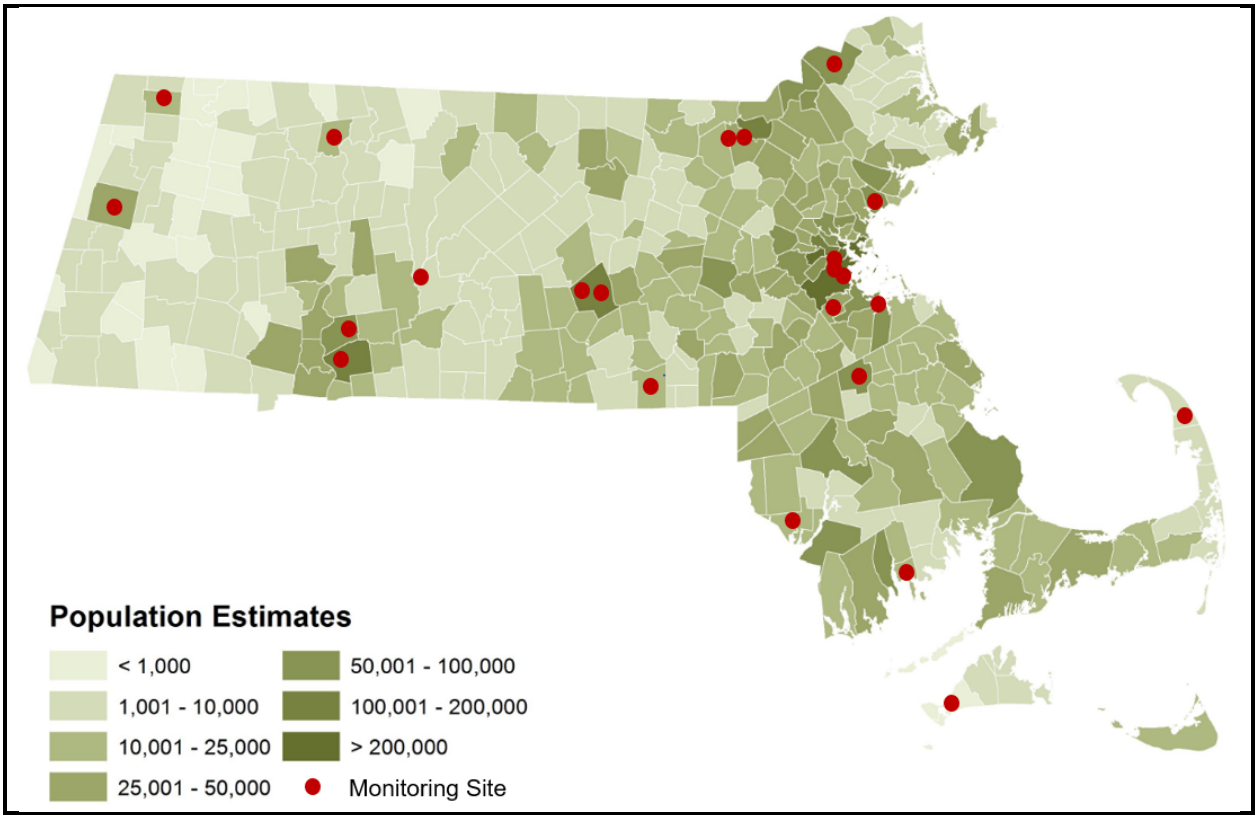
III. MASSACHUSETTS POPULATION

MassDEP believes the air monitoring network is appropriately designed given the demographic, spatial, and health characteristics of the Massachusetts population:

- There have been no major population shifts Massachusetts in the past 5 years. The shifts that have occurred have moved population closer to areas with existing monitors (e.g., urban areas).
- Sensitive populations are adequately covered by air monitoring, and pollutant levels are well below National Ambient Air Quality Standards.
- EJ areas are well covered by air monitors.

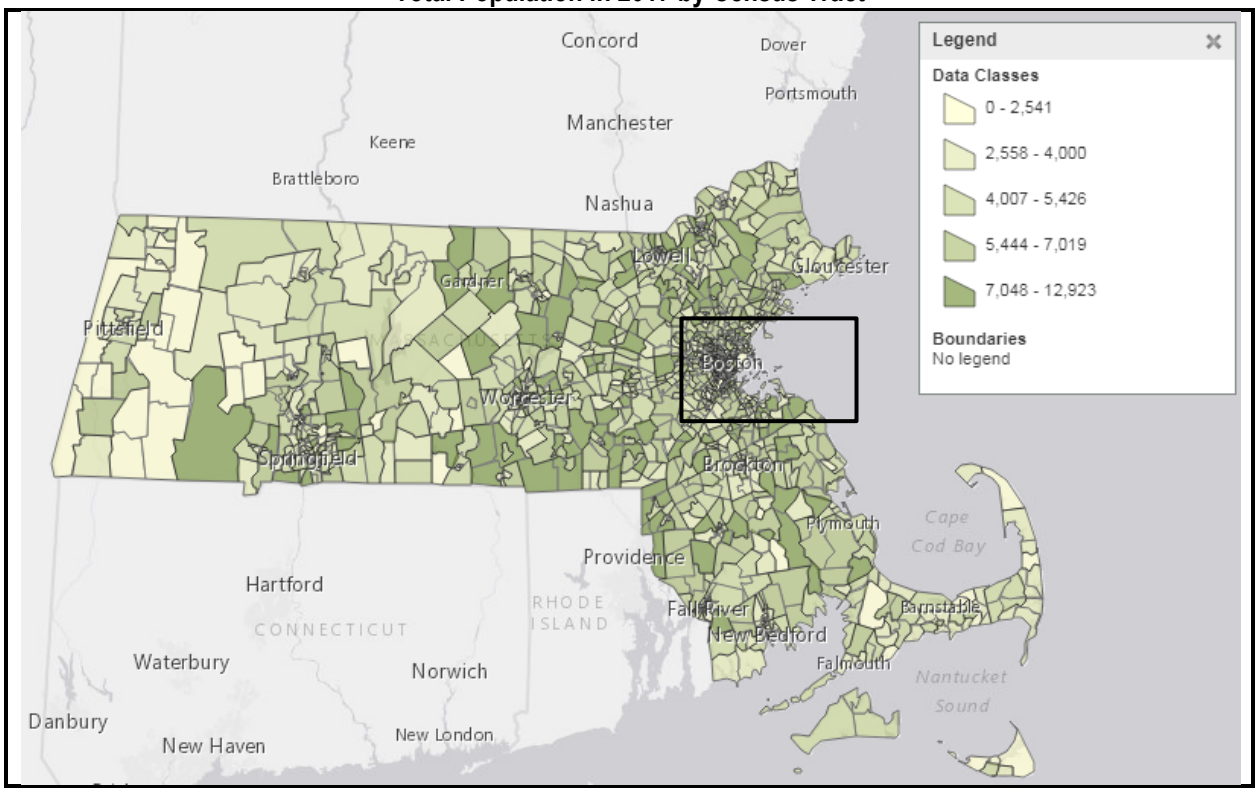
The U.S. Census Bureau estimates that as of 2018, Massachusetts had just over 6.9 million inhabitants in 351 towns/cities and 14 counties. The vast majority of the population is concentrated in the Boston metropolitan area, with additional concentrations in the Springfield and Worcester areas as shown in Figure 3-1 (based on US Census Annual Estimates of the Resident Population).

Figure 3-1
2018 Estimated Population of Massachusetts Municipalities with Air Monitoring Stations



Source – US Census - Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2018.

Figure 3-1.1
Total Population in 2017 by Census Tract



Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates
https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_B01003&prodType=table

Population Growth

The U.S. Census Bureau estimates that Massachusetts' population has grown by approximately 5% percent between 2010 and 2018, with the largest percent increases in Suffolk, Nantucket, and Middlesex counties (see Figure 3-2). Rural areas such as Barnstable, Berkshire and Franklin counties seen small population decreases. However, because the total growth in all counties has been small, no county's proportional share of the total statewide population changed by more than + / – 0.4% between 2010 and 2018.

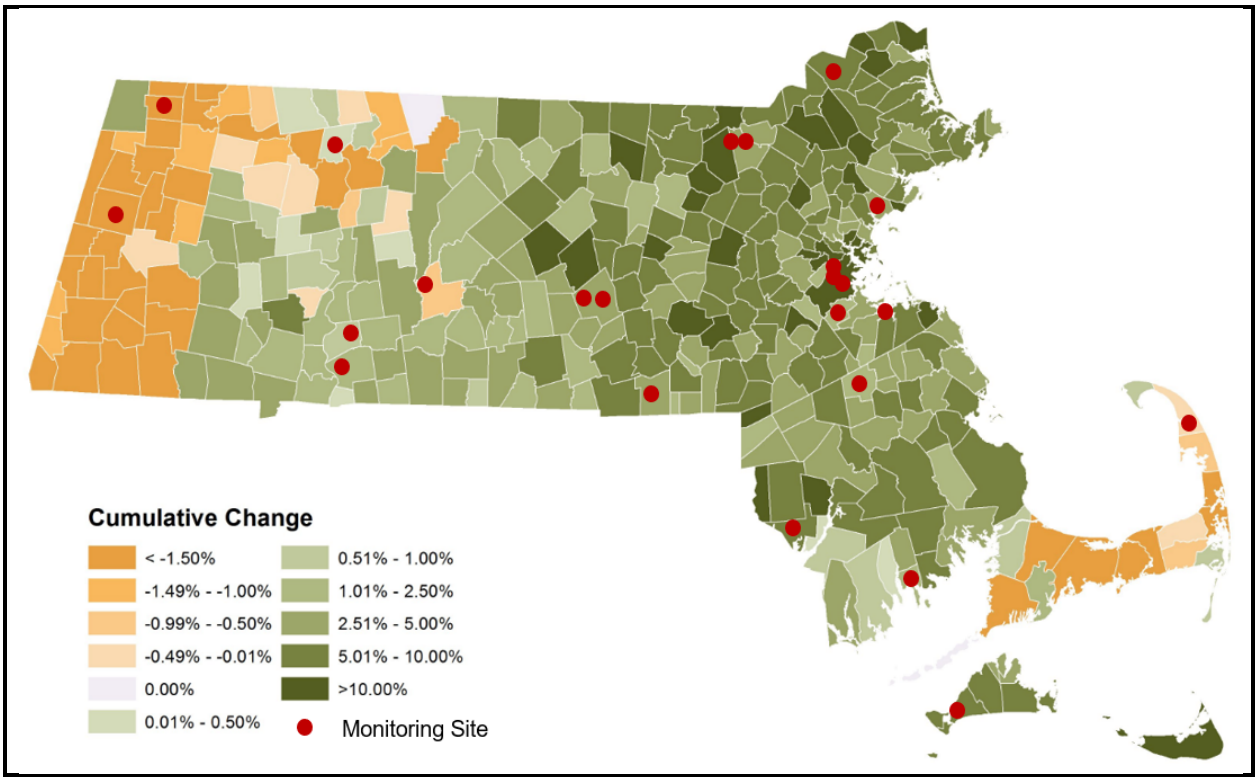
Figure 3-2
Massachusetts Population Change 2010 – 2018

	Population			% of State Population			Change 2010 - 2018	
County	2010	2015	2018	2010	2015	2018	Total	%
Barnstable	215,893	213,811	213,413	3.3%	3.1%	3.1%	-2,480	-1.1%
Berkshire	131,319	127,857	126,348	2.0%	1.9%	1.8%	-4,971	-3.8%
Bristol	549,177	556,878	564,022	8.4%	8.2%	8.2%	14,845	2.7%
Dukes	16,572	17,275	17,352	0.3%	0.3%	0.3%	780	4.7%
Essex	745,479	777,175	790,638	11.4%	11.4%	11.5%	45,159	6.1%
Franklin	71,366	70,902	70,963	1.1%	1.0%	1.0%	-403	-0.6%
Hampden	464,256	469,230	470,406	7.1%	6.9%	6.8%	6,150	1.3%
Hampshire	159,320	160,768	161,355	2.4%	2.4%	2.3%	2,035	1.3%
Middlesex	1,507,693	1,585,775	1,614,714	23.0%	23.3%	23.4%	107,021	7.1%
Nantucket	10,167	10,945	11,327	0.2%	0.2%	0.2%	1,160	11.4%
Norfolk	673,039	694,787	705,388	10.2%	10.2%	10.2%	32,349	4.8%
Plymouth	495,930	509,146	518,132	7.6%	7.5%	7.5%	22,202	4.5%
Suffolk	725,819	782,962	807,252	11.1%	11.5%	11.7%	81,433	11.2%
Worcester	800,401	818,380	830,839	12.2%	12.0%	12.0%	30,438	3.8%
Total	6,566,431	6,795,891	6,902,149	100.0%	100.0%	100.0%	335,718	5.1%

Source: U.S. Census Bureau, Population Division
Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2018
Release Dates: April 2019

Figure 3-3 shows population change at the municipal level from 2010 to 2018. The figure shows modest population changes, including slight decreases in Western Massachusetts and Cape Cod and increases in Eastern Massachusetts. Generally, these changes would not indicate a need to reconfigure the network, and areas showing population growth have adequate monitoring coverage.

Figure 3-3
Massachusetts Population Change 2010 – 2018



Source – US Census - Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2018.

MassDEP used EPA's Population Served Network Assessment Tool and NetAssess2020 (https://sti-r-shiny.shinyapps.io/EPA_Network_Assessment/) to calculate the population served by each monitor. These tools compute shapes known as Voronoi or Thiessen polygons that are used as an indicator of the area served by each monitor. A Voronoi polygon is the shape formed by the line connecting the points equidistant between a given monitor and each of the other monitors closest to it. The area within the shape created by the lines surrounding the monitor is geographically closer to that monitor than to any other monitor in the network and is therefore considered an approximation of its coverage area. Note that this is a mathematical construct. Geographic features such as hills or valleys, manmade features such as pollution sources, meteorology, and the development pattern of an area could make the actual area represented by a monitor different from its polygon. Nevertheless, these polygons provide a reasonable starting point for looking at the area served by the monitors.

These network assessment tools calculated populations within each polygon and the results are presented in Figure 3-4 (see Section 5 maps showing the polygons). Note that 2018 was the latest population data available.

Figure 3-4
Change in Population in Voronoi Polygon for Each $PM_{2.5}$ Monitor: 2010 to 2018

Site ID	Site Name	Population Served			% of Total Population Served		
		2010	2018	Growth	2010*	2018	Change
25-005-1004	Fall River	386,913	476,726	23%	6%	7%	1%
25-009-2006	Lynn	445,800	591,026	33%	7%	9%	2%
25-009-5005	Haverhill	227,031	413,740	82%	4%	6%	2%
25-013-0008	Chicopee	248,630	230,123	-7%	4%	4%	0%
25-015-4002	Ware	117,547	118,289	1%	2%	2%	0%
25-025-0002	Boston - Kenmore	883,390	1,051,918	19%	15%	16%	1%
25-025-0042	Boston - Harrison Ave	183,079	347,811	90%	3%	5%	2%
25-027-0023	Worcester - Summer St	440,462	730,898	66%	7%	11%	4%
25-025-0044	Boston - Von Hillern	259,286	274,168	59%	4%	4%	0%
25-023-0005	Brockton	717,147	758,288	23%	12%	12%	0%
25-011-2005	Greenfield	101,945	100,576	-1%	2%	2%	0%
25-003-6001	North Adams	NA	43,769	NA	NA	1%	NA
25-013-0018	Springfield	NA	402,000	NA	NA	6%	NA
25-017-0010	Chelmsford - Near Road	NA	538,361	NA	NA	8%	NA
25-003-0008	Pittsfield	NA	105,701	NA	NA	2%	NA
25-021-2004	Weymouth	NA	265,694	NA	NA	4%	NA

Site ID	Site Name	2018 Demographics				$PM_{2.5}$ Monitoring	
		Age < 15	Age 65+	Sensitive	Minority	Monitor Type	Probability >35 µg/m³
25-005-1004	Fall River	80,358	79,569	159,927	80,497	FEM	<10%
25-009-2006	Lynn	104,858	91,124	195,982	155,954	FEM	<10%
25-009-5005	Haverhill	83,242	50,998	134,240	152,496	FRM/FEM	<10%
25-013-0008	Chicopee	35,442	32,382	67,824	70,392	FRM/FEM	<10%
25-015-4002	Ware	21,435	15,755	37,190	9,671	FEM	<10%
25-025-0002	Boston - Kenmore	150,018	130,916	280,934	330,106	FRM	<10%
25-025-0042	Boston - Harrison Ave	64,715	44,805	109,520	216,548	FRM/FEM	<10%
25-027-0023	Worcester - Summer St	140,249	92,630	232,879	183,714	FRM/FEM	<10%
25-025-0044	Boston - Von Hillern	44,994	29,680	74,674	180,097	FRM/FEM	<10%
25-023-0005	Brockton	137,536	120,203	257,739	139,654	FRM/FEM	<10%
25-011-2005	Greenfield	15,649	15,022	30,671	9,940	FRM/FEM	<10%
25-003-6001	North Adams	6,495	7,806	14,301	3,572	FEM	<10%
25-013-0018	Springfield	75,991	56,132	132,123	168,692	FRM/FEM	<10%
25-017-0010	Chelmsford - Near Road	107,098	68,816	175,914	122,749	FEM	<10%
25-003-0008	Pittsfield	16,627	19,670	36,297	11,621	FEM	<10%
25-021-2004	Weymouth	47,333	42,192	89,525	50,686	FEM	<10%

Source: U.S. Census through NetAssess2020
* As stated in the 2015 Network Assessment which included additional sites that have since been shut down.

Notes about Figure 3-4:

- Changes to the $PM_{2.5}$ network since the 2015 assessment:
  - North Adams, Chelmsford – Near Road, and Weymouth sites were added.
  - Monitors at Milton – Blue Hill, Lawrence, North End, and Worcester – Washington Street sites were discontinued.
  - Springfield and Pittsfield sites were moved to new locations within the same municipal boundaries.
- Most sites experienced significant population gains since 2010. Only two sites experienced population losses: Chicopee (-7%) and Greenfield (-1%).
- The Boston – Kenmore, Brockton and Worcester – Summer Street polygons serve the largest populations. Together these three sites account for 41% of the total population served. North Adams serves the smallest population at about 1%.
- The largest change in total population served and population share is at Worcester – Summer Street (+290,436 and +4%).
- Sensitive populations at all sites account for between 27% to 34% of the populations served. Boston – Kenmore and Boston – Von Hillern showed the lowest sensitive population share (27%), while Fall River, Brockton, Pittsfield and Weymouth showed the highest sensitive population share (34%).
- Boston – Von Hillern serves the highest minority population by percentage (66%) and Boston – Kenmore serves the largest minority population in total (330,106).
- All sites in the network have very low (<10%) probabilities of exceeding the 24-hour $PM_{2.5}$ NAAQS of 35 $\mu g/m^3$.

Figure 3-5
Change in Population in Voronoi Polygon for Each Ozone Monitor: 2018 to 2010

Site ID	Site Name	Population Served			% of Total Population Served		
		2010	2018	Growth	2010*	2018	Change
25-001-0002	Truro	114,294	127,567	12%	2%	2%	0%
25-005-1004	Fall River	195,043	232,712	19%	3%	4%	1%
25-009-2006	Lynn	530,743	648,062	22%	9%	10%	1%
25-009-5005	Haverhill	377,233	423,004	12%	6%	7%	1%
25-013-0008	Chicopee	544,158	544,158	0%	9%	8%	-1%
25-015-4002	Ware	83,452	79,877	-4%	1%	1%	0%
25-021-3003	Milton - Blue Hill	486,526	460,672	-5%	8%	7%	-1%
25-025-0042	Boston - Harrison Ave	1,372,383	1,384,784	1%	22%	22%	0%
25-027-0015	Worcester - Airport	474,637	474,595	0%	8%	7%	-1%
25-007-0001	Aquinnah	40,167	59,299	48%	1%	1%	0%
25-017-0009	Chelmsford - EPA	465,395	458,645	-1%	8%	7%	-1%
25-027-0024	Uxbridge	446,291	446,291	0%	7%	7%	0%
25-005-1006	Fairhaven	265,898	306,157	15%	4%	5%	1%
25-023-0005	Brockton	501,608	551,096	10%	8%	9%	1%
25-011-2005	Greenfield	105,142	101,933	-3%	2%	2%	0%
25-003-0008	Pittsfield	NA	123,680	NA	NA	2%	NA

Site ID	Site Name	2018 Demographics				O_3 Probability of Exceeding 70 ppb
		Age < 15	Age 65+	Sensitive	Minority	
25-001-0002	Truro	16,114	34,431	50,545	12,547	<10%
25-005-1004	Fall River	39,200	38,122	77,322	25,811	10%-25%
25-009-2006	Lynn	115,184	98,302	213,486	179,593	50%-75%
25-009-5005	Haverhill	85,646	51,886	137,532	155,146	<10%
25-013-0008	Chicopee	97,034	74,899	171,933	224,822	>90%
25-015-4002	Ware	14,399	10,628	25,027	7,282	25%-50%
25-021-3003	Milton - Blue Hill	89,968	68,119	158,087	121,186	<10%
25-025-0042	Boston - Harrison Ave	200,278	164,999	365,277	625,171	<10%
25-027-0015	Worcester - Airport	88,739	61,561	150,300	136,172	10%-25%
25-007-0001	Aquinnah	8,703	12,942	21,645	7,768	<10%
25-017-0009	Chelmsford - EPA	91,900	58,353	150,253	108,362	<10%
25-027-0024	Uxbridge	89,362	54,895	144,257	86,467	10%-25%
25-005-1006	Fairhaven	53,999	48,096	102,095	57,709	<10%
25-023-0005	Brockton	107,889	74,783	182,672	109,068	<10%
25-011-2005	Greenfield	15,908	15,240	31,148	9,976	<10%
25-003-0008	Pittsfield	19,241	23,076	42,317	12,891	10%-25%

Source: U.S. Census through NetAssess2020
* As stated in the 2015 Network Assessment which included additional sites that have since been shut down.

Notes about Figure 3-5:

- Changes to the ozone network since the 2015 assessment:
  - Pittsfield site was added.
  - The Newburyport site was discontinued.
- The Roxbury polygon is significantly larger than all other sites, representing 22% of the total population served. The Aquinnah and Ware polygons are the smallest, representing about 1% each. The remainder ranged from about 2% to 10%.
- Seven sites (Truro, Fall River, Lynn, Haverhill, Aquinnah, Fairhaven, Brockton) experienced double-digit positive growth. Lynn experienced the largest growth by total number (117,319).
- Child populations at all sites account for between 13% to 20% of the populations served, and senior populations ranged between 12% to 27%. Truro showed the largest sensitive population by percentage at 40%. Boston – Harrison Ave shows the largest total number of sensitive receptors (365,277); however, it was also the smallest percentage of sensitive receptors as a percentage of the total population served at 26%.
- Boston – Harrison Ave shows the largest population of minorities as both a total number (625,171) and percentage (45%).
- Thirteen of the 16 sites show very low to low probabilities (<10% or 10%-25%) of an exceedance. Only Chicopee showed a probability >90%.

Figure 3-6
Change in Population in Voronoi Polygon for Each NO_2 Monitor: 2010 to 2018

Site ID	Site Name	Population Served			% of Total Population Served		
		2010	2018	Growth	2010*	2018	Change
25-009-2006	Lynn	681,639	753,187	10%	12%	12%	0%
25-013-0008	Chicopee	331,622	374,856	13%	6%	6%	0%
25-015-4002	Ware	262,804	271,701	3%	5%	4%	-1%
25-021-3003	Milton - Blue Hill	1,094,820	1,137,954	4%	19%	18%	-1%
25-025-0002	Boston - Kenmore	1,091,887	934,098	-14%	19%	15%	-4%
25-025-0042	Boston - Harrison Ave	186,988	186,988	0%	3%	3%	0%
25-027-0023	Worcester - Summer Street	799,807	860,631	8%	14%	14%	0%
25-025-0044	Boston - Von Hillern	429,349	450,782	5%	7%	7%	0%
25-013-0018	Springfield	NA	522,583	NA	NA	8%	NA
25-017-0010	Chelmsford - Near Road	NA	768,618	NA	NA	12%	NA

Site ID	Site Name	2018 Demographics			
		Age < 15	Age 65+	Sensitive	Minority
25-009-2006	Lynn	132,700	116,333	249,033	165,832
25-013-0008	Chicopee	58,675	56,190	114,865	84,981
25-015-4002	Ware	45,891	38,508	84,399	21,679
25-021-3003	Milton - Blue Hill	212,030	174,915	386,945	250,725
25-025-0002	Boston - Kenmore	126,031	114,871	240,902	297,795
25-025-0042	Boston - Harrison Ave	33,944	19,425	53,369	159,365
25-027-0023	Worcester - Summer Street	163,919	109,102	273,021	207,501
25-025-0044	Boston - Von Hillern	75,528	60,569	136,097	207,683
25-013-0018	Springfield	95,539	76,348	171,887	181,407
25-017-0010	Chelmsford - Near Road	155,249	96,824	252,073	264,697

Source: U.S. Census through NetAssess2020
* As stated in the 2015 Network Assessment which included additional sites that have since been shut down.

Notes about Figure 3-6:

- Changes to the NO_2 network since the 2015 assessment:
  - The Chelmsford – Near Road site was added.
  - The Newburyport site was discontinued.
  - The Springfield site was moved to a new location within the same municipal boundaries.
- Child populations at all sites account for between 13% to 20% of the populations served, and senior populations ranged between 10% to 15%. Blue Hill shows the largest sensitive population by percentage at 34% and by total number (386,945).
- Boston – Harrison Ave shows the largest population of minorities by percentage (85%); however, Boston – Kenmore shows the largest by total number (297,795).

- The population share for individual monitors may not be as significant for NO_2 as traffic counts and congestion since NO_2 is primarily a mobile source pollutant in Massachusetts, which limits the utility of the polygon analysis for NO_2.

Figure 3-7
Change in Population in Voronoi Polygon for Each SO_2 Monitor: 2010 to 2018

Site ID	Site Name	Population Served			% of Total Population Served		
		2010	2018	Growth	2010*	2018	Change
25-005-1004	Fall River	720,610	902,163	25%	13%	14%	1%
25-015-4002	Ware	223,576	253,751	13%	4%	4%	0%
25-025-0002	Boston - Kenmore	1,845,482	1,853,376	0%	34%	29%	-5%
25-025-0042	Boston - Harrison Ave	1,181,913	1,264,640	7%	22%	20%	-2%
25-027-0023	Worcester - Summer Street	833,068	867,746	4%	15%	13%	-2%
25-013-0018	Springfield	607,176	1,328,609	119%	11%	21%	9%

Site ID	Site Name	2018 Demographics			
		Age < 15	Age 65+	Sensitive	Minority
25-005-1004	Fall River	148,566	158,758	307,324	129,111
25-015-4002	Ware	40,110	33,524	73,634	29,127
25-025-0002	Boston - Kenmore	300,050	246,754	546,804	556,354
25-025-0042	Boston - Harrison Ave	230,132	171,136	401,268	509,587
25-027-0023	Worcester - Summer Street	166,251	110,391	276,642	202,125
25-013-0018	Springfield	242,876	184,840	427,716	555,225

Source: U.S. Census through NetAssess2020
* As stated in the 2015 Network Assessment which included additional sites that have since been shut down.

Notes about Figure 3-7:

- Changes to the SO_2 network since the 2015 assessment:
  - The Springfield site was moved to a new location within the same municipal boundaries.
- Springfield shows a significant change in population (+119%) compared to 2010. This may be due to changes in Connecticut's monitoring network. According to the NetAssess2020 tool, the Springfield polygon covers a large portion of Connecticut, including portions of Hartford.
- Child populations at all sites account for between 16% to 19% of the populations served, and senior populations ranged between 13% to 18%. Boston - Kenmore shows the largest sensitive population by total number (546,804); however, all show sensitive populations in the range of 29% to 34% of populations served.
- Springfield and Boston – Harrison Ave show the largest population of minorities by percentage (42% and 40%); however, Boston – Kenmore shows the largest by total number (556,354).
- The population share for individual monitors may not be as significant for SO_2 as the location of large stationary sources since SO_2 is primarily a point source pollutant, which limits the utility of the polygon analysis.

Since Massachusetts' population distribution has remained largely stable since 2010 and no significant shifts are expected in the future, MassDEP does not believe that it needs to change its network design based on population distribution.

Sensitive Populations

Children

The U.S. Census estimates that in 2017 there were 1,383,532 persons under the age of 18 years in Massachusetts comprising 20.4% of the population (down from about 21% in 2013).[1] Figure 3-8 shows the distribution of children by census tract for the state and Boston area. This distribution of children closely matches that of the general population. Figure 3-9 shows asthma prevalence in children throughout the state. Because the state is well covered by ozone and $PM_{2.5}$ monitors, the monitoring network provides good coverage for where children live and where pediatric asthma prevalence may be higher.

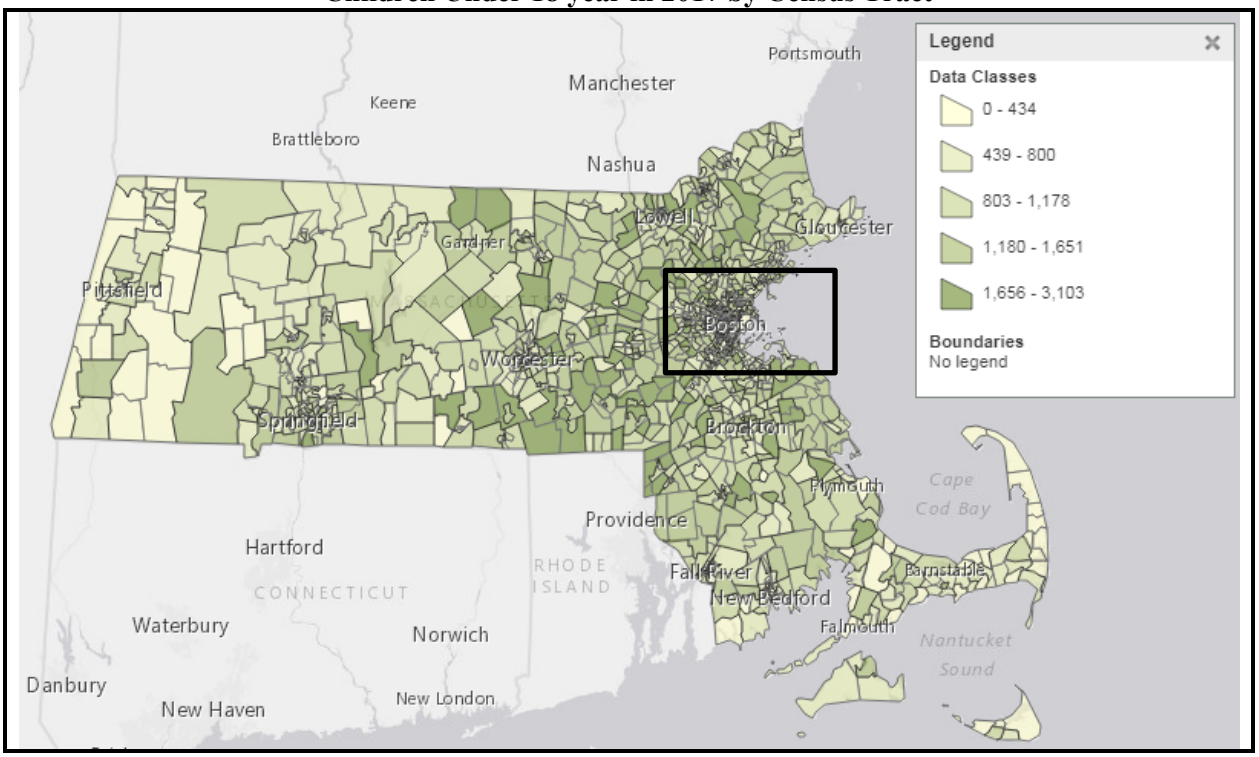
Elderly

The U.S. Census estimates that in 2017 there were 1,049,751 persons 65 years or older in Massachusetts comprising about 15.5% of the population.[2] Figure 3-10 shows the distribution of elders by census tract for the state and Boston area. This distribution closely matches that of the general population as shown in Figure 3-1.1. Because the state is well covered by ozone and $PM_{2.5}$ monitors, the monitoring network provides good coverage for where persons 65 years or older live.

[1] U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_DP05&prodType=table

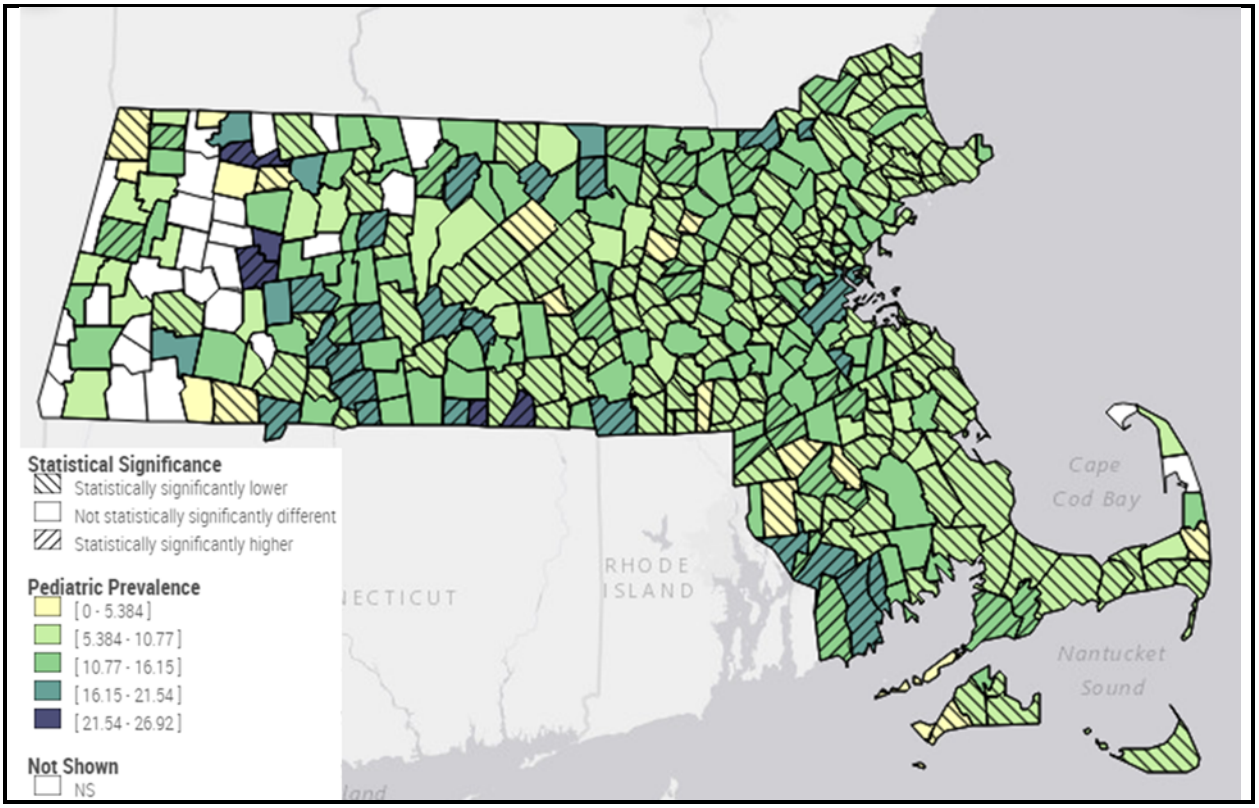
[2] U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_DP05&prodType=table

Figure 3-8
Children Under 18 year in 2017 by Census Tract



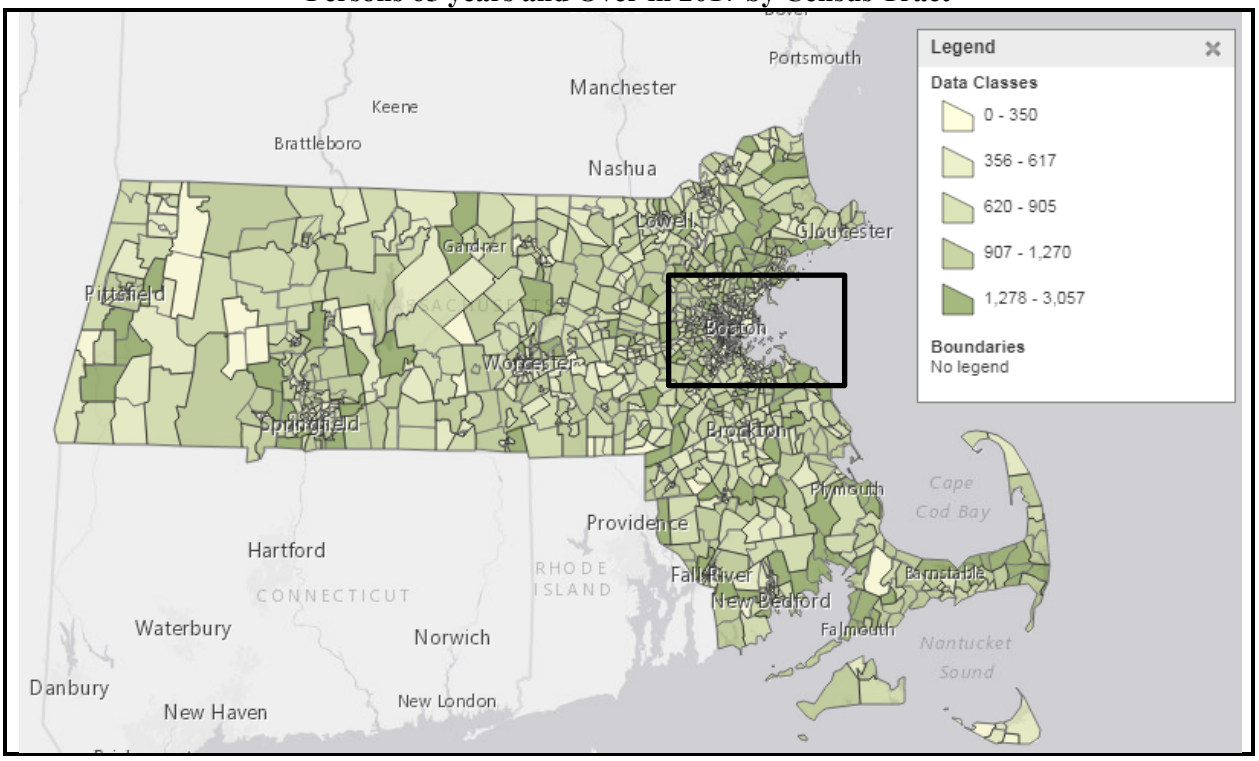
Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates
https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_DP05&prodType=table

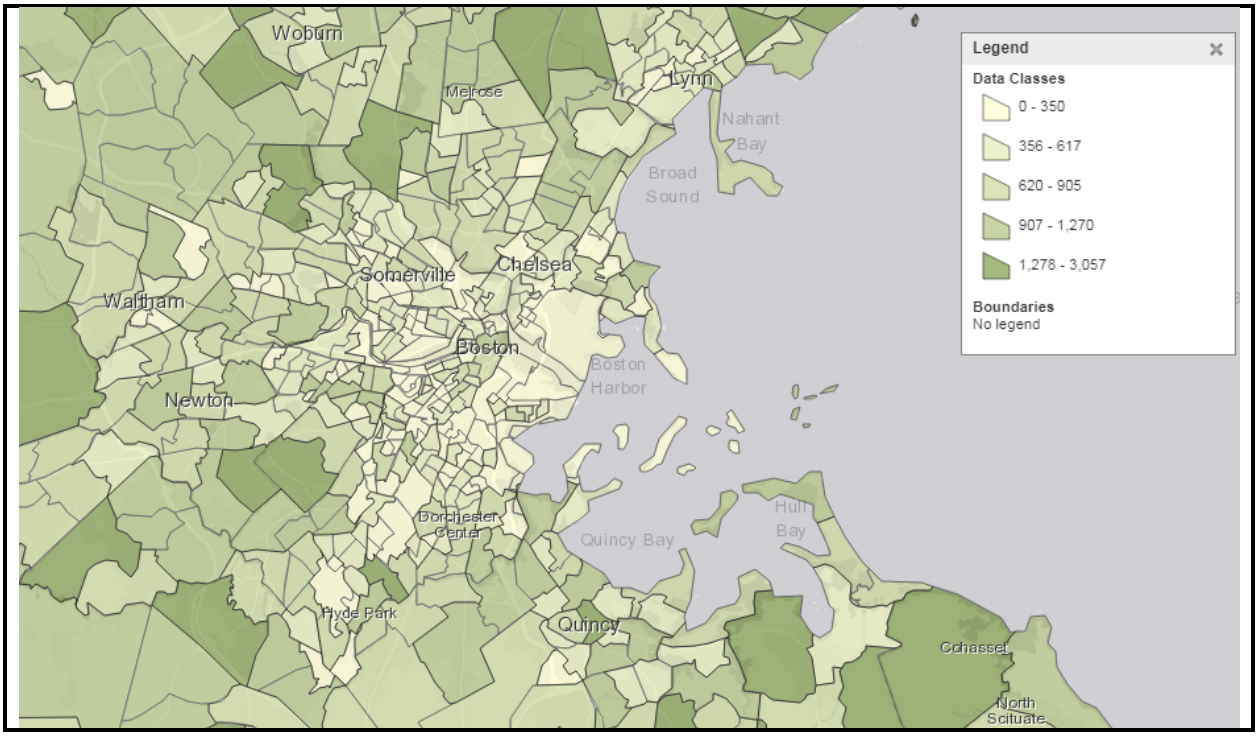
Figure 3-9
Pediatric Asthma Prevalence per 100 Students School Years 2016-2017 Ages 5-14



Source: Massachusetts Environmental Public Health Tracking system
https://matracking.ehs.state.ma.us/Health-Data/Asthma/index.html

Figure 3-10
Persons 65 years and Over in 2017 by Census Tract





Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates
https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_DP05&prodType=table

Environmental Justice Populations

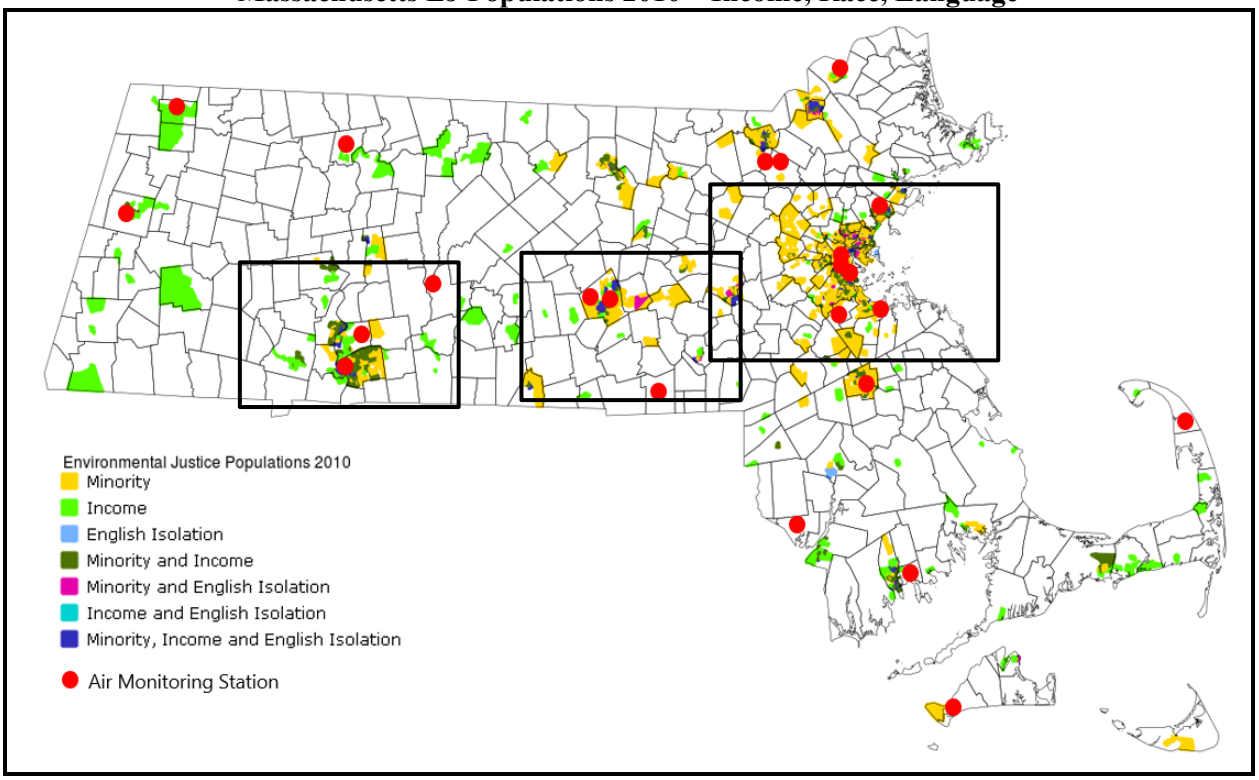
Figure 3-14 shows environmental justice (EJ) communities with monitoring stations overlaid. In Massachusetts a community is identified as an EJ community if any of the following are true:

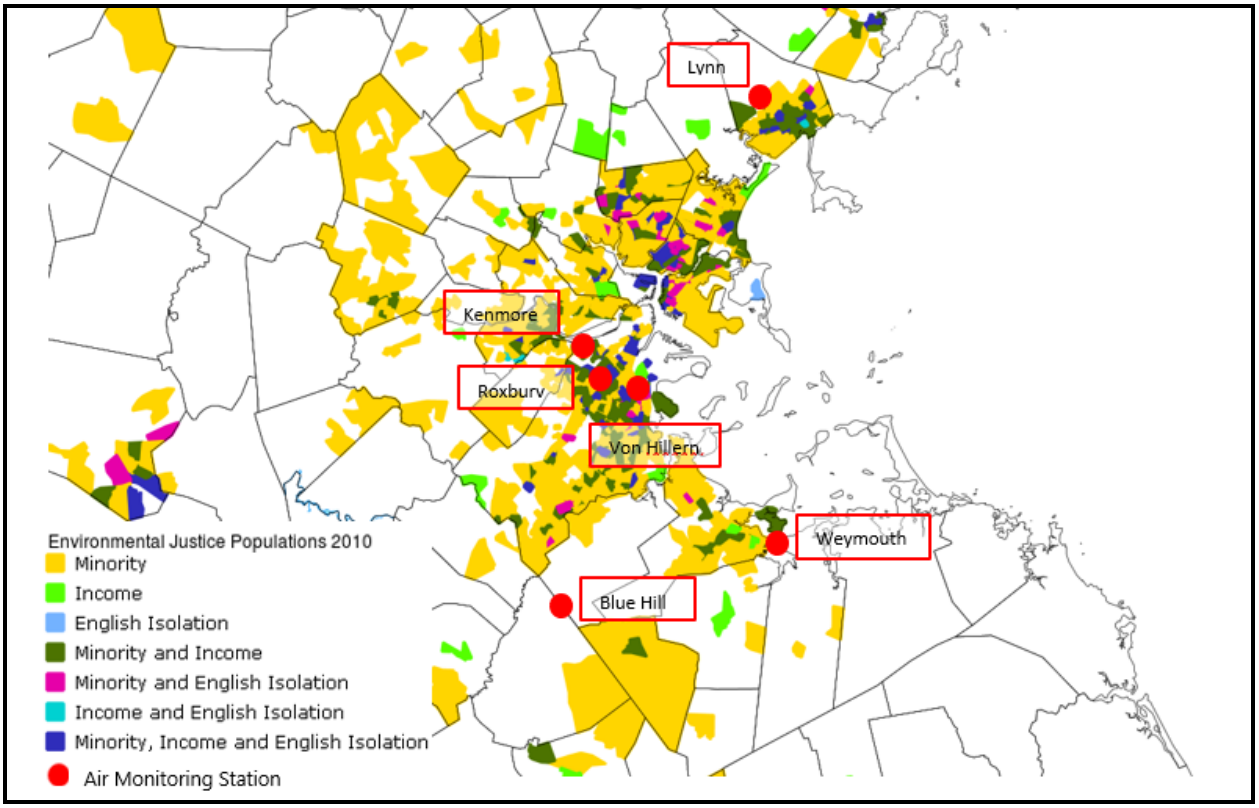
- Block group whose annual median household income is equal to or less than 65 percent of the statewide median; or
- 25% or more of the residents identify as a race other than white; or
- 25% or more of households have no one over the age of 14 who speaks English only or very well.

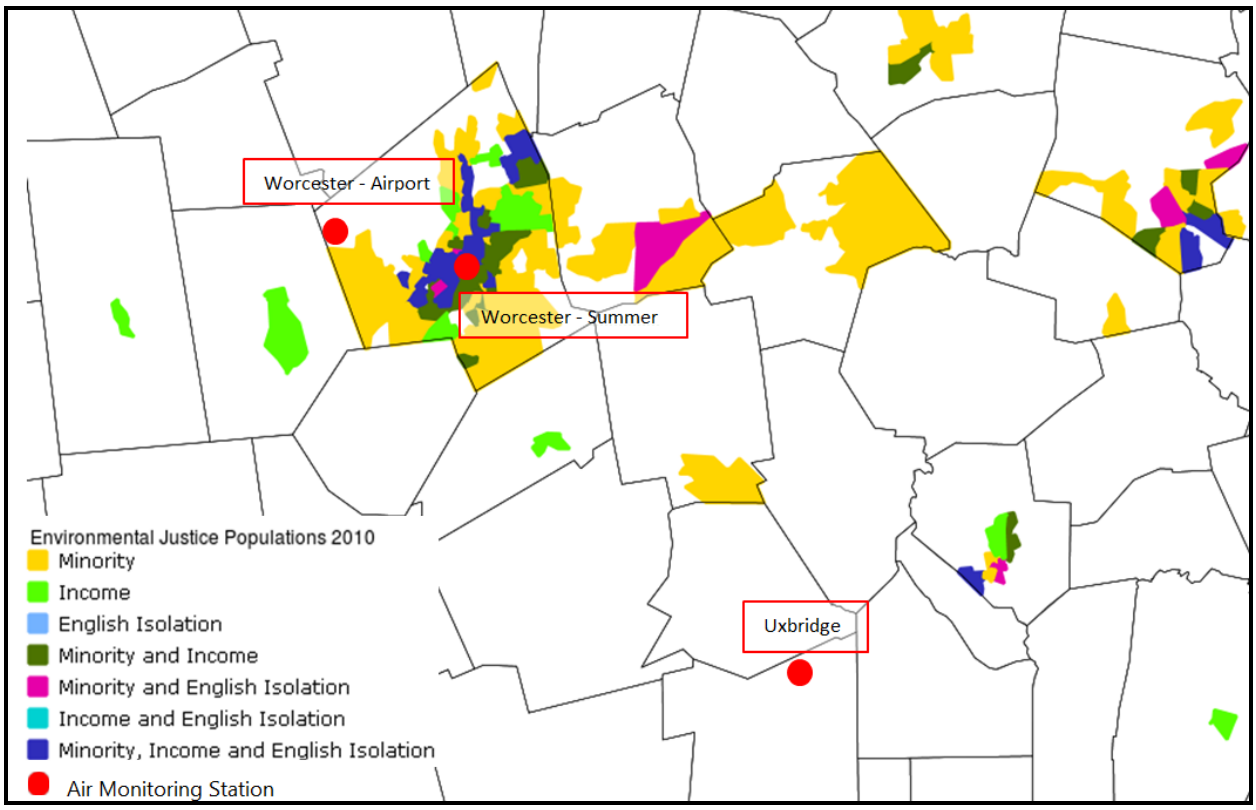
Based on the location of pollutant-specific monitors (as described in Section VI below), the following observations can be made:

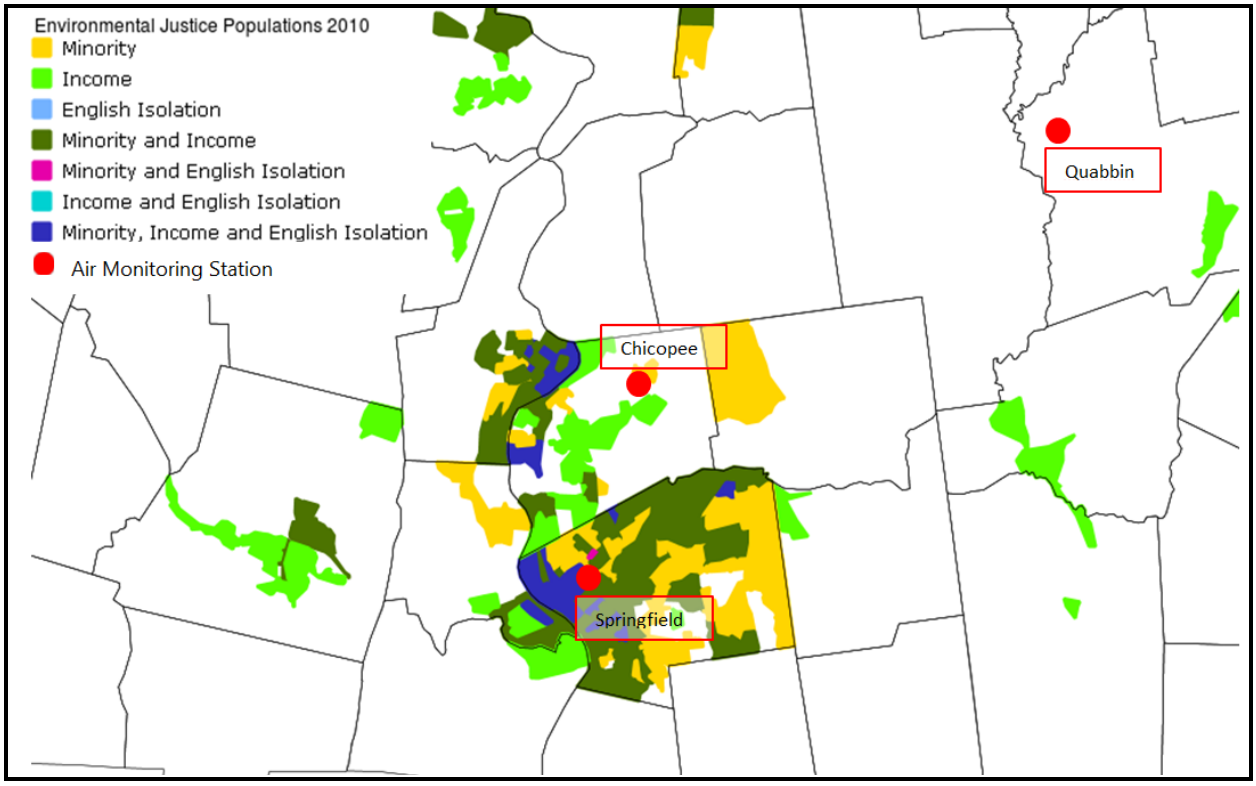
- $PM_{2.5}$ – Most of the larger clusters of urban EJ areas are adequately covered by $PM_{2.5}$ monitors. Urban EJ areas without $PM_{2.5}$ monitors (e.g., Leominster/Fitchburg and Framingham) generally would be expected to experience levels similar to other urban areas. Likewise, rural EJ areas in Western Massachusetts would be expected to experience levels similar to rural monitors in North Adams, Greenfield and Pittsfield. Importantly, $PM_{2.5}$ levels are well below the National Ambient Air Quality Standards statewide.
- Ozone – The state is adequately covered by ozone monitors, and levels do not vary dramatically over small distances.
- NO_2 – The near-road monitors at Chelmsford – Near Road and Boston – Von Hillern are designed to measure a maximum exposure level, and therefore generally would cover other areas of the state.
- SO_2 – The last coal-fired power station in Massachusetts, Brayton Point in Somerset, discontinued operations in 2017. SO_2 values throughout the state have remained very low for several years.
- CO – CO levels are so very low and have not been a concern for many years.

Figure 3-11
Massachusetts EJ Populations 2010 – Income, Race, Language









Source: MassGIS Environmental Justice Viewer
http://maps.massgis.state.ma.us/map_ol/ej.php

IV. AIR QUALITY SUMMARY

MassDEP believes that emissions trends in Massachusetts do not suggest a need to change the distribution of monitors throughout the state for the following reasons:

- The decline in emissions has been uniform across the State;
- The number of new major point sources is limited and those that are permitted are well controlled;
- Existing point sources are emitting less;
- The monitoring network is designed to characterize highest concentrations and general background concentrations and population exposures rather than the impacts of individual sources; and
- There has been no significant change in population or distribution of vehicle miles travelled across the state and therefore limited change in the distribution of area and mobile source emissions across the state.

Ozone and $PM_{2.5}$ continue to be important pollutants to monitor and MassDEP maintains an extensive ozone and $PM_{2.5}$ monitoring network. Several ozone monitors are located in the southern and eastern part of the state where ozone transport entering the state is most likely to occur. MassDEP monitors $PM_{2.5}$ and black carbon to characterize wood smoke emissions. Continuous and filter-based $PM_{2.5}$ monitors are located throughout the state. Black carbon monitors are located at Boston – Roxbury, Boston – Von Hillern, Chelmsford – Near Road, Greenfield, North Adams, Pittsfield, and Springfield.

National Ambient Air Quality Standards

Figure 4-1 shows the National Ambient Air Quality Standards (NAAQS) for the six criteria pollutants: ozone (O_3); nitrogen dioxide (NO_2); particulate matter (PM_{10} and $PM_{2.5}$); carbon monoxide (CO); sulfur dioxide (SO_2); and lead (Pb). EPA has classified Massachusetts as "attainment / unclassified" for all the NAAQS.

Figure 4-1

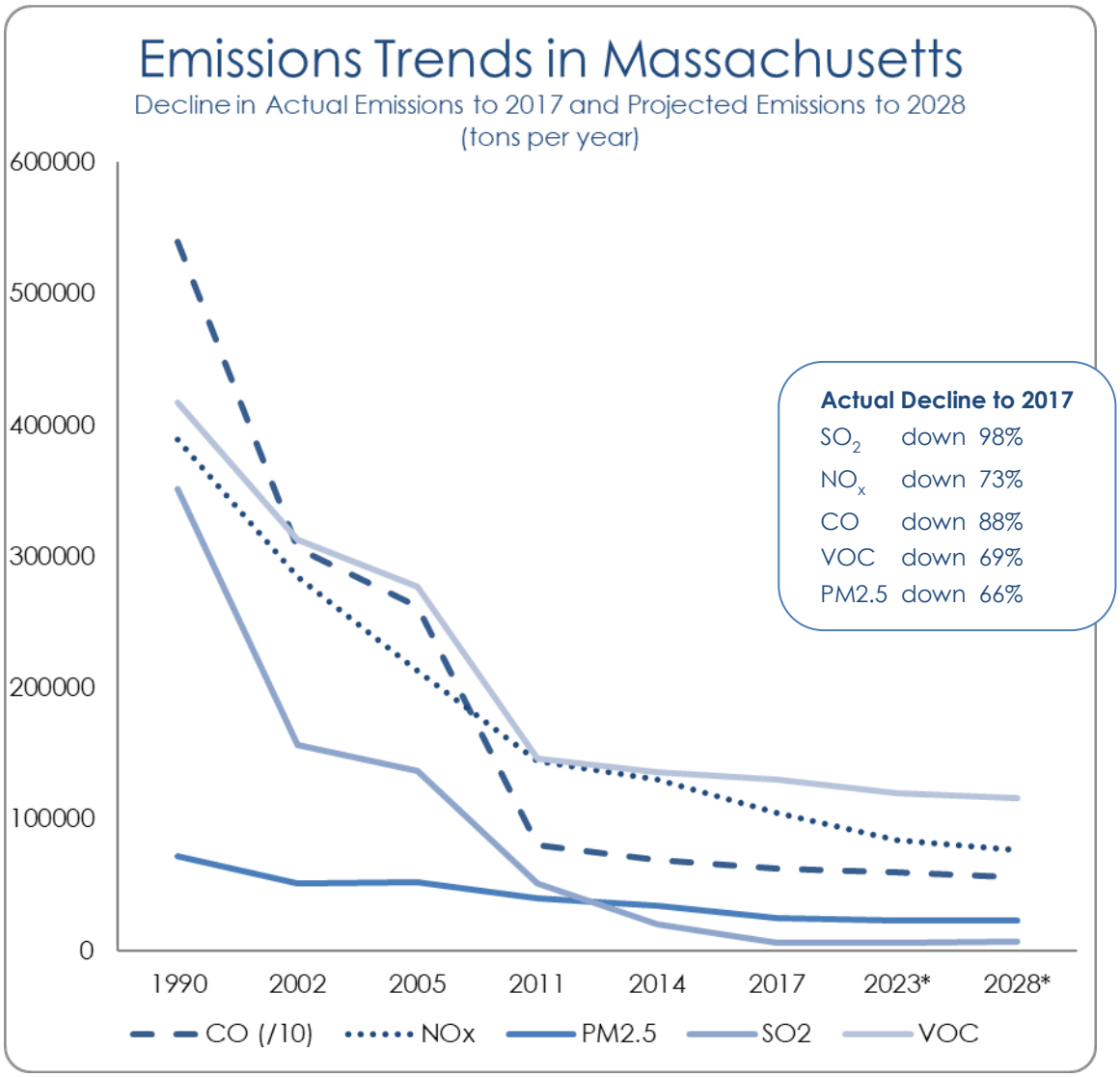
National Ambient Air Quality Standards					
Pollutant		**Primary/ Secondary**	**Averaging Time**	**Level**	**Form**
Carbon Monoxide		primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead		primary and secondary	Rolling 3-month average	0.15 μg/m^3	Not to be exceeded
Nitrogen Dioxide		primary	1-hour	100 ppb	98th percentile, averaged over 3 years
		primary and secondary	Annual	0.053 ppm	Annual Mean
Ozone		primary and secondary	8-hour	0.070 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particle Pollution	$PM_{2.5}$	primary	Annual	12 μg/m^3	annual mean, averaged over 3 years
		secondary	Annual	15 μg/m^3	annual mean, averaged over 3 years
		primary and secondary	24-hour	35 μg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24-hour	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide		primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Emissions Inventory Summary

Reductions in air pollution emissions since 1990 have led to significant improvements in air quality in Massachusetts. Figure 4-2 shows emissions reductions based on Massachusetts emissions inventory data from 1990 to 2017 (the most recent published inventory) and EPA projections to 2028, which show that the downward trends are expected to continue.

Figure 4-2

Source: MassDEP emissions inventories (file: Emissions by Pollutant County 2020.xlsx)



* Projected emissions from EPA 2016 Modeling Platform: ftp://newftp.epa.gov/air/emismod/2016/v1/reports/
Note: CO tons divided by 10 for ease of display with the other pollutants.

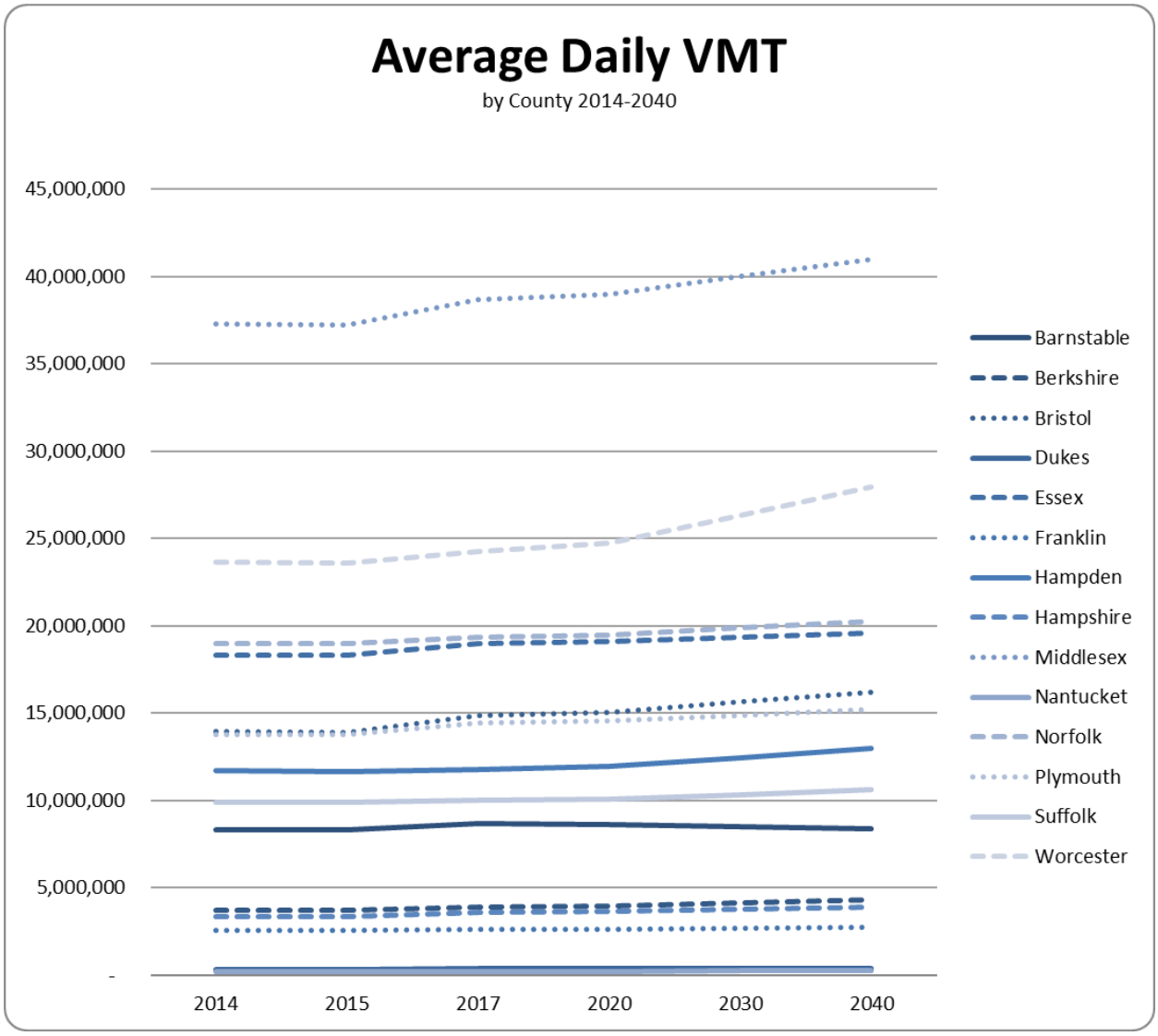
Vehicles make up one of the largest sources of VOC and NO_x emissions. Vehicle miles travelled (VMT) indicate the relative distribution and magnitude of those emissions. In the past, as VMT

increased, emissions increased. Today, due to new cleaner vehicles in the fleet, VMT does not always result in increased emissions.

Figure 4-3 shows there has been little change in the distribution of VMT across the state, and projections from the Massachusetts Department of Transportation (MassDOT) indicate this general distribution is expected to remain constant into the future. The one exception is Worcester County, where VMT is expected to rise gradually at a higher rate than other areas of the state. This change in VMT in Worcester County is not deemed significant for the purpose of designing the monitoring network.

Figure 4-3

Source: MassDOT Planning – emails from Bob Frey 5/15/2017 and 5/2/2019. Underlying sources: Highway Performance Monitoring System (HPMS), MassDOT Traffic Counting Program Data, Massachusetts Statewide Travel Demand Model, MassDOT Planning staff calculations. (file:



VMT Massachusetts by County 2020.xlsx)

Distribution of Emission Reductions

Figure 4-4 shows that emissions reductions have been relatively uniform across the state.

Figure 4-4
Emissions Reduction by Pollutant and County 1990 – 2017

County	Pollutant	1990*	2002	2005	2011	2014	2017	% change 1990 - 2017
Barnstable	CO	213,453	201,372	210,206	47,949	41,556	37,259	-83%
Barnstable	NOx	18,652	23,181	12,723	8,141	7,356	5,928	-68%
Barnstable	$PM_{2.5}$	3,603	4,074	3,346	1,491	1,281	913	-75%
Barnstable	SO_2	63,372	28,445	28,276	1,309	512	146	-100%
Barnstable	VOC	19,681	21,209	15,975	8,245	7,636	7,329	-63%
Berkshire	CO	98,671	54,441	27,745	30,996	26,863	24,085	-76%
Berkshire	NOx	10,665	8,349	6,105	4,364	3,943	3,178	-70%
Berkshire	$PM_{2.5}$	4,315	2,414	2,393	2,631	2,260	1,612	-63%
Berkshire	SO_2	10,629	1,962	2,521	707	276	79	-99%
Berkshire	VOC	14,161	11,139	7,869	5,676	5,256	5,045	-64%
Bristol	CO	447,624	188,978	160,148	58,119	50,369	45,161	-90%
Bristol	NOx	62,226	28,237	23,756	12,619	11,402	9,189	-85%
Bristol	$PM_{2.5}$	5,223	5,874	5,843	2,786	2,394	1,706	-67%
Bristol	SO_2	103,652	48,701	41,578	20,516	8,018	2,287	-98%
Bristol	VOC	32,154	24,870	19,159	11,125	10,303	9,888	-69%
Dukes	CO	25,104	24,053	20,948	12,283	10,645	9,544	-62%
Dukes	NOx	696	4,291	2,119	2,544	2,299	1,853	-57%
Dukes	$PM_{2.5}$	532	895	738	744	639	456	-49%
Dukes	SO_2	229	1,557	313	526	206	59	-96%
Dukes	VOC	4,248	3,398	2,460	2,466	2,284	2,192	-48%
Essex	CO	606,854	264,599	233,286	90,005	78,004	69,938	-88%
Essex	NOx	48,276	25,299	21,906	16,523	14,930	12,032	-75%
Essex	$PM_{2.5}$	6,114	3,457	4,525	4,050	3,480	2,481	-59%
Essex	SO_2	56,349	20,259	17,201	6,233	2,436	695	-99%
Essex	VOC	50,166	30,433	26,192	16,435	15,220	14,608	-71%
Franklin	CO	131,409	78,095	53,340	22,215	19,166	17,184	-87%
Franklin	NOx	6,726	5,950	3,971	2,856	2,581	2,080	-69%
Franklin	$PM_{2.5}$	2,914	2,342	2,324	2,140	1,839	1,311	-55%
Franklin	SO_2	2,370	895	1,029	567	222	63	-97%
Franklin	VOC	12,687	8,581	30,042	4,691	4,344	4,170	-67%
Hampden	CO	403,137	207,516	166,954	62,090	53,811	48,247	-88%
Hampden	NOx	26,049	19,981	10,861	10,827	9,783	7,884	-70%
Hampden	$PM_{2.5}$	4,830	3,940	3,858	3,400	2,921	2,083	-57%
Hampden	SO_2	20,242	9,851	9,710	2,453	959	273	-99%
Hampden	VOC	25,328	20,105	16,192	11,505	10,655	10,226	-60%

Hampshire	CO	155,653	87,955	63,832	24,911	21,589	19,357	-88%
Hampshire	NOx	7,683	5,698	4,337	3,539	3,198	2,577	-66%
Hampshire	$PM_{2.5}$	2,905	2,512	2,498	2,206	1,895	1,351	-53%
Hampshire	SO_2	3,248	1,000	1,526	587	229	65	-98%
Hampshire	VOC	12,788	9,191	6,382	4,170	3,862	3,707	-71%
Middlesex	CO	1,194,565	686,832	581,188	157,134	136,182	122,101	-90%
Middlesex	NOx	62,563	49,016	43,608	26,233	23,704	19,103	-69%
Middlesex	$PM_{2.5}$	12,491	7,391	7,418	5,459	4,690	3,344	-73%
Middlesex	SO_2	36,758	14,068	15,249	5,336	2,085	595	-98%
Middlesex	VOC	87,722	62,071	54,218	27,230	25,217	24,203	-72%
Nantucket	CO	16,927	21,379	15,134	7,082	6,138	5,503	-67%
Nantucket	NOx	2,325	18,760	644	1,139	1,029	829	-64%
Nantucket	$PM_{2.5}$	302	1,899	611	270	232	165	-45%
Nantucket	SO_2	625	10,541	99	271	106	30	-95%
Nantucket	VOC	2,612	2,890	1,632	1,161	1,075	1,032	-60%
Norfolk	CO	620,449	430,702	375,218	74,817	64,841	58,136	-91%
Norfolk	NOx	27,280	28,588	25,053	13,135	11,869	9,565	-65%
Norfolk	$PM_{2.5}$	5,560	3,931	3,899	2,556	2,196	1,566	-72%
Norfolk	SO_2	10,548	4,137	4,270	2,796	1,093	312	-97%
Norfolk	VOC	42,215	33,557	27,741	12,847	11,897	11,419	-73%
Plymouth	CO	391,226	193,139	168,608	60,471	52,408	46,989	-88%
Plymouth	NOx	18,899	13,313	11,060	10,417	9,413	7,586	-60%
Plymouth	$PM_{2.5}$	6,851	4,191	4,147	2,808	2,412	1,720	-75%
Plymouth	SO_2	7,606	3,005	2,723	2,463	963	275	-96%
Plymouth	VOC	36,613	22,757	16,980	11,279	10,445	10,025	-73%
Suffolk	CO	388,528	202,518	178,554	53,251	46,151	41,379	-89%
Suffolk	NOx	59,772	21,453	18,719	14,784	13,359	10,766	-82%
Suffolk	$PM_{2.5}$	6,075	1,781	2,403	2,241	1,925	1,373	-77%
Suffolk	SO_2	21,869	5,787	5,367	4,388	1,715	489	-98%
Suffolk	VOC	25,017	20,254	18,613	11,059	10,242	9,830	-61%
Worcester	CO	701631	421,181	366,744	101,129	87,645	78,582	-89%
Worcester	NOx	37,342	32,895	28,065	17,606	15,908	12,821	-66%
Worcester	$PM_{2.5}$	10,254	6,882	7,941	7,556	6,492	4,628	-55%
Worcester	SO_2	14,381	6,159	6,837	3,600	1,407	401	-97%
Worcester	VOC	52,203	42,911	34,030	18,682	17,301	16,606	-68%
Statewide	CO	5,395,231	3,062,760	2,621,905	802,452	695,368	623,465	-88%
Statewide	NOx	389,154	285,011	212,927	144,727	130,774	105,391	-73%
Statewide	$PM_{2.5}$	71,969	51,583	51,944	40,338	34,656	24,709	-66%
Statewide	SO_2	351,878	156,367	136,699	51,752	20,227	5,769	-98%
Statewide	VOC	417,595	313,366	277,485	146,571	135,737	130,280	-69%

Source:
2017 data: EPA NEI v.1.0 -- EIS Gateway report download (file: Emissions by Pollutant County 2020.xlsx)
2014 data: EPA NEI v.2 -- EIS Gateway report download
2011 data: MassDEP 2011 Emissions Inventory (http://www.mass.gov/eea/agencies/massdep/air/reports/emissions-inventories.html)
2005 data: State and County Emission Summaries http://www.epa.gov/air/emissions/index.htm
1990 and 2002 data: Air Data: Access to Air Pollution Data Reports and Maps http://www.epa.gov/air/data/geosel.html
* For 1990, VOC, NOx and CO were estimated by multiplying TPSD from Table 1.2 of Section 1 of MA 2014 PEI Report by 312 days (52wks x 6days). Value estimate for 1990 for NOx for Dukes county appears anomalous and so reductions were calculated from 2002 instead of 1990.
Note: Used the county percent from 2011 and applied to 2014 and 2017 statewide values

V. POLLUTANT NETWORK STATUS

Section V summarizes the status of the ambient air quality monitoring for each of the following pollutants:

- Particulate matter (PM) (including speciation and air toxics)
- Ozone (O_3) (including PAMS monitoring)
- Carbon monoxide (CO)
- Lead (Pb)
- Sulfur dioxide (SO_2)
- Nitrogen dioxide (NO_2) (including NO_x, other oxides of nitrogen)

The following topics are covered for each of these pollutants:

- Monitor locations/descriptions/purposes
- Coverage area
- Monitoring data
- Technological issues
- Adequacy of the Monitoring Network including, for ozone and $PM_{2.5}$, Correlations, New Sites Analysis, and Removal Bias Data
- Analysis results

Section V also assesses the Meteorological Network and describes Quality Assurance and Quality Control (QA/QC) activities.

Particulate Matter (PM)

Network Description

MassDEP operates PM monitors at 16 locations across the Commonwealth. The National Park Service and Wampanoag Tribe operate PM monitors at two additional locations for the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. At least one monitor is located in each county except for Norfolk and Nantucket. The PM network consists of:

- PM_{10} – 3 sites:
  - All with low volume samplers.
  - One (Boston-Harrison Avenue) with collocated low-volume samplers. Filters from this site are analyzed for toxic elements as part of the National Air Toxics Trends Stations (NATTS) air monitoring program and for lead as required by the NCore program.

- $PM_{2.5}$ – 18 sites:
  - 15 Federal Equivalent Method (FEM) sites, nine of which are collocated with Federal Reference Method (FRM) samplers. Data from all sites in MassDEP's FEM network are currently used to determine compliance with the $PM_{2.5}$ NAAQS. FEMs provide the hourly $PM_{2.5}$ data that appears on MassDEP's website.

  - Ten FRM $PM_{2.5}$ sites. One (Chicopee) with collocated samplers. Five sites are on a 1-in-3 day schedule and five sites are on a 1-in 6 day schedule.

  - Two IMPROVE samplers operated by the National Park Service and Wampanoag Tribe are on a 1-in-3 day schedule.

- PM_{coarse} (PM_{10} – $PM_{2.5}$) – One site in compliance with NCore requirements at the designated NCore site at Boston-Harrison Avenue.

- Speciated $PM_{2.5}$ – Four sites:
  - Two FRM sites (Boston-Harrison Avenue and Chicopee). The speciated $PM_{2.5}$ program is designed to determine some of the chemical constituents (elements, sulfates, nitrates, carbon species) that are contained in $PM_{2.5}$, which can provide information about the sources of the PM.

  - Two IMPROVE sampling sites (Truro and Aquinnah – Martha's Vineyard) that provide speciated $PM_{2.5}$ data. The IMPROVE program measures, at rural locations, parameters that are similar to those measured by the speciation program. The data are used to evaluate the role of fine particulates and their constituents in the degradation of visibility.

Figure 5-1 lists the particulate matter sites, their location, type of monitoring and purpose of the monitoring.

Figure 5-1
PM Monitoring Sites

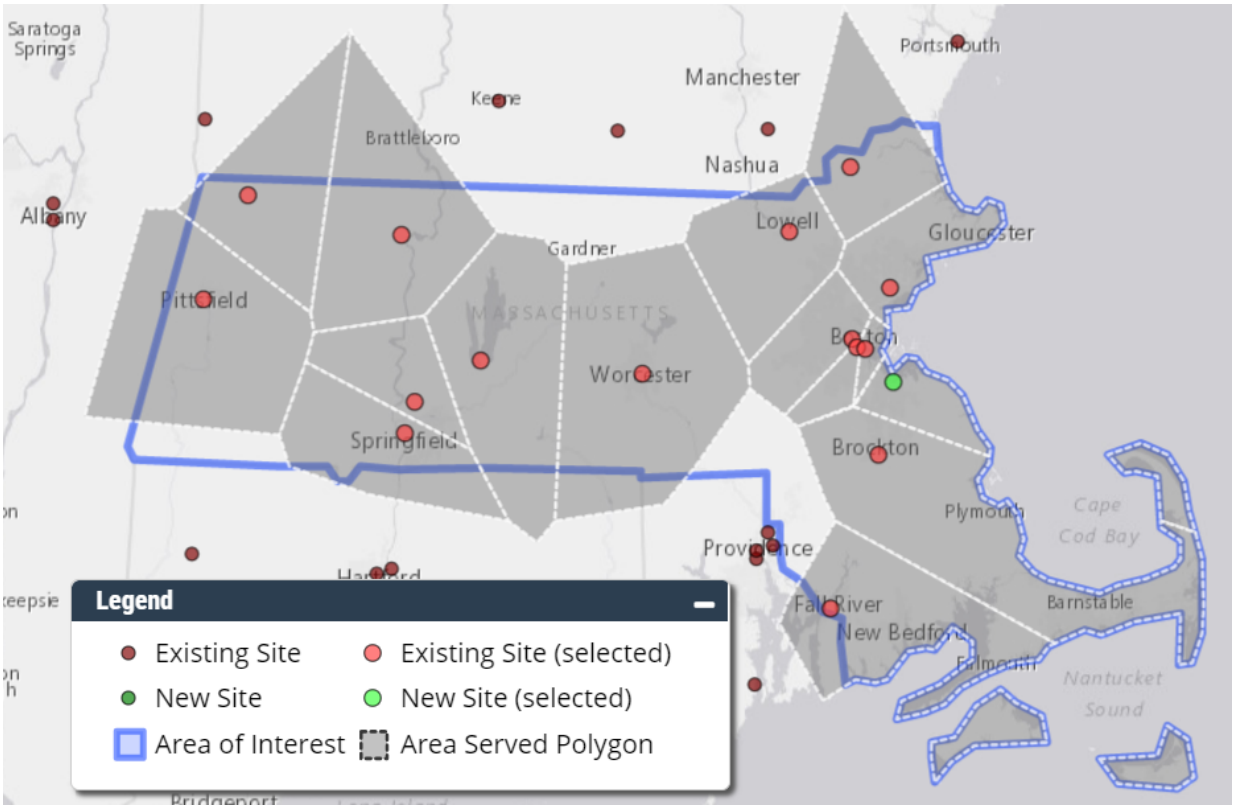
Site ID	Site Name	Scale	Reason for Monitor	Date Established	MSA / MiSA	PM Type
25-025-0002	Boston - Kenmore	Micro	Highest Concentration; Pop Exposure	1/1/1965	Boston-Cambridge-Newton	FRM
25-025-0042	Boston - Harrison Ave	Neighborhood	Population Exposure	12/15/1998	Boston-Cambridge-Newton	PM_{10}, FRM, FEM
25-025-0044	Boston - Von Hillern	Middle	Pop Exposure; Highest Concentration	6/15/2013	Boston-Cambridge-Newton	FRM, FEM
25-023-0005	Brockton	Neighborhood	Population Exposure	6/30/2013	Boston-Cambridge-Newton	FRM, FEM
25-017-0010	Chelmsford - Near Road	Middle	Population Exposure	7/1/2018	Boston-Cambridge-Newton	FEM
25-013-0008	Chicopee	Urban	Population Exposure	1/1/1983	Springfield	FRM, FEM
25-005-1004	Fall River	Neighborhood	Population Exposure	2/1/1975	Providence-Warwick	FEM
25-011-2005	Greenfield	Neighborhood	Population Exposure	1/1/2014	Greenfield Town	FRM, FEM
25-009-5005	Haverhill	Neighborhood	Population Exposure	7/19/1994	Boston-Cambridge-Newton	FRM, FEM
25-009-2006	Lynn	Neighborhood	PAMS - Max Precursor O_3; Pop Exposure	1/1/1992	Boston-Cambridge-Newton	FEM
25-003-6001	North Adams	Neighborhood	Population Exposure	7/1/2017	Pittsfield	FEM
25-003-0008	Pittsfield	Neighborhood	Population Exposure	7/1/2018	Pittsfield	FEM
25-013-0018	Springfield	Urban	Highest Concentration; Pop Exposure	5/1/2018	Springfield	FRM, FEM
25-001-0002	Truro	Regional	General Background	4/1/1987	Barnstable	IMPROVE
25-015-4002	Ware	Urban	Highest O_3; Background other pollutants	6/1/1985	Springfield	PM_{10}, FEM
25-021-2004	Weymouth	Neighborhood	Population Exposure	2/4/2020	Boston-Cambridge-Newton	FEM
25-027-0023	Worcester - Summer St	Urban	Population Exposure	1/1/2004	Worcester	PM_{10}, FRM, FEM
25-007-0001	Aquinnah	Regional	Regional	4/1/2004	Vineyard Haven	IMPROVE

MSA = Metropolitan Statistical Area
MiSA = Micropolitan Statistical Area

Monitor Area Served

Figure 5-2 shows the area served by each $PM_{2.5}$ monitor as defined by Voroni polygons. These polygons were developed using EPA's NetAssess tool. The polygons show that the state is well covered by monitors in Massachusetts or in neighboring states.

Figure 5-2
Area Served – $PM_{2.5}$ FRM and FEM sites



Source: NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool https://sti-r-shiny.shinyapps.io/EPA_Network_Assessment/.

Notes: Co-located PM2.5 monitors are treated as a single location. One site (Weymouth - 25-021-2004) was established after the NetAssess2020 tool was compiled; therefore the site was added manually using functions in the NetAssess2020 tool.

PM MONITORING DATA

2019 PM_{10} Data Summary

Figure 5-3 shows a summary of 2019 PM_{10} data. All values are well below applicable NAAQS.

Figure 5-3
2019 PM_{10} FRM Annual Data Summary ($\mu g/m^3$)

City	County	Address	1ST MAX 24-HR	2ND MAX 24-HR	3RD MAX 24-HR	4TH MAX 24-HR	DAYS MAX >STD	ARITH MEAN
Boston	Suffolk	Harrison Avenue	27	27	22	20	0	10.1
Boston	Suffolk	Harrison Avenue*	28	22	20	19	0	9.9
Ware	Hampshire	Skyline Drive	17	15	15	13	0	6.0
Worcester	Worcester	Summer St	52	37	33	27	0	12.7

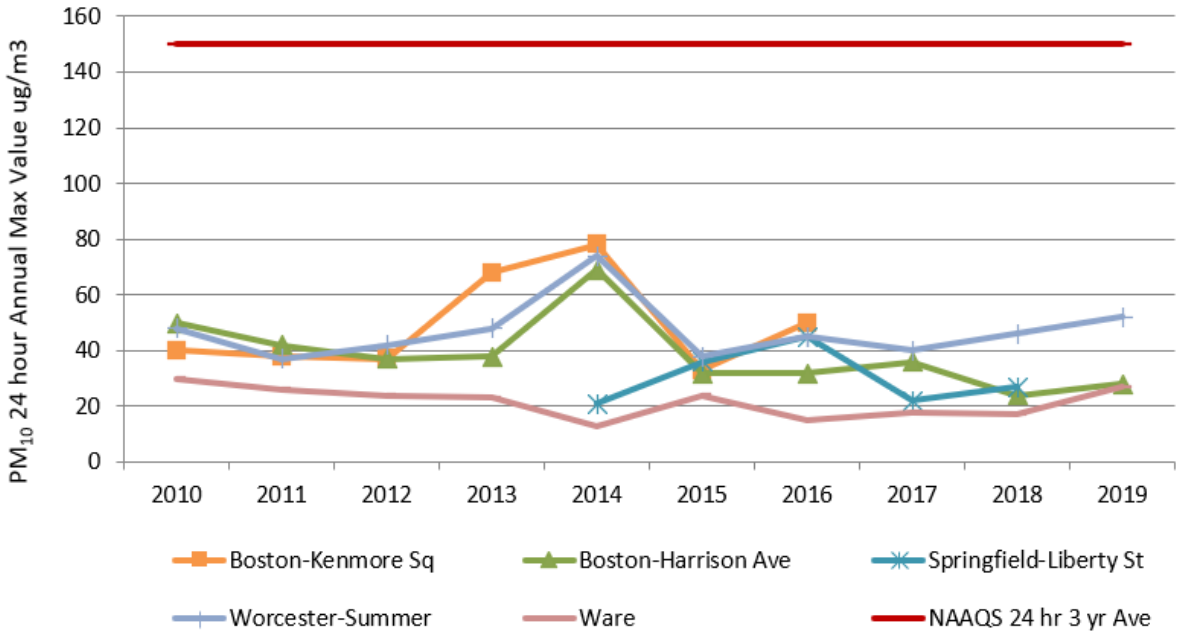
Standard: 24-hour = 150 µg/m3

* = Collocated monitors
1ST, 2ND, 3RD, 4TH 24-HR MAX = 1ST, 2ND, 3RD, and 4TH Highest 24-hr Values for the Year
ARITH MEAN = Annual Arithmetic Mean

PM_{10} Trends

Figure 5-4 shows trends for each PM_{10} monitor relative to the 24-hour standard of 150 $\mu g/m^3$.

Figure 5-4
PM_{10} Trends 2010-2019 Annual Arithmetic Mean



$PM_{2.5}$ 2019 Data Summary

Figure 5-5 shows a summary of the 2019 FRM $PM_{2.5}$ data. All values are well below applicable NAAQS.

Figure 5-5
2019 $PM_{2.5}$ FRM Annual Data Summary (µg/m^3)

City	County	Address	1ST MAX 24-HR	2ND MAX 24-HR	3RD MAX 24-HR	4TH MAX 24-HR	98TH PECENTILE 24-HR	ARITH MEAN
Boston	Suffolk	Kenmore Square	15.0	13.3	12.9	12.7	12.9	5.67
Boston	Suffolk	Harrison Avenue	13.5	13.2	13.0	12.1	13.0	5.22
Boston	Suffolk	Von Hillern Street	12.0	12.0	11.7	11.6	12.0	5.66
Brockton	Plymouth	Clinton Street	12.2	11.6	11.5	9.9	11.6	4.82
Chicopee	Hampden	Anderson Road	13.4	12.9	12.7	12.4	12.7	4.98
Chicopee	Hampden	Anderson Road*	13.1	13.0	13.0	12.7	13.0	5.15
Greenfield	Franklin	Barr Avenue	20.0	13.5	13.2	13.1	13.2	5.47
Haverhill	Essex	Washington Street	11.3	10.6	9.8	8.7	10.6	4.49
Pittsfield	Berkshire	Silver Lake Blvd	19.0	15.7	13.2	13.2	13.2	5.32
Springfield	Hampden	Liberty Street	16.2	15.0	14.5	13.4	15.0	6.67
Worcester	Worcester	Summer Street	13.4	11.1	10.8	10.6	11.1	5.03

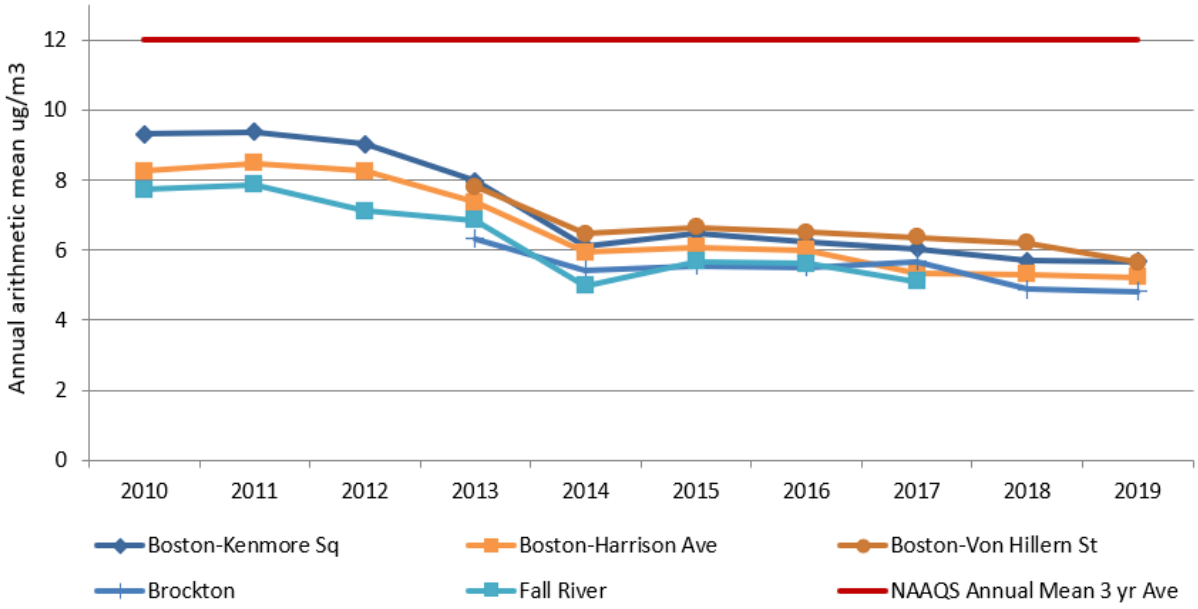
Standards: Annual Mean = 12 µg/m^3 (primary)
24-hour (98th percentile) = 35 µg/m^3

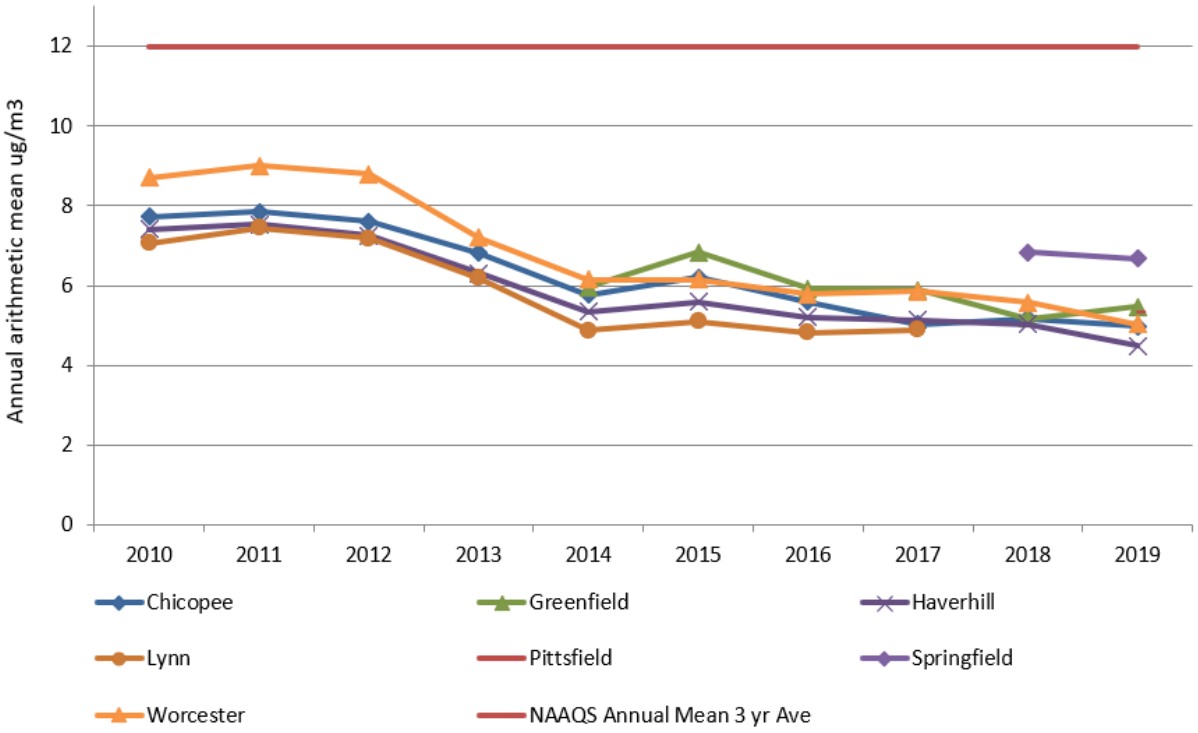
* = Collocated monitors
1ST, 2ND, 3RD, 4TH 24-HR MAX = 1ST, 2ND, 3RD, and 4TH Highest 24-hr Values for the Year
98TH PERCENTILE 24-HR = 98TH Percentile Value for the Year
ARITH MEAN = Annual Arithmetic Mean

$PM_{2.5}$ Monitoring Data Trends

Figure 5-6 shows trends for each FRM $PM_{2.5}$ monitor relative to the annual standard of 12 µg/m^3.

Figure 5-6
$PM_{2.5}$ Annual Arithmetic Mean Trends





2019 FEM $PM_{2.5}$ Data Summary

Figure 5-7 shows a summary of the 2019 FEM $PM_{2.5}$ data. All values are well below applicable NAAQS.

Figure 5-7
2019 PM_{10} FEM 24-Hour Data Summary (µg/m^3)

City	County	Address	1ST MAX 24-HR	2ND MAX 24-HR	3RD MAX 24-HR	4TH MAX 24-HR	98TH PECENTILE 24-HR	ARITH MEAN
Boston	Suffolk	Harrison Ave	23.1	21.5	19.0	18.7	17.0	8.08
Boston	Suffolk	Von Hillern St	21.7	20.7	20.4	20.3	17.3	7.57
Boston	Suffolk	Von Hillern St*	18.9	14.4	13.8	12.2	13.8	5.60
Brockton	Plymouth	Clinton Street	19.7	17.2	15.6	15.6	13.9	6.80
Chelmsford	Middlesex	Manning Road	20.9	17.8	17.3	17.0	14.5	6.98
Chicopee	Hampden	Anderson Road	26.3	18.4	18.3	18.0	12.5	4.62
Fall River	Bristol	Globe Street	27.3	26.2	23.0	20.3	15.3	6.60
Greenfield	Franklin	Barr Avenue	29.4	26.5	24.9	23.2	17.3	6.56
Haverhill	Essex	Washington St	18.6	18.2	17.0	16.2	15.1	5.64
Lynn	Essex	Parkland Ave	28.3	22.1	19.0	18.1	16.2	6.57
North Adams	Berkshire	Holden Street	18.3	17.0	16.5	16.2	15.2	6.19
Pittsfield	Berkshire	Silver Lake Blvd	25.2	24.0	23.4	19.7	16.6	7.11
Springfield	Hampden	Liberty Street	31.6	27.2	26.3	21.7	16.6	7.71
Ware	Hampshire	Skyline Drive	24.0	22.8	18.5	17.5	15.5	5.61
Worcester	Worcester	Summer Street	24.4	20.7	20.0	20.0	16.7	8.23

Standards: Annual Mean = 12 µg/m3 (primary)
24-hour (98th percentile) = 35 µg/m3

* = Collocated monitors
1ST, 2ND, 3RD, 4TH 24-HR MAX = 1ST, 2ND, 3RD, and 4TH Highest 24-hr Values for the Year
98TH PERCENTILE 24-HR = 98TH Percentile Value for the Year
ARITH MEAN = Annual Arithmetic Mean

$PM_{2.5}$ Design Values

The design value is a statistic that describes the air quality measured by a monitor relative to the NAAQS in order to classify attainment and nonattainment areas, assess progress towards meeting the NAAQS, and develop control strategies. Design values are defined in EPA guidance and are based on the NAAQS in 40 CFR Part 50. They often require multiple years of data that help to ensure a stable indicator. EPA computes and publishes design values for each monitor annually.

The annual $PM_{2.5}$ design value is computed at each site by averaging the daily samples taken each quarter, averaging these quarterly averages to obtain an annual average, and then averaging three years of annual averages. The 24-hour $PM_{2.5}$ design value is computed at each site by determining the 98th percentile of the daily samples collected each year for three years, and then averaging these three numbers. Because design values are computed over a 3-year time period they are more stable than the measurements recorded in any one year.

Several $PM_{2.5}$ monitoring sites include collocated FRM and FEM instruments. At each site with collocated FRM and FEM instruments, the FEM is considered the primary source of data for NAAQS compliance. Sites with only one, either FRM or FEM, the individual instrument is considered the primary monitor by default. Design values are calculated using data from the primary monitor. Boston – Kenmore is the only site with a standalone FRM. All other design values are based on FEM values.

Figure 5-8 shows the most recent design values for each $PM_{2.5}$ FRM monitor. All design values are well below applicable NAAQS.

Figure 5-8
FEM $PM_{2.5}$ 2019 Design Values

City	County	Address	2017-2019 Design Values	
			24 Hour Standard 35 µg/m³	Annual Standard 15 µg/m³
Boston	Suffolk	Kenmore Square	13	5.9
Boston	Suffolk	Harrison Ave	18	7.4
Boston	Suffolk	Von Hillern St	18	7.9
Brockton	Plymouth	Clinton Street	16	5.8
Chelmsford	Middlesex	Manning Road	15	7.2
Chicopee	Hampden	Anderson Road	13	5.0
Fall River	Bristol	Globe Street	16	6.5
Greenfield	Franklin	Barr Avenue	16	5.7
Haverhill	Essex	Washington St	14	5.2
Lynn	Essex	Parkland Ave	17	5.9
North Adams	Berkshire	Holden Street	15	7.1
Pittsfield	Berkshire	Silver Lake Blvd	17	7.4
Springfield	Hampden	Liberty Street	16	7.3
Ware	Hampshire	Skyline Drive	15	5.3
Worcester	Worcester	Summer Street	16	6.5

Note: Does not include Chelmsford – Manning Road because three full years of data have not yet been collected.

PM MONITORING TECHNOLOGY

PM_{10}

MassDEP uses low volume size-selective gravimetric filters. The FRM monitor works by drawing air through a small Teflon filter for 24 hours (midnight to midnight) on the designated sample day, after which the filter is removed from the monitor and transported to the MassDEP Laboratory in Lawrence for weighing. The samples are run every 3rd or 6th day for 24 hours.

$PM_{2.5}$

Currently, MassDEP operates 11 FRM filter-based monitors and 16 Beta Attenuation Monitors (BAMs), including collocated monitors, for measuring $PM_{2.5}$ concentrations at locations throughout the state. In Massachusetts, the $PM_{2.5}$ FRM monitor is identical to the PM_{10} monitor with the addition of a cyclone on the air intake to select for particles that are 2.5 micron or below. Filter-based monitors have several disadvantages:

- There is a time delay between sample collection and sample results
- The samples do not provide a continuous analysis of air quality, which could result in missing important $PM_{2.5}$ events.
- There is extra staff time and expense associated with:
  - visiting sites to collect the samples and bring them to the laboratory for analysis
  - conducting the necessary sample management and analysis quality assurance.

BAMs make it possible to collect and report $PM_{2.5}$ concentrations on an hourly basis without having to transport the filters and weigh them in the laboratory. BAM have been designated as a Federal Equivalent Method (FEM), which makes a BAM an acceptable alternate to the FRM monitor. MassDEP is using data from all FEM monitors for comparison to the $PM_{2.5}$ NAAQS. A new scattered light spectrometry monitor was recently designated as FEM for $PM_{2.5}$, PM_{10} and PM_{coarse} measurements. It provides real time, continuous PM measurements by a broadband spectroscopy method, using 90° white-light scattering with Polychromatic LED. MassDEP has begun to implement this new technology in its network.

PM_{coarse} ($PM_{10} - PM_{2.5}$)

MassDEP has used the Federal Reference Method (FRM) for PM_{coarse} in compliance with NCore requirements at the NCore site at Boston – Harrison Avenue since January 2011. This method consists of the subtraction of $PM_{2.5}$ values from PM_{10} values at a site that has side-by-side monitors of each type of sampling on the same dates. Harrison Avenue currently has monitors of the appropriate types.

Speciation

MassDEP has been collecting $PM_{2.5}$ samples for speciation at the Boston – Harrison Avenue air monitoring station since 2000 and in Chicopee since 2001. Speciation is the analysis of particulate matter collected on Teflon, nylon and quartz filters simultaneously to determine the chemical composition of the particulate matter collected. During each sampling event, the three separate filters are collected and shipped to an out-of-state national contract laboratory for analysis. Each different filter medium is analyzed for a different category of pollutant. These include elements (e.g., metals), sulfates and nitrates, and carbon (total and organic). MassDEP upgraded these sites to the new carbon method (comparable to the IMPROVE method) in 2009. Note that the IMPROVE monitors acquire $PM_{2.5}$ filter samples for speciation analysis using a different protocol than that of the speciation program. At this time, MassDEP does not see a need to change either the speciation or IMPROVE methods.

ADEQUACY OF THE PM NETWORK

EPA Requirements

As demonstrated in Figure 5-9, the PM network meets or exceeds federal requirements for PM_{10}, $PM_{2.5}$, and speciation.

Figure 5-9
$PM_{2.5}$ Monitor Siting Requirements, including Speciation

	MSA Population	Most Recent 3-Year Design Value ≥85% of any $PM_{2.5}$ NAAQS	Most Recent 3-Year Design Value <85% of any $PM_{2.5}$ NAAQS or No Design Value
EPA Requirements for Number of $PM_{2.5}$ Monitors	>1,000,000	3	2
	500,000–1,000,000	2	1
	50,000–<500,000	1	0

MSA	2018 Population	3 Year Design Values (2019 Maximum for a Monitor in MSA)				> 85% of any NAAQS?	Monitors Needed	Monitors in Network
		24 Hour - 35 µg/m3		Annual - 15 µg/m3				
		Value	% of STD	Value	% of STD			
Boston-Cambridge-Newton MSA	4,875,390	15.9 (18)	45% (51%)	6.5 (7.9)	43% (53%)	NO	2	7
Barnstable MSA	213,413	NA	NA	NA	NA	NA	0	0
Worcester MSA	947,866	16	46%	6.5	43%	NO	1	1
Springfield MSA	631,761	15 (16)	43% (46%)	5.8 (7.3)	39% (49%)	NO	1	4
Pittsfield MSA	126,348	16 (17)	46% (49%)	7.3 (7.4)	48% (49%)	NO	0	2

Additional $PM_{2.5}$ Monitor Requirements	MSA		
	Boston-Cambridge-Newton MSA	Worcester MSA	Springfield MSA
At least one monitoring station is to be sited in a population-oriented area of expected maximum concentration.	Boston-Von Hillern	Summer Street	Liberty Street
For areas with more than one required SLAMS, a monitoring station is to be sited in an area of poor air quality.	Boston-Kenmore Boston-Harrison Ave Boston-Von Hillern	Summer Street	Liberty Street Chicopee Westover
The State, or where appropriate, local agencies must operate continuous $PM_{2.5}$ analyzers equal to at least one-half (round up) the minimum required sites listed in Table D–5 of this appendix. At least one required continuous analyzer in each MSA must be collocated with one of the required FRM/FEM/ARM monitors, unless at least one of the required FRM/FEM/ARM monitors is itself a continuous FEM or ARM monitor in which case no collocation requirement applies.	6 Continuous 4 Collocated	1 Continuous 1 Collocated	3 Continuous 2 Collocated
Each State shall install and operate at least one $PM_{2.5}$ site to monitor for regional background and at least one $PM_{2.5}$ site to monitor regional transport. These monitoring sites may be at community-oriented sites and this requirement may be satisfied by a corresponding monitor in an area having similar air quality in another State. Methods used at these sites may include non-federal reference method samplers such as IMPROVE or continuous $PM_{2.5}$ monitors	1 Continuous (Ware)		
Each State shall continue to conduct chemical speciation monitoring and analyses at sites designated to be part of the $PM_{2.5}$ Speciation Trends Network (STN).	1	0	1

Correlations, Exceedance Probability, Removal Bias

EPA recommends three analytical approaches for identifying potentially underserved areas and redundant sites.

1. Identifying potential new sites based on the likelihood of the site exceeding a standard.
2. Evaluating the correlation between site measurements to find redundancies.
3. Estimating the removal bias – the difference between the measured concentrations at a site and those that would be estimated for that site based on data from surrounding sites.

NetAssess2020 is an online tool that provides these analyses. NetAssess2020 was used to implement these approaches for this report. The reference is provided below.

> NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool. The latest data in this version is from 2018. https://sti-r-shiny.shinyapps.io/EPA_Network_Assessment/

Exceedance Probability

NetAssess2020 provides a probability map to help determine where new monitors may be needed. The method is explained in the excerpt below from the NetAssess2020 documentation.

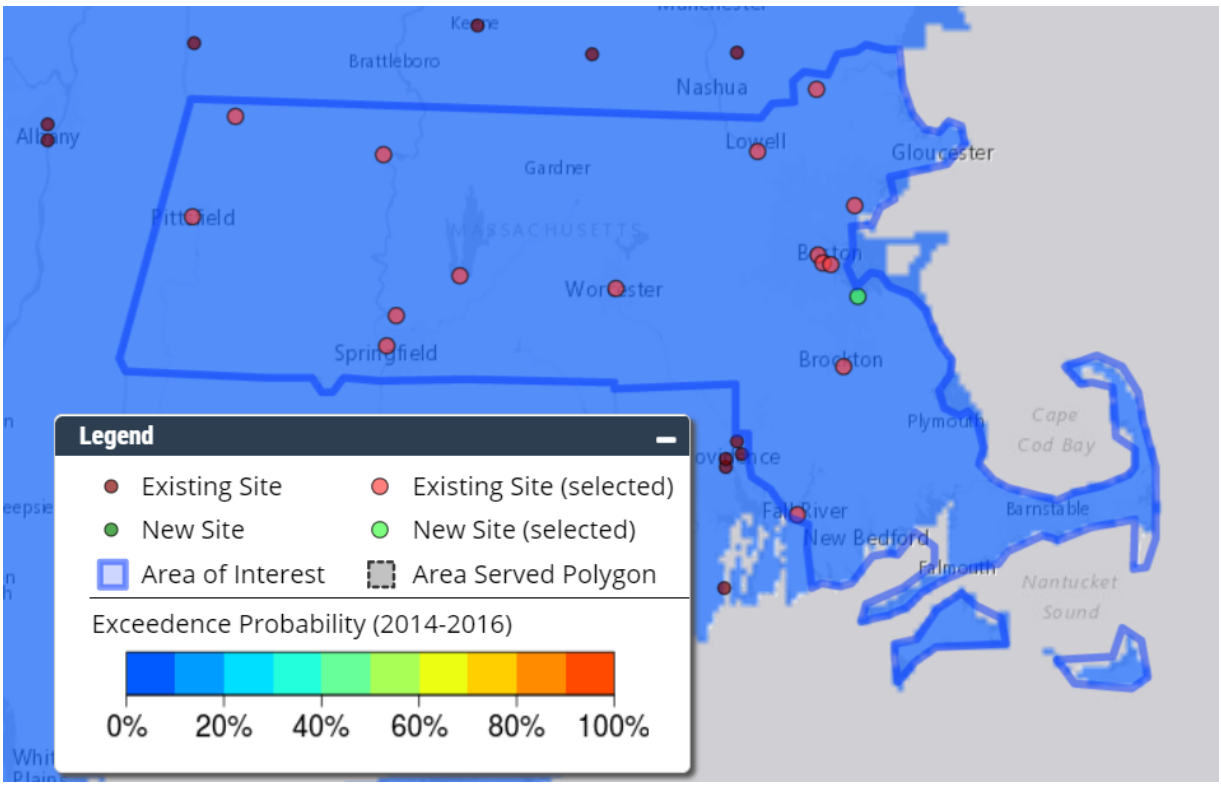
> Exceedance Probabilities
>
> One objective of the network assessment is to determine if new sites are needed. In order to make that decision, it is helpful to have some estimation of the extreme pollution levels in areas where no monitors currently exist. NetAssess2020 provides ozone and $PM_{2.5}$ maps of the contiguous US that can be used to make spatial comparisons regarding the probability of daily values exceeding a certain threshold.
>
> Surface Probability Maps
>
> To clarify, these maps do not show the probability of violating the National Ambient Air Quality Standards (NAAQS). They provide information about the spatial distribution of the highest daily values for a pollutant (not, for example, the probability of the 4th highest daily 8-hour ozone maximum exceeding a threshold).
>
> These maps are intended to be used as a spatial comparison and not for probability estimates for a single geographic point or area. The probability estimates alone should not be used to justify a new monitor. The maps should be used in conjunction with existing monitoring data. If a monitor has historically measured high values, then the probability map gives an indication of areas where you would expect to observe similar extreme values. This information, along with demographic and emissions data, could be used in a weight of evidence approach for proposing new monitor locations.

Data

The surface probability maps were created by using EPA/CDC downscaler data. Downscaler data are daily estimates of ground level ozone and $PM_{2.5}$ for every census tract in the continental US. These are statistical estimates from "fusing" photochemical modeling data and ambient monitoring data using Bayesian space-time methods. For more details on how the data were generated, see the meta data document on the EPA website.

Figure 5-10 shows the probability of exceeding the 35 µg/m^3 $PM_{2.5}$ NAAQS. The spatial comparison map indicates all areas of the state have a low probability of daily values exceeding the $PM_{2.5}$ threshold. No areas of high or moderate probability were indicated.

Figure 5-10
Probability of Exceeding the $PM_{2.5}$ 35 µg/m3 Daily NAAQS



Source: NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool

Site Correlation Analysis

The NetAssess2020 tool was used to provide correlations between monitors. The Correlation Matrix tool calculates and displays the correlation, relative difference, and distance between pairs of sites within a user selected set of air monitoring sites. The correlation matrix graphic displays information about how concentrations at monitors within your Area of Interest compare to one another. Each monitor comparison is represented by a square in the chart.

The blue squares in the bottom-left corner show the correlation between each pair of monitors, with text indicating the number of days used in the calculation. The red squares in the top-right corner show the mean absolute difference in concentrations between each pair of monitors, with text indicating the distance in kilometers between each pair of monitors. The numbers along the diagonal indicate the most recent design value for each monitor.

The purpose of this tool is to provide a means of determining possible redundant sites that could be removed. Possible redundant sites would exhibit fairly high correlations consistently across all their pairings and would have low average relative difference despite the distance. Usually, it is expected that correlation between sites will decrease as distance increases. However, for a regional air pollutant such as ozone, sites in the same air shed can have very similar concentrations and be highly correlated. More unique sites would exhibit the opposite characteristics. They would not be very well correlated with other sites and their relative difference would be higher than other site to site pairs.

The Correlation Matrix tool generates a graphical display that summarizes the correlation, relative difference and distance between pairs of monitoring sites. The correlation between two sites quantitatively describes the degree of relatedness between the measurements made at two sites. That relatedness could be caused by various influences including a common source affecting both sites to pollutant transport caused meteorology. The correlation, however, may indicate whether a pair of sites is related, but it does not indicate if one site consistently measures pollutant concentrations at levels substantially higher or lower than the other.

The average relative difference between the two sites is an indicator of the overall measurement similarity between the two sites. Site pairs with a lower average relative difference are more similar to each other than pairs with a larger difference. Both the correlation and the relative difference between sites are influenced by the distance by which site pairs are separated. Usually, sites with a larger distance between them will generally be more poorly correlated and have large differences in the corresponding pollutant concentrations.

Figure 5-11 shows the correlation between the measured air quality at each $PM_{2.5}$ monitoring site based on FRM and FEM data.

Figure 5-11
Correlation Matrix for FRM and BAM $PM_{2.5}$ Monitors

Correlation Matrix

	250030008	250036001	250051004	250092006	250095005	250112005	250130008	250130018	250154002	250170010	250230005	250250002	250250042	250250044	250270023
250030008	NA/NA	30	191	186	178	55	63	65	76	159	188	176	177	180	120
250036001	162	NA/NA	195	177	164	43	72	78	78	148	186	169	171	173	118
250051004	148	474	6.4/15	89	120	155	128	126	118	103	44	74	72	71	82
250092006	158	494	991	5.5/16	35	134	134	138	114	31	45	17	18	18	71
250095005	157	486	972	986	5.2/13	123	135	141	114	24	78	47	49	49	80
250112005	164	506	991	1011	994	5.9/16	46	54	40	105	143	126	128	130	76
250130008	71	182	370	365	377	374	5.3/13	9	22	112	128	121	122	124	63
250130018	166	225	209	225	223	234	99	NA/NA	29	118	130	125	126	128	67
250154002	142	479	984	999	973	997	369	206	5.1/14	91	112	102	103	105	45
250170010	171	190	176	190	189	196	88	198	173	NA/NA	65	34	36	38	55
250230005	151	478	992	1006	984	1007	373	217	991	181	5.8/16	32	30	29	68
250250002	32	140	303	299	304	307	300	57	298	42	305	6/13	2	4	58
250250042	162	485	989	1010	985	1010	379	213	992	186	1003	306	7.5/18	2	59
250250044	158	500	999	1013	997	1017	372	223	1002	188	1010	304	1010	8.2/18	61
250270023	166	500	1010	1033	1007	1033	376	231	1018	196	1027	307	1029	1034	6.1/16

Values in lower triangle = # of obs used in correlation
Values in upper triangle = Distance in km between sites
Values along the diagonal = Most recent design values

Pollutant = PM2.5
Area of Interest = Massachusetts
To save chart, right-click and select 'Save image as...'

Mean Absolute Difference (ug/m3): Inf, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0

Pearson Correlation (R): 1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0, -1

Source: NetAssess2020 v1.1
Note: The Weymouth (25-021-2004) site was added in February 2020, after the NetAssess2020 tool was completed, and correlation data was not available for this assessment.

All monitors exhibit correlations less than 0.9 and most correlations are less than 0.8. Three pairs exhibit correlations between 0.8 and 0.9, as shown in Figure 5-12. The sample sizes (n) for some of these are very small and therefore can be ignored. The relative difference between some pairs is close to the mean relative difference for all sites (0.257) and therefore they are not very similar in magnitude. This leaves the valid highly correlated sites indicated in white in Figure 5-12.

Figure 5-12
Correlation Over 0.8 for FRM and FEM $PM_{2.5}$ Monitors

Site 1	Site 2	Correlation	Distance (km)	n	Mean Difference
25-009-2006 - Lynn	25-023-0005 - Brockton	0.8246	45	1006	1.7857
25-011-2005 - Greenfield	25-013-0018 - Springfield	0.8711	54	234	1.9932
25-013-0018 - Springfield	25-027-0023 - Worcester	0.8236	67	231	1.9931

Source: NetAssess2020 v1.1

n = Number of observations used in correlation
km = kilometers

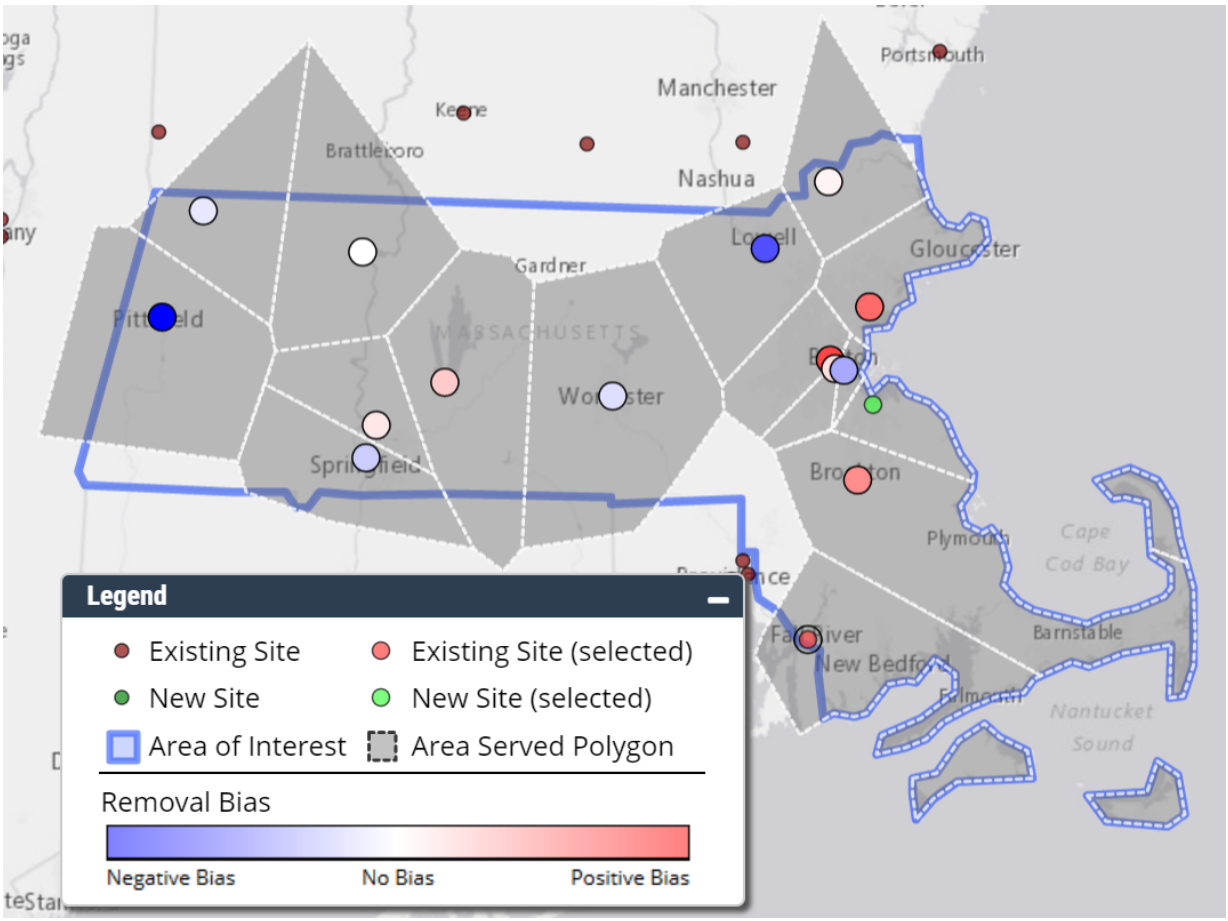
Removal Bias Analysis

Removal bias was calculated among all the $PM_{2.5}$ monitors within the state, treating FRM and FEM as equivalent. Removal bias was calculated with NetAssess2020, which explains the process in its documentation as follows:

> The removal bias tool is meant to aid in determining redundant sites. The bias estimation uses the nearest neighbors to each site to estimate the concentration at the location of the site if the site had never existed. This is done using the Voronoi Neighborhood Averaging algorithm with inverse distance squared weighting. The squared distance allows for higher weighting on concentrations at sites located closer to the site being examined. The bias was calculated for each day at each site by taking the difference between the predicted value from the interpolation and the measured concentration. A positive average bias would mean that if the site being examined was removed, the neighboring sites would indicate that the estimated concentration would be larger than the measured concentration. Likewise, a negative average bias would suggest that the estimated concentration at the location of the site is smaller than the actual measured concentration.

If the bias is small, that may indicate that the monitor is redundant and could be removed. Removal bias results are displayed in Figures 5-13 and 5-14.

Figure 5-13
Removal Bias for FRM and FEM $PM_{2.5}$ Monitors



Source: NetAssess2020 v1.1

Figure 5-14
Removal Bias for FRM and FEM $PM_{2.5}$ Monitors

Site ID	Site Name	Mean Removal Bias	Min Removal Bias	Max Removal Bias	Removal Bias Standard Deviation	Neighbors Included
25-003-0008	Pittsfield	-2.73	-13.2	6.5	5.55	7
25-003-6001	North Adams	-0.27	-6.3	6	2.15	4
25-005-1004	Fall River	0.01	-11.8	12	3.27	7
25-009-2006	Lynn	1.61	-17.1	11.6	2.95	6
25-009-5005	Haverhill	0.14	-16.8	10.1	2.03	4
25-011-2005	Greenfield	-0.02	-10.2	9.2	2.27	5
25-013-0008	Chicopee	0.27	-13.7	7.9	2.8	4
25-013-0018	Springfield	-0.56	-8	11.9	3.04	6
25-015-4002	Ware	0.58	-9.5	11.5	2.74	8
25-017-0010	Chelmsford	-1.88	-6.3	1.9	1.7	6
25-023-0005	Brockton	1.23	-11.3	8.3	2.71	9
25-025-0002	Boston - Kenmore	1.99	-9.1	13	2.68	6
25-025-0042	Boston - Harrison Ave	0.36	-11.5	11.3	2.79	4
25-025-0044	Boston - Von Hillern	-0.94	-11.4	11.2	2.86	4
25-027-0023	Worcester - Summer St	-0.37	-22.3	8.2	2.65	7

Source: NetAssess2020 v1.1
Note: The Weymouth (25-021-2004) site was added in February 2020, after the NetAssess2020 tool was completed, and removal bias data was not available for this assessment.

As shown in Figure 5-14, mean removal bias ranged from -2.73 to 1.99. Fall River (0.01) and Greenfield (-0.02) exhibited values closest to zero. Although redundancies may be indicated by these low values, these sites are located in areas of interest and should be retained.

ANALYSIS RESULTS

MassDEP's PM monitoring network meets EPA monitoring requirements and objectives and provides good coverage for the state. Monitored PM levels are well below the NAAQS and additional monitors are not needed at this time. However, given the health impacts of $PM_{2.5}$, MassDEP is evaluating opportunities to enhance $PM_{2.5}$ monitoring in Environmental Justice communities.

Ozone

NETWORK DESCRIPTION

MassDEP operates 16 ozone monitoring sites in 15 municipalities across the state. There is at least one state-operated ozone monitor located in each county except Dukes (Martha's Vineyard) and Nantucket. The Wampanoag Tribe of Gay Head (Aquinnah) operates an ozone monitor in Dukes County.

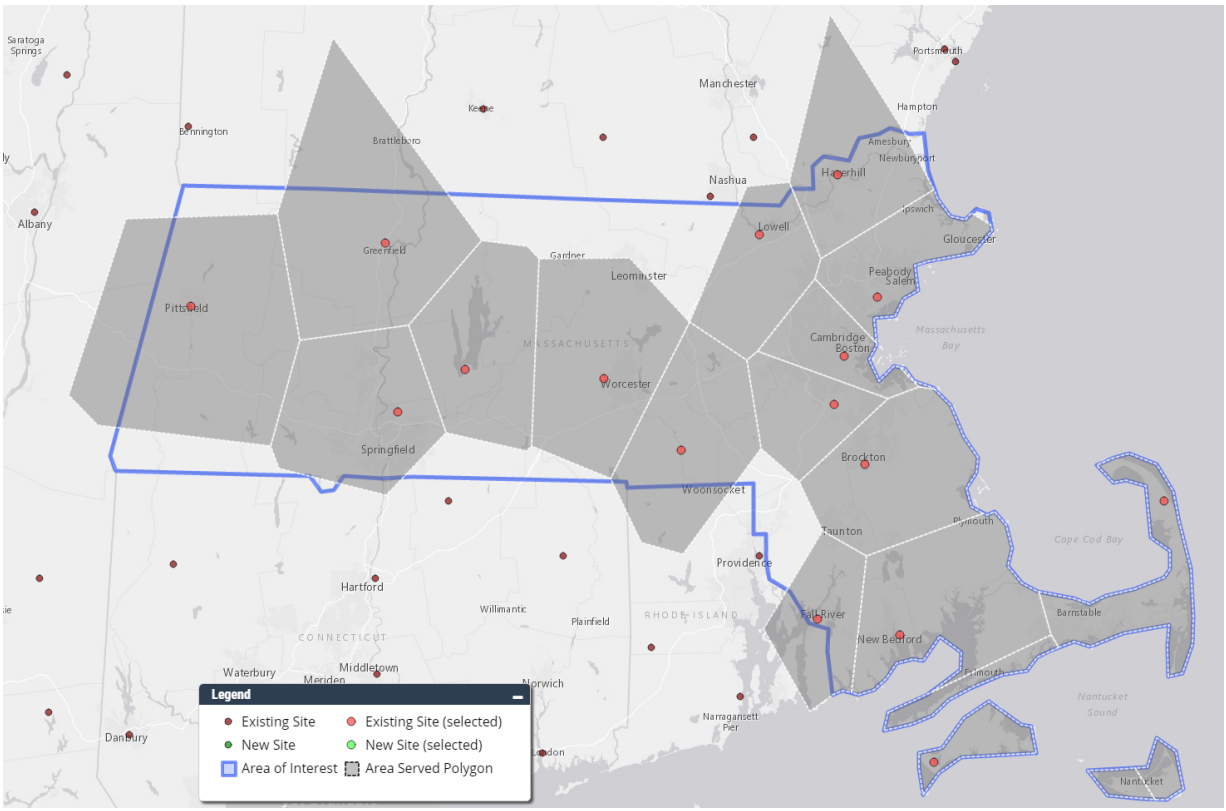
Figure 5-16
Ozone Monitoring Sites, Location, Scale and Purpose

Site ID	Site Name	Scale	Reason for Monitor	Date Established	MSA/MiSA
25-001-0002	Truro	Regional	General Background	4/1/1987	Barnstable MSA
25-005-1004	Fall River	Neighborhood	Population Exposure	2/1/1975	Providence-Warwick MSA
25-009-2006	Lynn	Urban	PAMS - Max Precursor O_3; Population Exposure	1/1/1992	Boston-Cambridge-Newton MSA
25-009-5005	Haverhill	Regional	Population Exposure	7/19/1994	Boston-Cambridge-Newton MSA
25-013-0008	Chicopee	Urban	Population Exposure	1/1/1983	Springfield MSA
25-015-4002	Ware	Urban	Max. O_3 Conc.; Background for other pollutants	6/1/1985	Springfield MSA
25-021-3003	Milton - Blue Hill	Regional	Upwind Background $PM_{2.5}$; Maximum O_3	4/2/2002	Boston-Cambridge-Newton MSA
25-025-0042	Boston - Harrison Ave	Neighborhood	Population Exposure	12/15/1998	Boston-Cambridge-Newton MSA
25-027-0015	Worcester - Airport	Urban	Population Exposure	5/7/1979	Worcester MSA
25-007-0001	Aquinnah	Regional	Regional	4/1/2004	Providence-Warwick MSA
25-017-0009	Chelmsford - EPA	Neighborhood	Population Exposure	4/1/2005	Boston-Cambridge-Newton MSA
25-027-0024	Uxbridge	Regional	O_3 Transport; Population Exposure	11/1/2008	Worcester MSA
25-005-1006	Fairhaven	Regional	Population Exposure	6/30/2013	Providence-Warwick MSA
25-023-0005	Brockton	Urban	Population Exposure	6/30/2013	Boston-Cambridge-Newton MSA
25-011-2005	Greenfield	Regional	Population Exposure	1/1/2014	Greenfield Town MiSA
25-003-0008	Pittsfield	Regional	Population Exposure	7/1/2018	Pittsfield MSA

OZONE MONITOR AREAS SERVED

Figure 5-17 shows the area served by each ozone monitor as defined by Voronoi polygons. These polygons were developed using NetAssess2020. The polygons show that the state is well covered by monitors in Massachusetts or in neighboring states.

Figure 5-17
Area Served – Ozone sites



Source: NetAssess2020 v1.1

OZONE MONITORING DATA

2019 Ozone Data Summary

Figure 5-18 shows a summary of 2019 ozone season data (March 1 – September 30).

Figure 5-18
2019 O_3 Monitoring Data Summary (ppm)

City	County	Address	1ST MAX 8-HR	2ND MAX 8-HR	3RD MAX 8-HR	4TH MAX 8-HR	8-HR MAX>0.070 STD
Aquinnah (Tribal)	Dukes	Herring Creek Drive	0.078	0.075	0.074	0.071	4
Boston	Suffolk	Harrison Avenue	0.066	0.063	0.062	0.061	0
Brockton	Plymouth	Clinton Street	0.067	0.063	0.062	0.061	0
Chelmsford	Middlesex	Technology Drive	0.064	0.060	0.058	0.057	0
Chelmsford	Middlesex	Manning Road	0.053	0.053	0.051	0.051	0
Chicopee	Hampden	Anderson Road	0.068	0.068	0.067	0.066	0
Fairhaven	Bristol	School Street	0.069	0.063	0.062	0.060	0
Fall River	Bristol	Globe Street	0.069	0.065	0.064	0.062	0
Greenfield	Franklin	Barr Avenue	0.065	0.065	0.061	0.056	0
Haverhill	Essex	Washington Street	0.062	0.057	0.056	0.055	0
Lynn	Essex	Parkland Avenue	0.077	0.067	0.066	0.065	1
Milton	Norfolk	Canton Avenue	0.070	0.063	0.062	0.059	0
Pittsfield	Berkshire	Silver Lake Blvd	0.066	0.066	0.060	0.060	0
Truro	Barnstable	Collins Road	0.068	0.066	0.062	0.060	0
Uxbridge	Worcester	E. Hartford Ave	0.068	0.065	0.060	0.060	0
Ware	Hampshire	Skyline Drive	0.068	0.068	0.067	0.066	0
Worcester	Worcester	Airport Drive	0.065	0.065	0.060	0.060	0

Standard: 8-hour = 0.070 ppm

1ST, 2ND, 3RD, 4TH MAX 8-HR = Maximum 8-hour Value for the 1st, 2nd, 3rd and 4th Highest Day
8-HR MAX > 0.070 STD = Number of Measured Daily 8-hr Maximum Values Greater Than the 0.070 ppm 8-hr Standard

Note: The Chelmsford – Near Road site on Manning Road does not meet ozone siting criteria but is operating for informational purposes. Therefore, it is not a consideration for determining adequacy of the O_3 monitoring network.

Ozone Design Values

The 2015 8-hour NAAQS for ozone is 0.070 parts per million (ppm). The design value is the 3-year average of the annual fourth-highest daily maximum 8-hour ozone concentration. Figure 5-19 shows ozone design values based on 2017-2019 monitored data. All monitors currently attain the 8-hour 0.070 ppm ozone standard except for the tribal monitor on Martha's Vineyard (Dukes County).

Figure 5-19
Ozone Monitor 2019 Design Values (ppm)

City	County	Address	Design Value 2017-2019
Aquinnah (Tribal)	Dukes	Herring Creek Drive	0.071
Boston	Suffolk	Harrison Avenue	0.065
Brockton	Plymouth	Clinton Street	0.067
Chelmsford	Middlesex	Technology Drive	0.062
Chelmsford	Middlesex	Manning Road	0.050
Chicopee	Hampden	Anderson Road	0.069
Fairhaven	Bristol	School Street	0.066
Fall River	Bristol	Globe Street	0.070
Greenfield	Franklin	Barr Avenue	0.062
Haverhill	Essex	Washington Street	0.061
Lynn	Essex	Parkland Avenue	0.068
Milton	Norfolk	Canton Avenue	0.066
Pittsfield	Berkshire	Silver Lake Blvd	0.055
Truro	Barnstable	Collins Road	0.067
Uxbridge	Worcester	E. Hartford Ave	0.066
Ware	Hampshire	Skyline Drive	0.066
Worcester	Worcester	Airport Drive	0.064

8-hour Ozone Exceedance Trends

Figure 5-20 shows the trends of 8-hour ozone exceedances for each monitor based on the 2015 8-hour standard.

Figure 5-20
8-hour Ozone Exceedance Trends 2010 – 2019
Based on the 0.070 ppm 8-hour Standard

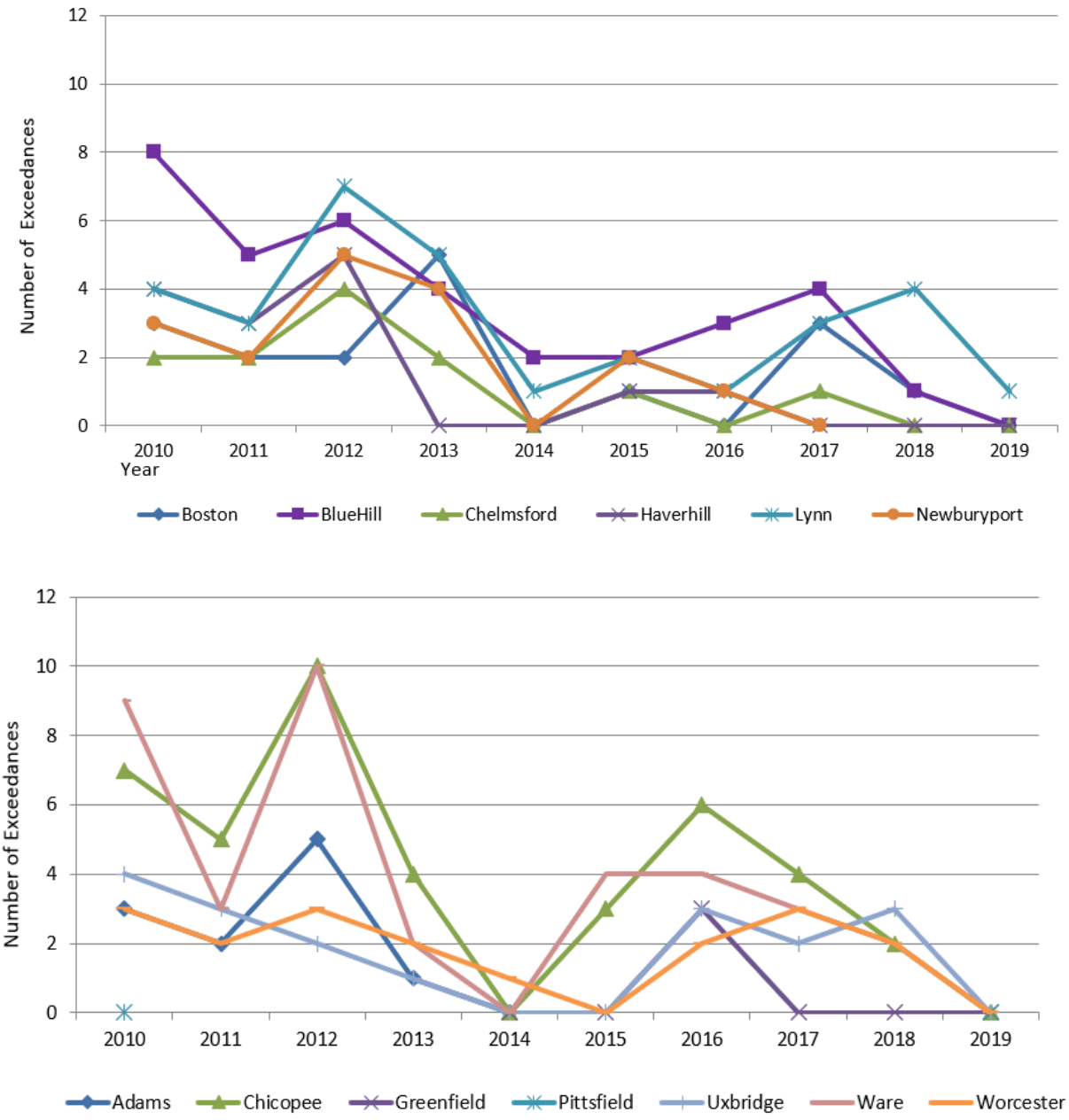
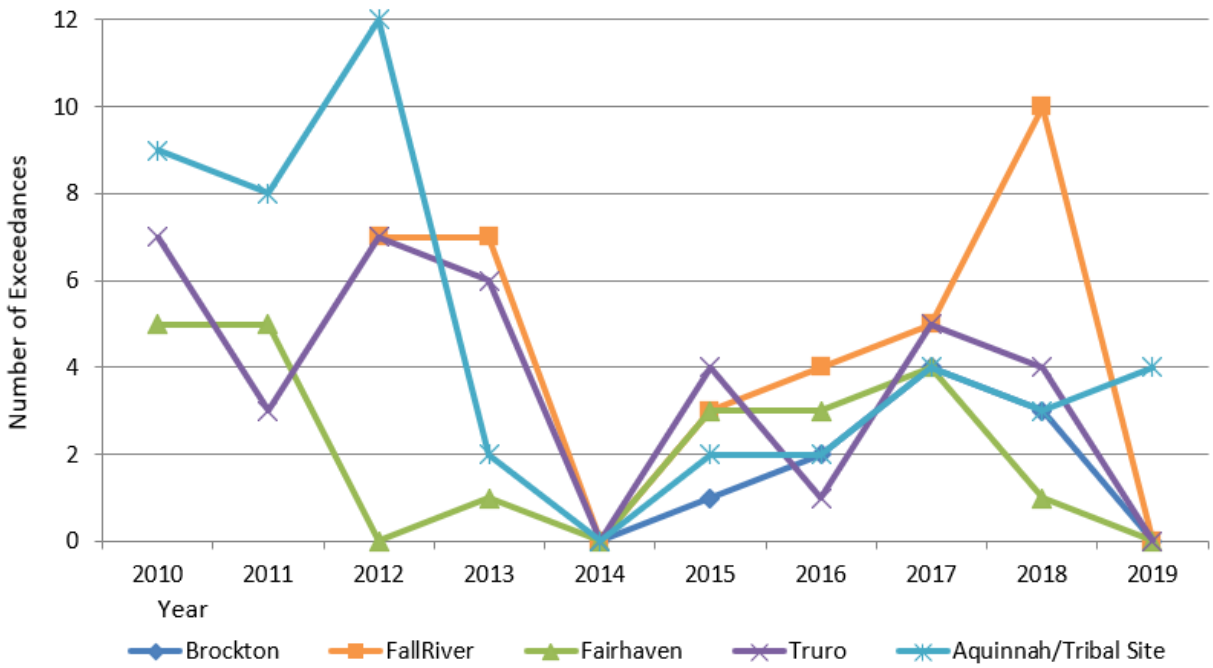


Figure 5-20 (continued)
8-hour Ozone Exceedance Trends 2010 – 2019
Based on the 0.070 ppm 8-hour Standard



PAMS MONITORING

Ground-level ozone is unique because it is not emitted directly into the atmosphere from a stack or a tailpipe. Instead, it forms in the atmosphere from the photochemical reactions of other pollutants such as volatile organic compounds (VOCs) and nitrogen oxides (NO_x). Ozone formation can occur many miles downwind from the source of the original emissions. These reactions occur in the presence of strong sunlight and are most pronounced during the hottest days of the summer.

PAMS (Photochemical Assessment Monitoring Station) is a special designation for enhanced monitoring stations that gather information on the ozone formation process. Instrumentation at these sites measures pollutants and meteorological parameters that are specific to the photochemical processes by which ozone is created in the atmosphere at ground level. This data makes it possible to assess ozone attainment progress independent of the meteorological variation that occurs between years.

In addition to the standard NAAQS pollutants (ozone, NO_2, etc.) that are measured at other sites, other ozone precursors such as VOCs, including hydrocarbons and carbonyl compounds (e.g., aldehydes), are measured at PAMS stations on either an hourly basis or at regular intervals during June, July and August. NO_x (total oxides of nitrogen) measurements (including NO_x, NO and NO_2) and NO_y (total reactive oxides of nitrogen) are also required at PAMS sites. NO_y characterizes atmospheric nitrogen reactions better than traditional NO_x measurements. The target

carbonyl compounds (formaldehyde and acetaldehyde), which have been measured as indicators of photochemical reactions, have received renewed attention regarding their air toxics relevance.

Meteorology is a critical component of ozone formation. Each PAMS site has a full complement of meteorological sensors including wind speed, wind direction, temperature, relative humidity, barometric pressure and solar radiation.

Although Massachusetts is currently in attainment with the ozone NAAQS, MassDEP continues to operate one PAMS site in Lynn (25-009-2006). Based on changes EPA made to the PAMS program, MassDEP discontinued PAMS monitoring in Chicopee (25-013-0008), Newburyport (25-009-4005) and Ware (25-015-4002). MassDEP continues to measure ozone in Chicopee and Ware; however, all measurements were discontinued in Newburyport.

The benefits of continued PAMS monitoring in Lynn include obtaining spatial and temporal trends. MassDEP is in the ozone transport region (OTR) and has collected PAMS data for over 25 years. Continued PAMS measurements can be compared with regional and historic data to demonstrate trends in ozone precursor pollutants as they move through the heavily populated northeast corridor.

When the ozone and PAMS sites were originally established, MassDEP worked closely with EPA to ensure that the proper analyses were done to ensure that each site met the network design requirements. Since population and pollution sources have not significantly changed since the mid-1990s, MassDEP is confident that the ozone sites and the PAMS site still meet the appropriate design criteria.

MassDEP continues to participate in regional and national discussions designed to make sure the PAMS and ozone networks are both efficient and relevant. MassDEP believes the current configuration is sufficient for air pollution forecasting and ozone SIP development and implementation.

Figure 5-21
Location and Description of the PAMS Site

Site ID	Site Name	Reason for Monitor	Date Established	Pollutant Measurements	Meteorological Measurements
25-009-2006	Lynn	PAMS - Max. Precursor; Population Exposure	1/1/1992	O_3, NO, NO_2, NO_X, NO_Y, $PM_{2.5}$, VOCs, Carbonyls	WS, WD, TEMP, RH, BP, SOLAR, PRECIP

WS = wind speed
WD = wind direction
TEMP = temperature
RH = relative humidity
BP = barometric pressure
SOLAR = solar radiation
PRECIP = precipitation

OZONE MONITORING TECHNOLOGY

Ozone

MassDEP uses continuous ultraviolet (UV) light photometry to monitor ambient ozone concentrations. This is the Federal Automated Equivalent Method and there is no reason to change this equipment, although there is current research into the reintroduction of chemiluminescence method.

PAMS

MassDEP operates an Automated Gas Chromatograph (AutoGCs) with a flame ionization detector (FID) to measure ozone precursor target hydrocarbon VOCs (volatile organic compounds) at the Lynn PAMS site. This instrument completes an hourly sample collection and analysis cycle to measure target VOCs.

ADEQUACY OF THE OZONE MONITORING NETWORK

EPA Requirements

As demonstrated in Figure 5-22, MassDEP's ozone monitoring network meets minimum EPA requirements.

Figure 5-22
Minimum Ozone Monitoring Requirements

MSA	2018 Population	Design Value (max for MSA)	≥85% of Std?	Monitors Required	Monitors in Network	Maximum Concentration Site
Boston-Cambridge-Newton	4,875,390	0.068	Yes	3	7	Lynn
Barnstable	213,413	0.067	Yes	1	1	Truro
Worcester	947,866	0.066	Yes	2	2	Uxbridge
Springfield	631,761	0.069	Yes	2	2	Chicopee
Pittsfield	126,348	0.055	No	1	1	Pittsfield

Design Criteria:

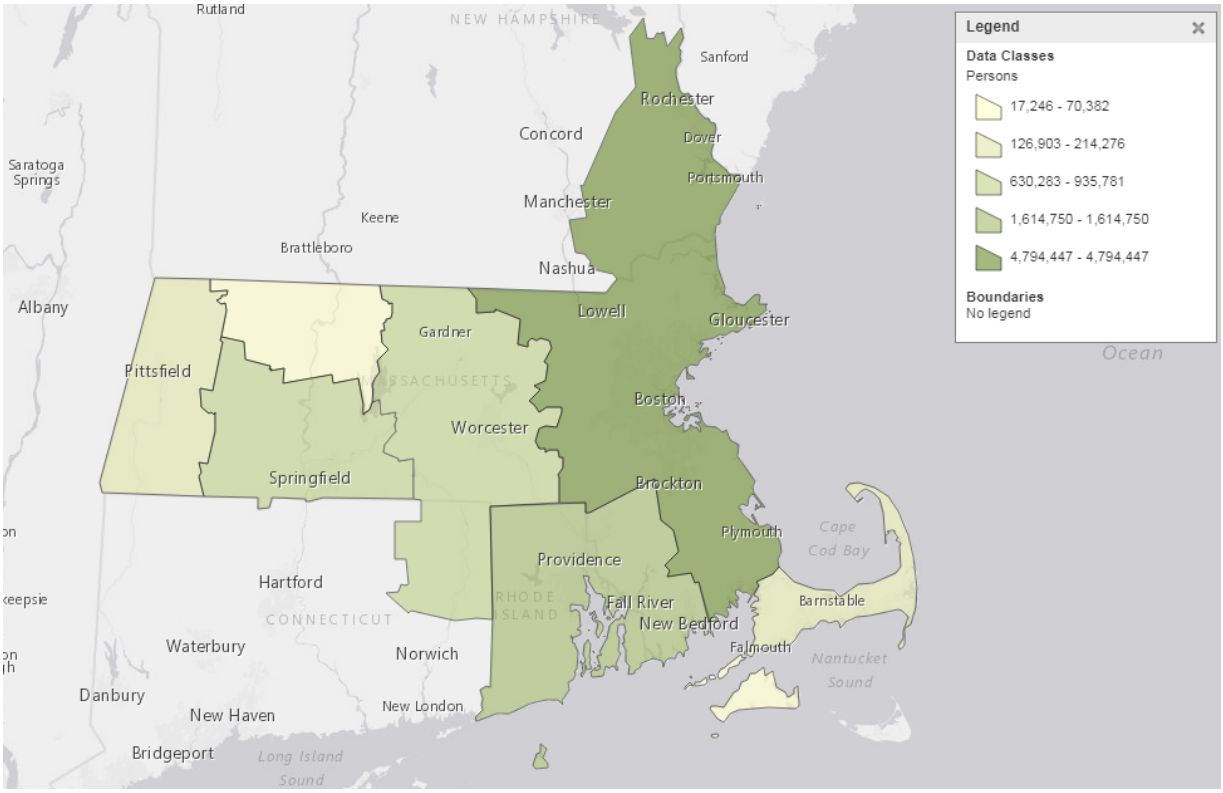
If the Design value is ≥85% of the standard:

- MSAs with a population of > 10 million require 4 monitors
- MSAs with a population of 4 - 10 million require 3 monitors
- MSAs with a population of 350,000 - < 4 million require 2 monitors
- MSAs with a population of 50,000 - 349,999 require 1 monitor

If the Design value is <85% of the standard:

- MSAs with a population of > 10 million require 2 monitors
- MSAs with a population of 4 - 10 million require 1 monitor
- MSAs with a population of 350,000 - < 4 million require 1 monitor
- MSAs with a population of 50,000 - 349,999 require 0 monitor

Figure 5-23
Metro/Micro Statistical Areas in Massachusetts
Thematic Map of Population Estimate (as of July 1, 2016)
Geography: by Metro/Micro Statistical Area



Source: U.S. Census Bureau. Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2016

The benefits of continued PAMS monitoring in Lynn include monitoring spatial and temporal trends. MassDEP is in the ozone transport region (OTR) and has collected PAMS data for over 25 years. Continued PAMS measurements can be compared with regional and historical data to demonstrate trends in ozone precursor pollutants as they move through the heavily populated northeast corridor.

When the ozone and PAMS sites were originally established, MassDEP worked closely with EPA to ensure that the proper analyses were done to ensure that each site met the network design requirements. Since population and pollution sources have not significantly changed since the mid-1990s, MassDEP is confident that the ozone and PAMS sites still meet the appropriate design criteria.

Exceedance Probability, Correlations, Removal Bias

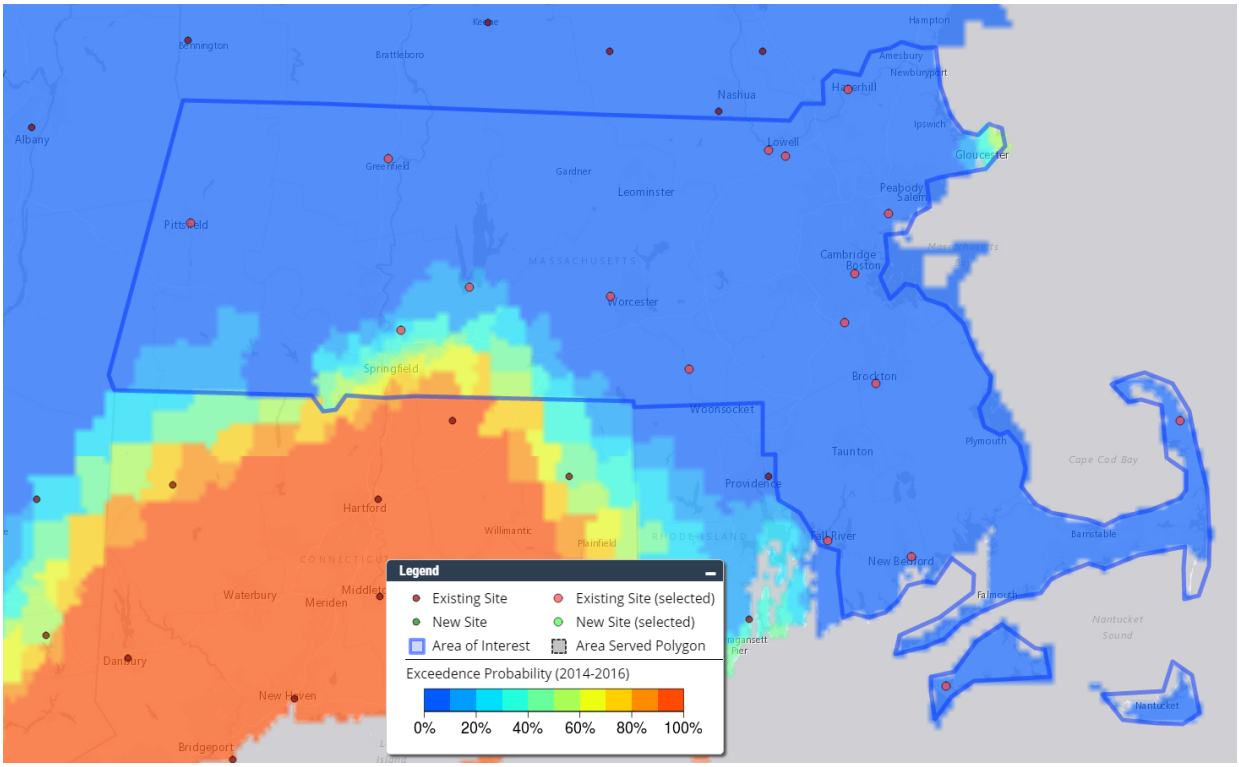
EPA recommends three analytical approaches for identifying potentially underserved areas and redundant sites in the ozone monitoring network. MassDEP used NetAssess2020 to conduct these analyses.

Exceedance Probability

NetAssess2020 provides a probability map to help determine where new monitors may need to be located.

Figure 5-24 shows the probability of exceeding the existing 70 ppb NAAQS. All areas of moderate to high probability are covered by existing monitors and are supplemented by monitors in Connecticut and New York to the south and southwest.

Figure 5-24
Probability of Exceeding the O_3 70 ppb NAAQS



Source: NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool

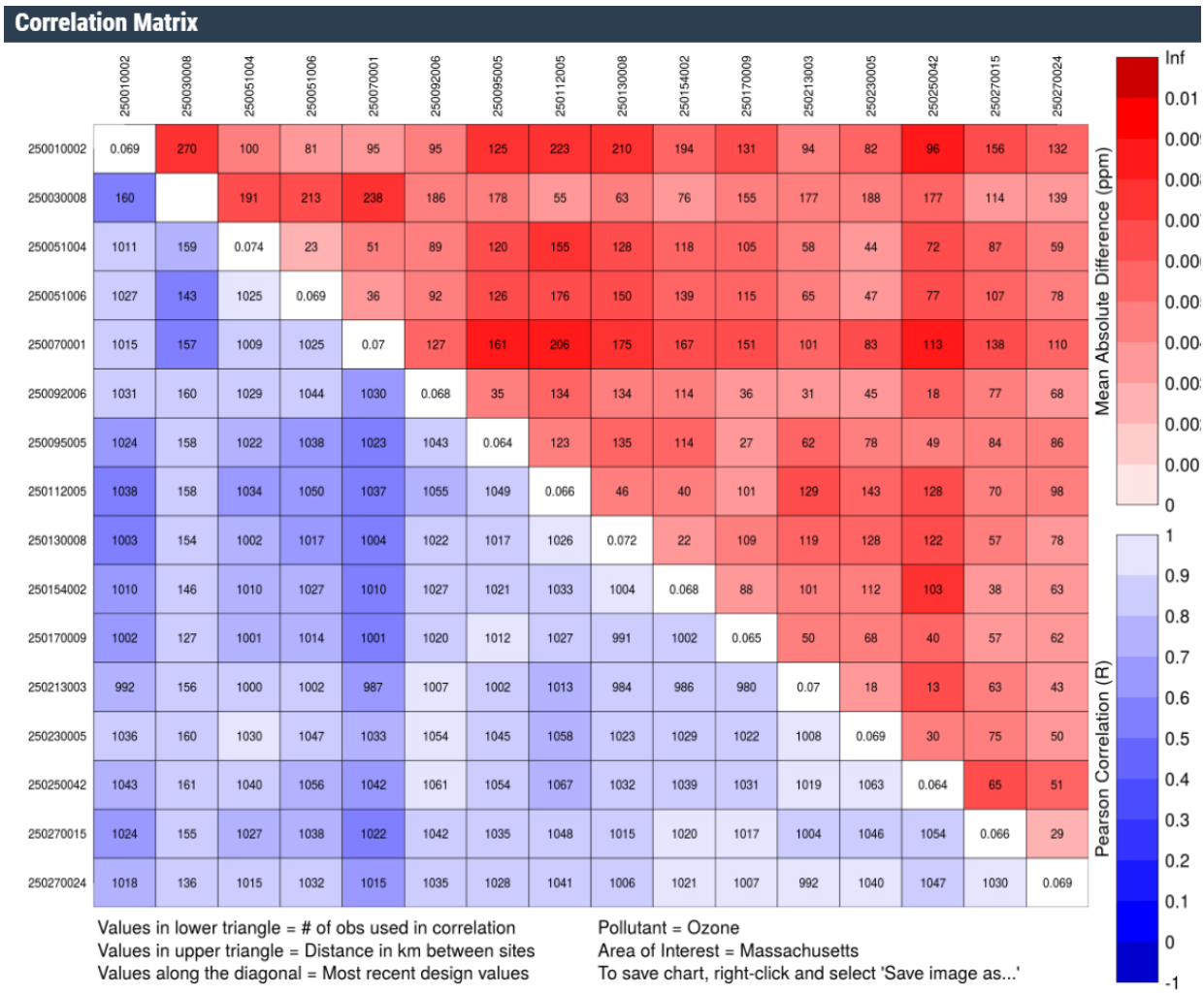
Site Correlation Analysis

The NetAssess2020 tool was used to provide correlations between ozone monitors. The Correlation Matrix tool uses daily summary pollutant concentration data for ozone and fine particles. For ozone, the correlation matrix tool calculates a Pearson Correlation (r) for all valid 8-hour average ozone concentration pairs. If a site has more than one monitor collecting ozone data, the daily maximum 8-hour ozone concentration is the average of all valid results for that site on that date.

Figure 5-25 shows the correlation between ozone measurements at monitoring sites in Massachusetts. Overall, the ozone monitors are highly correlated with an average correlation value of 0.80 and an average mean difference value of 0.005. Figure 5-26 shows highly correlated sites with correlation values greater than 0.90, mean difference less than 0.005 and distance less than 65 km (~40 miles).

The Brockton (25-023-0005) and Uxbridge (25-027-0024) sites appear most frequently in Figure 5-26, with each pairing to another site five times including one pairing between the two sites themselves. No other site appears in Figure 5-26 more than three times.

Figure 5-25
Correlation Between Ozone Monitors in Massachusetts



	250010002	250030008	250051004	250051006	250070001	250092006	250095005	250112005	250130008	250154002	250170009	250213003	250230005	250250042	250270015	250270024
250010002	0.069	270	100	81	95	95	125	223	210	194	131	94	82	96	156	132
250030008	160		191	213	238	186	178	55	63	76	155	177	188	177	114	139
250051004	1011	159	0.074	23	51	89	120	155	128	118	105	58	44	72	87	59
250051006	1027	143	1025	0.069	36	92	126	176	150	139	115	65	47	77	107	78
250070001	1015	157	1009	1025	0.07	127	161	206	175	167	151	101	83	113	138	110
250092006	1031	160	1029	1044	1030	0.068	35	134	134	114	36	31	45	18	77	68
250095005	1024	158	1022	1038	1023	1043	0.064	123	135	114	27	62	78	49	84	86
250112005	1038	158	1034	1050	1037	1055	1049	0.066	46	40	101	129	143	128	70	98
250130008	1003	154	1002	1017	1004	1022	1017	1026	0.072	22	109	119	128	122	57	78
250154002	1010	146	1010	1027	1010	1027	1021	1033	1004	0.068	88	101	112	103	38	63
250170009	1002	127	1001	1014	1001	1020	1012	1027	991	1002	0.065	50	68	40	57	62
250213003	992	156	1000	1002	987	1007	1002	1013	984	986	980	0.07	18	13	63	43
250230005	1036	160	1030	1047	1033	1054	1045	1058	1023	1029	1022	1008	0.069	30	75	50
250250042	1043	161	1040	1056	1042	1061	1054	1067	1032	1039	1031	1019	1063	0.064	65	51
250270015	1024	155	1027	1038	1022	1042	1035	1048	1015	1020	1017	1004	1046	1054	0.066	29
250270024	1018	136	1015	1032	1015	1035	1028	1041	1006	1021	1007	992	1040	1047	1030	0.069

Source: NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool

Figure 5-26
Highly Correlated Ozone Monitors in Massachusetts

Site 1	Site 2	Correlation	Distance (km)	n	Mean Difference
25-005-1004 - Fall River	25-005-1006 - Fairhaven	0.9359	23	1025	0.0028
25-005-1004 - Fall River	25-023-0005 - Brockton	0.9236	44	1030	0.0033
25-009-2006 - Lynn	25-021-3003 - Milton	0.9218	31	1007	0.0030
25-009-2006 - Lynn	25-023-0005 - Brockton	0.9317	45	1054	0.0030
25-009-5005 - Haverhill	25-017-0009 - Chelmsford EPA	0.9071	27	1012	0.0031
25-011-2005 - Greenfield	25-013-0008 - Chicopee	0.9115	46	1026	0.0041
25-013-0008 - Chicopee	25-015-4002 - Ware	0.9226	22	1004	0.0033
25-015-4002 - Ware	25-027-0015 - Worcester Airport	0.9213	38	1020	0.0030
25-015-4002 - Ware	25-027-0024 - Uxbridge	0.9084	63	1021	0.0033
25-017-0009 - Chelmsford EPA	25-027-0015 - Worcester Airport	0.9027	57	1017	0.0032
25-017-0009 - Chelmsford EPA	25-027-0024 - Uxbridge	0.9185	62	1007	0.0030
25-021-3003 - Milton	25-023-0005 - Brockton	0.9530	18	1008	0.0030
25-021-3003 - Milton	25-027-0024 - Uxbridge	0.9193	43	992	0.0031
25-023-0005 - Brockton	25-025-0042 - Boston Harrison Ave	0.9290	30	1063	0.0046
25-023-0005 - Brockton	25-027-0024 - Uxbridge	0.9239	50	1040	0.0033
25-027-0015 - Worcester Airport	25-027-0024 - Uxbridge	0.9225	29	1030	0.0028

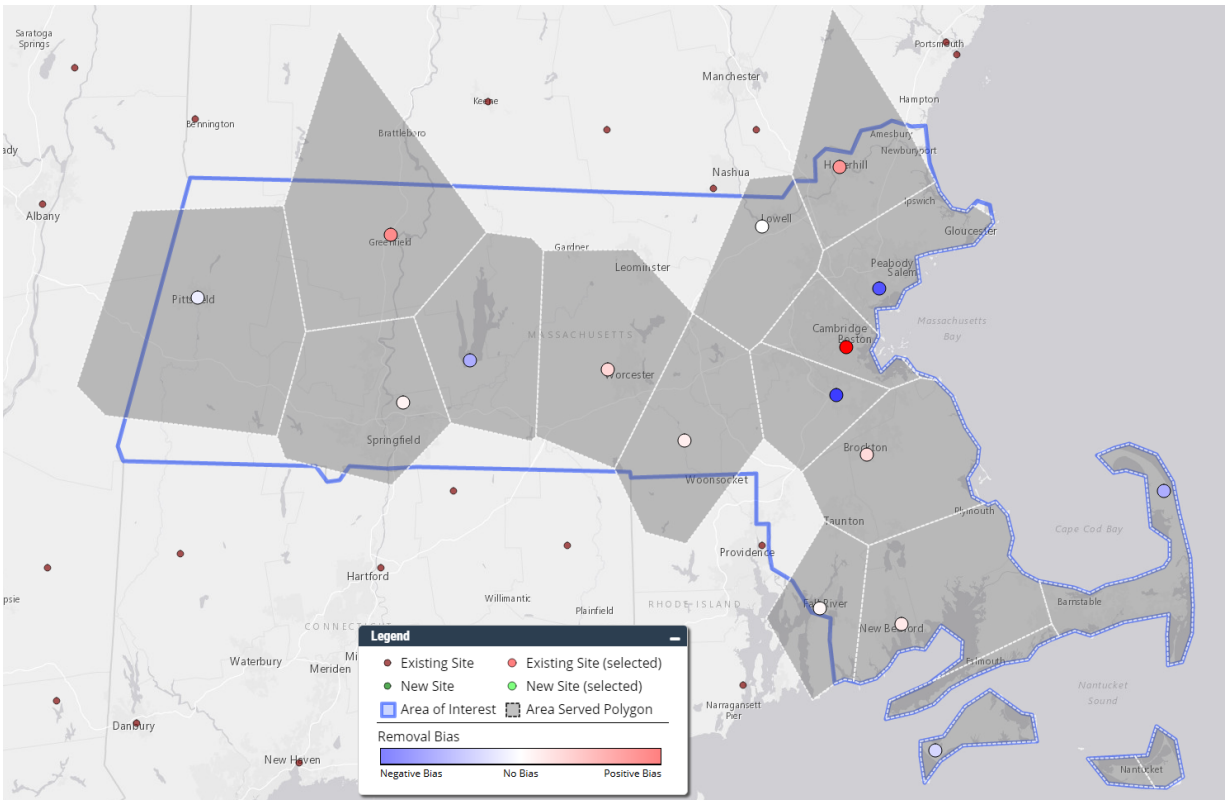
n = Number of observations used in correlation
km = kilometers

Source: NetAssess2020 v1.1

Removal Bias Analysis

Removal bias was calculated with NetAssess2002. Figures 5-27 and 5-28 show the removal bias that would result from eliminating each ozone monitor individually.

Figure 5-27
Removal Bias for Ozone Monitors



Source: NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool

Figure 5-28
Removal Bias Statistics for Ozone Monitors

Site ID	Site Name	Mean Removal Bias	Min Removal Bias	Max Removal Bias	Removal Bias Standard Deviation	Neighbors Included
25-021-3003	Milton - Blue Hill	-0.0042	-0.017	0.006	0.0034	5
25-009-2006	Lynn	-0.0037	-0.016	0.008	0.0029	6
25-001-0002	Truro	-0.0018	-0.019	0.019	0.0040	12
25-015-4002	Ware	-0.0018	-0.023	0.013	0.0031	7
25-007-0001	Aquinnah	-0.0009	-0.035	0.024	0.0050	9
25-003-0008	Pittsfield	-0.0004	-0.010	0.007	0.0026	6
25-017-0009	Chelmsford - EPA	0.0000	-0.013	0.018	0.0026	7
25-005-1004	Fall River	0.0002	-0.013	0.007	0.0028	5
25-013-0008	Chicopee	0.0003	-0.015	0.025	0.0038	6
25-027-0024	Uxbridge	0.0004	-0.009	0.011	0.0023	7
25-005-1006	Fairhaven	0.0005	-0.011	0.014	0.0028	4
25-023-0005	Brockton	0.0008	-0.011	0.011	0.0022	7
25-027-0015	Worcester - Airport	0.0009	-0.010	0.022	0.0033	5
25-009-5005	Haverhill	0.0023	-0.010	0.021	0.0039	5
25-011-2005	Greenfield	0.0025	-0.008	0.022	0.0036	5
25-025-0042	Boston - Harrison Ave	0.0055	-0.006	0.019	0.0036	4

Source: NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool

The mean removal bias is generally very small, but the standard deviation is relatively large and the distance between the minimum and maximum are substantial. Therefore, removing any one monitor would not introduce significant bias on average, but would introduce the potential for relatively large errors (imprecision). This analysis therefore does not point to any particular monitor as redundant and a good candidate for removal.

ANALYSIS RESULTS

MassDEP's ozone monitoring network meets EPA monitoring requirements and objectives and provides good coverage for the state, and there is no need for additional ozone or PAMS monitors at this time. While it is possible that some ozone monitors could be eliminated, MassDEP measures other pollutants at most ozone monitoring sites, providing additional benefits.

Carbon Monoxide (CO)

CO NETWORK DESCRIPTION

MassDEP currently operates three carbon monoxide (CO) monitors in Suffolk and Worcester Counties. The network consists of trace-level instruments that measure from 0 to 5 parts per million. Trace-level monitors are used at locations where CO levels are expected to be less than 2 parts per million. Values around the state have been consistently low for quite some time. Figure 5-29 lists the location, purpose, description and EPA scale of each of the CO monitoring stations.

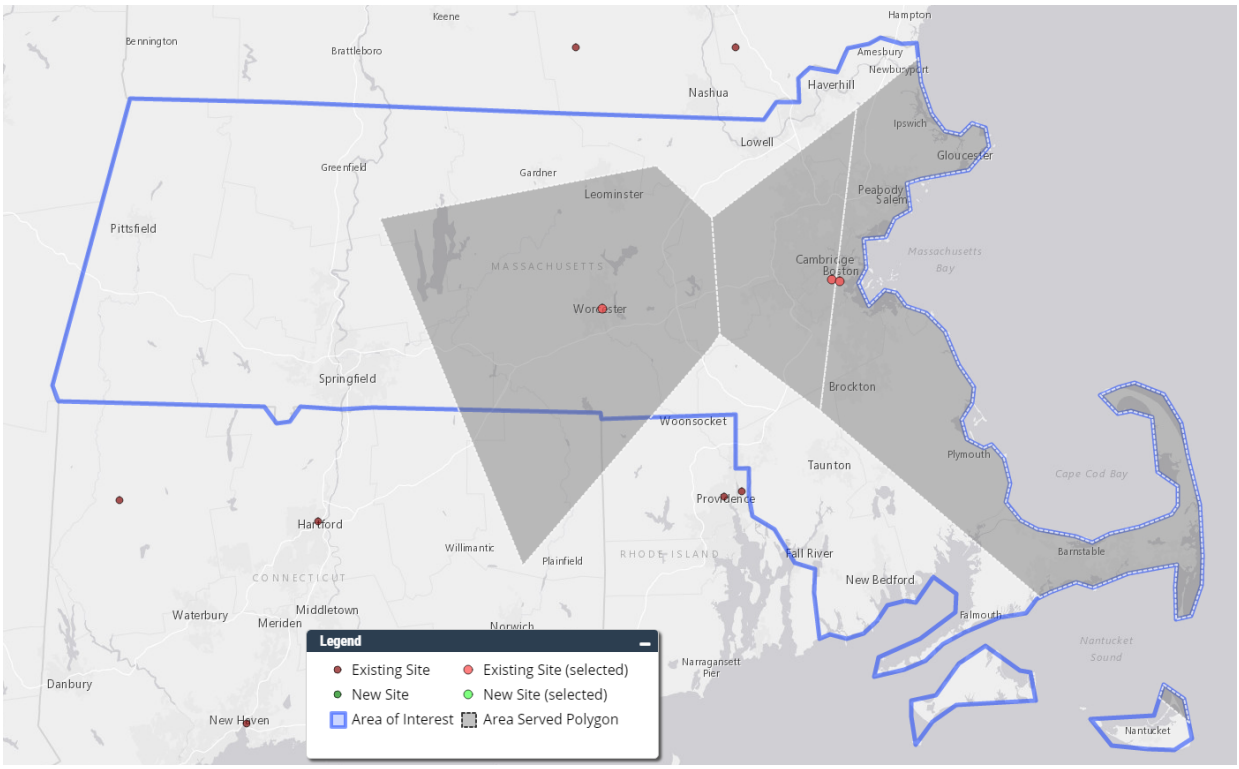
Figure 5-29
CO Monitoring Network Description

Site ID	Site Name	Scale	Reason for Monitor	Date Established	MSA/MiSA
25-025-0044	Boston - Von Hillern	Middle	Population Exposure; Max. Concentration; Near Road	6/15/2013	Boston-Cambridge-Newton MSA
25-025-0042	Boston - Harrison Ave	Neighborhood	Population Exposure	12/15/1998	Boston-Cambridge-Newton MSA
25-027-0023	Worcester - Summer St	Middle	Population Exposure	1/1/2004	Worcester MSA

CO MONITOR AREAS SERVED

Figure 5-30 shows the area served by each CO monitor as defined by Voronoi polygons. These polygons were developed using NetAssess2020. Due to the very low levels of CO monitored, CO has become much less of a concern for EPA and states, and MassDEP has worked with EPA to gradually reduce its CO monitoring network.

Figure 5-30
Area Served – CO sites



Source: NetAssess2020 v1.1 Ambient Air Monitoring Network Assessment Tool

CO DATA

2019 Summary Data

Figure 5-31 summarizes 2019 CO data. All values are well below the applicable NAAQS.

Figure 5-31
2019 CO Monitoring Data Summary (ppm)

City	County	Address	1ST MAX 1-HR	2ND MAX 1-HR	1ST MAX 8-HR	2ND MAX 8-HR
Boston	Suffolk	Harrison Avenue	1.855	1.609	1.2	1.0
Boston	Suffolk	Von Hillern Street	0.730	0.729	0.5	0.5
Springfield	Hampden	Liberty Street	1.629	1.596	1.3	1.2
Worcester	Worcester	Summer Street	1.995	1.570	1.1	0.9

Standards: 1-hour = 35 ppm
8-hour = 9 ppm

1ST, 2ND MAX 1-HR = First and Second Highest 1-hr Value
1ST, 2ND MAX 8-HR = First and Second Highest 8-hr Value

CO Design Values

There are no design values for CO, but only values not to be exceeded. The 8-hour NAAQS for CO is 9 parts per million (ppm) not to be exceeded more than once per year. The 1-hour NAAQS for CO is 35 ppm not to be exceeded more than once per year. Figure 5-32 shows that Massachusetts is consistently well below both the 8-hour and 1-hour CO standards.

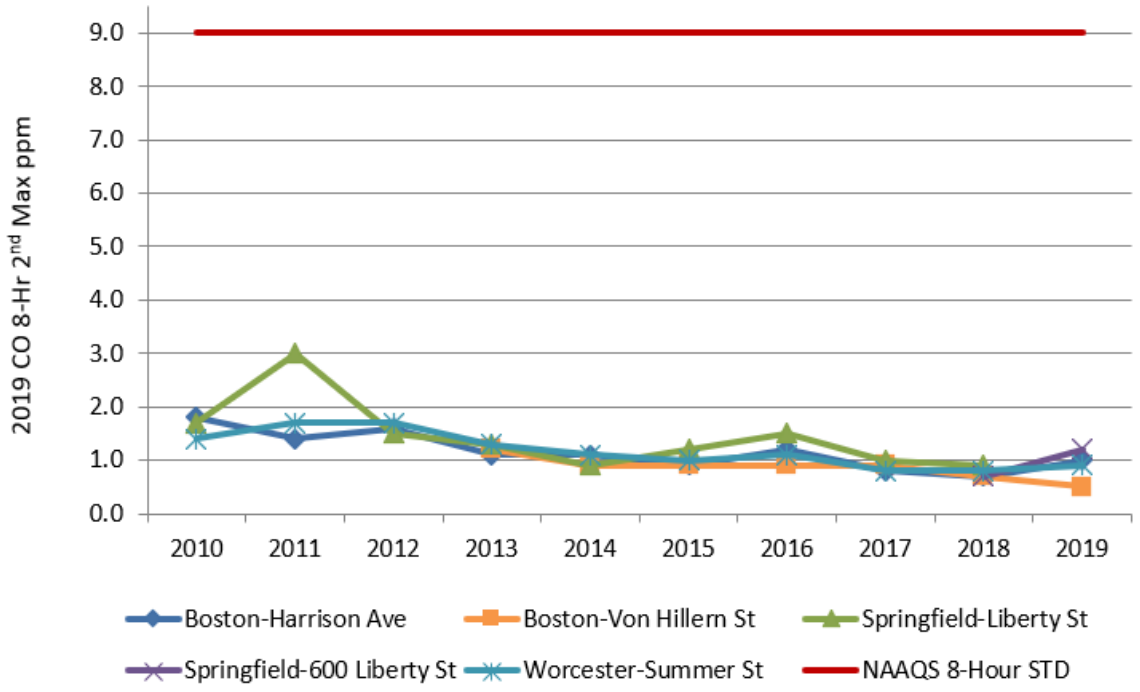
Figure 5-32
2019 Summary Values for CO (ppm)

City	County	Address	2017 – 2019 Maximum Value	
			1 Hour (35 ppm)	8 Hour (9 ppm)
Boston	Suffolk	Harrison Avenue	1.855	1.3
Boston	Suffolk	Von Hillern Street	1.674	1.3
Springfield	Hampden	Liberty Street	2.100	1.3
Worcester	Worcester	Summer Street	1.995	1.1

CO Trends

Figure 5-33 shows the trend of each CO monitor relative to the 8-hour standard of 9 ppm.

Figure 5-33
Carbon Monoxide Trends 2010-2019
2nd Maximum 8-hour Values



CO TECHNOLOGY

MassDEP uses infrared red (IR) absorption analyzers to monitor low concentration range (trace level) CO. There is no reason to change to another measurement technology at this time.

ADEQUACY OF THE CO MONITORING NETWORK

EPA Requirements

MassDEP has sited its CO monitors in compliance with EPA requirements, guidance and approval. Near-road sites in CBSAs having a population of 1,000,000 or more are required to collocate one CO monitor with one NO_2 monitor. MassDEP's Boston – Von Hillern site fulfills this requirement.

In addition, continued operation of existing CO sites using FRM or FEM monitors is required until discontinuation is approved by EPA. The discontinuation of the Springfield CO monitor was approved by EPA and the monitor was closed at the end of 2019. The Boston-Harrison Avenue

and Worcester - Summer Street monitors represent urban background, and Boston-Von Hillern monitors near-road concentrations.

ANALYSIS RESULTS

MassDEP's CO monitoring network meets EPA monitoring requirements and objectives and provides adequate coverage for the state given the very low levels of CO monitored, and no additional monitors are needed.

Sulfur Dioxide (SO_2)

SO_2 NETWORK DESCRIPTION

MassDEP currently operates six sulfur dioxide (SO_2) monitors in Suffolk, Worcester, Bristol, Hampden and Hampshire Counties. Similar to CO, SO_2 concentrations have decreased so significantly that trace instruments are used for monitoring. Figure 5-34 lists the location, purpose and description of the SO_2 monitoring stations and their EPA scales for SO_2 monitoring purposes.

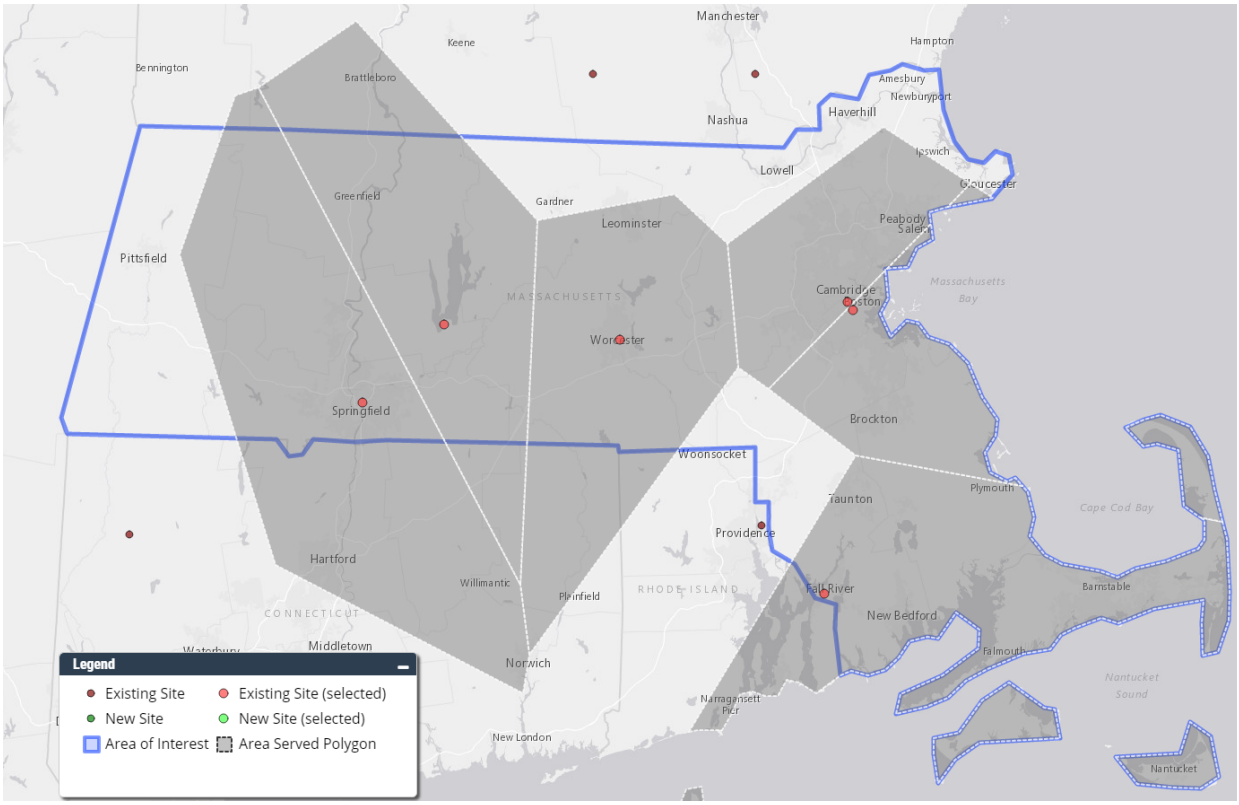
Figure 5-34
SO_2 Monitoring Network Description

Site ID	Site Name	Scale	Reason for Monitor	Date Established	MSA/MiSA
25-025-0002	Boston - Kenmore	Neighborhood	Population Exposure	1/1/1965	Boston-Cambridge-Newton MSA
25-025-0042	Boston - Harrison Ave	Neighborhood	Population Exposure	12/15/1998	Boston-Cambridge-Newton MSA
25-005-1004	Fall River	Neighborhood	Population Exposure	2/1/1975	Providence-Warwick MSA
25-013-0018	Springfield	Urban	Population Exposure	5/1/2018	Springfield MSA
25-015-4002	Ware	Urban	Population Exposure	6/1/1985	Springfield MSA
25-027-0023	Worcester - Summer St	Urban	Population Exposure	1/1/2004	Worcester MSA

COVERAGE AREA

Figure 5-35 shows the area served by each SO_2 monitor as defined by Voronoi polygons. These polygons were developed using NetAssess2020. The SO_2 monitoring network provides adequate coverage for the state given the low levels monitored. All major SO_2 emission sources in Massachusetts have ceased operation. The last coal-fired power station in Massachusetts, Brayton Point Station in Somerset, ceased operations in 2017. SO_2 values in the state have remained very low for several years.

Figure 5-35
Coverage Areas for SO_2 Monitor



Source: NetAssess2020 v1.1

SO_2 DATA

2019 SO_2 Data Summary

Figure 5-36 summarizes 2019 monitoring data for SO_2. All values are well below the applicable NAAQS.

Figure 5-37
2019 SO_2 Monitoring Data Summary (ppb)

City	County	Address	1ST MAX 1-HR	2ND MAX 1-HR	99TH PCTL 1-HR	ARITH MEAN	1ST MAX 24-HR	2ND MAX 24-HR
Boston	Suffolk	Kenmore Square	3.4	2.2	1.9	0.29	1.0	0.8
Boston	Suffolk	Harrison Avenue	2.9	1.9	1.7	0.33	0.9	0.7
Fall River	Bristol	Globe Street	5.1	3.4	3.0	0.49	1.6	1.3
Springfield	Hampden	Liberty Street	3.0	2.9	2.5	0.28	1.8	1.5
Ware	Hampshire	Skyline Drive	1.5	1.4	1.1	0.12	0.7	0.6
Worcester	Worcester	Summer Street	2.7	2.5	2.4	0.33	1.2	1.1

Standards: 1-hour = 75 ppb
3-hour = 0.5 ppm (500 ppb)

1ST, 2ND MAX 1-HR = First and Second Highest 1-hr Value
99TH PCTL 1-HR = 99th Percentile of the 1-hr Maximum Value
ARITH MEAN = Annual Arithmetic Mean
1st, 2nd MAX 24-HR = First and Second Highest 24-hr Value

SO_2 Design Values

Figure 5-37 shows the 2019 design values for each SO_2 monitor. The annual SO_2 NAAQS is 75 ppb measured as the 99th percentile of the 1-hour daily maximum concentrations averaged over three years. Design values for all monitors are well below the NAAQS.

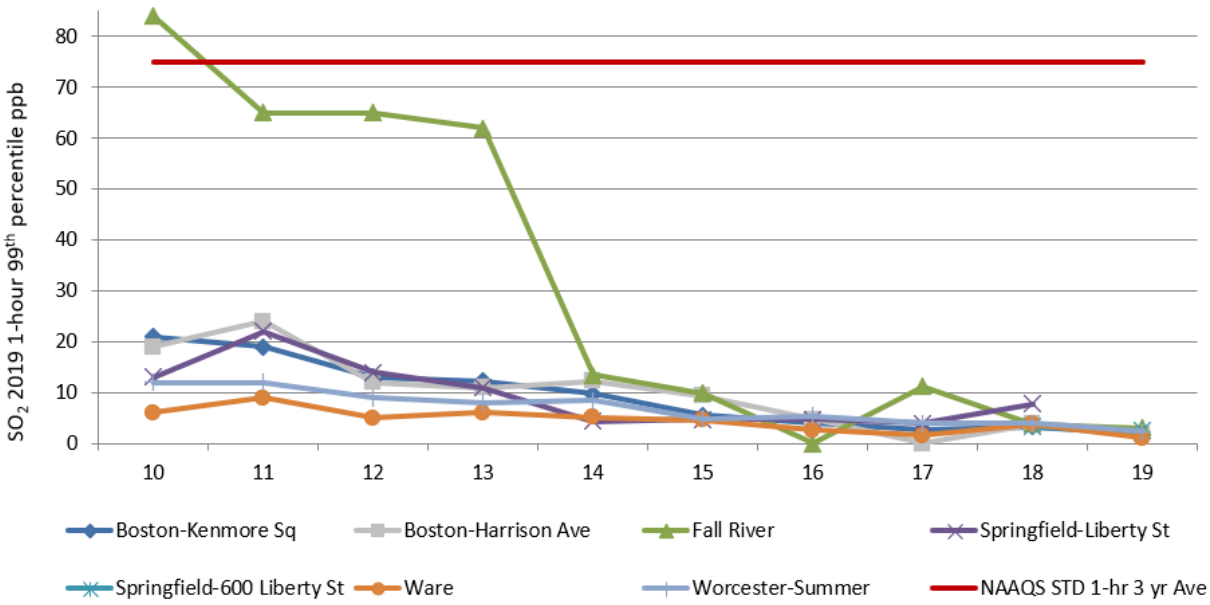
Figure 5-37
2017-2019 SO_2 Design Values (ppb)

City	County	Address	Design Value 2017-2019
Boston	Suffolk	Kenmore Square	3
Boston	Suffolk	Harrison Avenue	3
Fall River	Bristol	Globe Street	6
Springfield	Hampden	Liberty Street	3
Ware	Hampshire	Skyline Drive	2
Worcester	Worcester	Summer Street	3

SO_2 Trend Data

Figure 5-37 shows the trends for each SO_2 monitor relative to the 1-hour standard of 75 ppb.

Figure 5-37
Sulfur Dioxide Trends 2010 – 2019
1-hour 99th Percentile Annual Average



Note that the Fall River monitor was sited near coal-fired Brayton Point Station in Somerset, which ceased operations in 2017.

SO_2 TECHNOLOGY

MassDEP uses an ultraviolet (UV) fluorescence absorption continuous monitoring technology to measure ambient SO_2 trace concentrations. There is no need to change to a different monitoring technology at this time.

ADEQUACY OF THE SO_2 MONITORING NETWORK

EPA Requirements

The current SO_2 monitoring network meets EPA requirements. Figure 5-39 shows the population weighted emissions index (PWEI) and number of SO_2 monitors for the state's MSAs.

Figure 5-39
EPA Monitoring Requirements for SO_2

MSA	MA County in MSA	County Population	MA Population in MSA	SO_2 Emissions	PWEI	Monitors Required	Monitors in Network
Boston-Cambridge-Newton	Essex	790,638	4,436,124	2,366	10,496	1	2 (both in Boston)
	Middlesex	1,614,714					
	Suffolk	807,252					
	Norfolk	705,388					
	Plymouth	518,132					
Barnstable	Barnstable	213,413	213,413	146	31	0	0
Providence-Warwick	Bristol	564,022	564,022	2,287	1,290	0	1
Worcester	Worcester	830,839	830,839	401	333	0	1
Springfield	Hampden	470,406	631,761	338	214	0	2
	Hampshire	161,355					
Pittsfield	Berkshire	126,348	126,348	79	10	0	0

Notes: SO_2 emissions measured in tons per year. SO_2 emissions for all counties are presented in Figure 4-4.
PWEI = Population weighted emissions index
PWEI = (MA Population in MSA x SO_2 Emissions) / 1,000,000

Design criteria:
- MSAs with a PWEI greater than 1,000,000 require 3 monitors
- MSAs with a PWEI between 100,000 and 1,000,000 require 2 monitors
- MSAs with a PWEI between 5,000 and 100,000 require 1 monitor

ANALYSIS RESULTS

MassDEP's SO_2 monitoring network meets EPA monitoring requirements and objectives and provides adequate coverage for the state given the very low levels of SO_2 monitored, and no additional monitors are needed. Massachusetts no longer has significant SO_2 emissions sources that would warrant SO_2 monitoring.

Nitrogen Dioxide (NO_2)

NETWORK DESCRIPTION

MassDEP operates 10 NO_2 monitors in 8 municipalities (see Figure 5-40) located in Suffolk, Norfolk, Essex, Worcester, Hampshire and Hampden Counties. Because NO_2 is both a NAAQS pollutant and, along with other oxides of nitrogen, an ozone precursor, MassDEP operates five NO_2 sites for NAAQS compliance based on population exposure, and operates five NO_2 monitors at for ozone monitoring and PAMS purposes. Boston - Von Hillern Street and Chelmsford – Manning Road are required near-road sites for monitoring compliance with the 1-hour NO_2 standard.

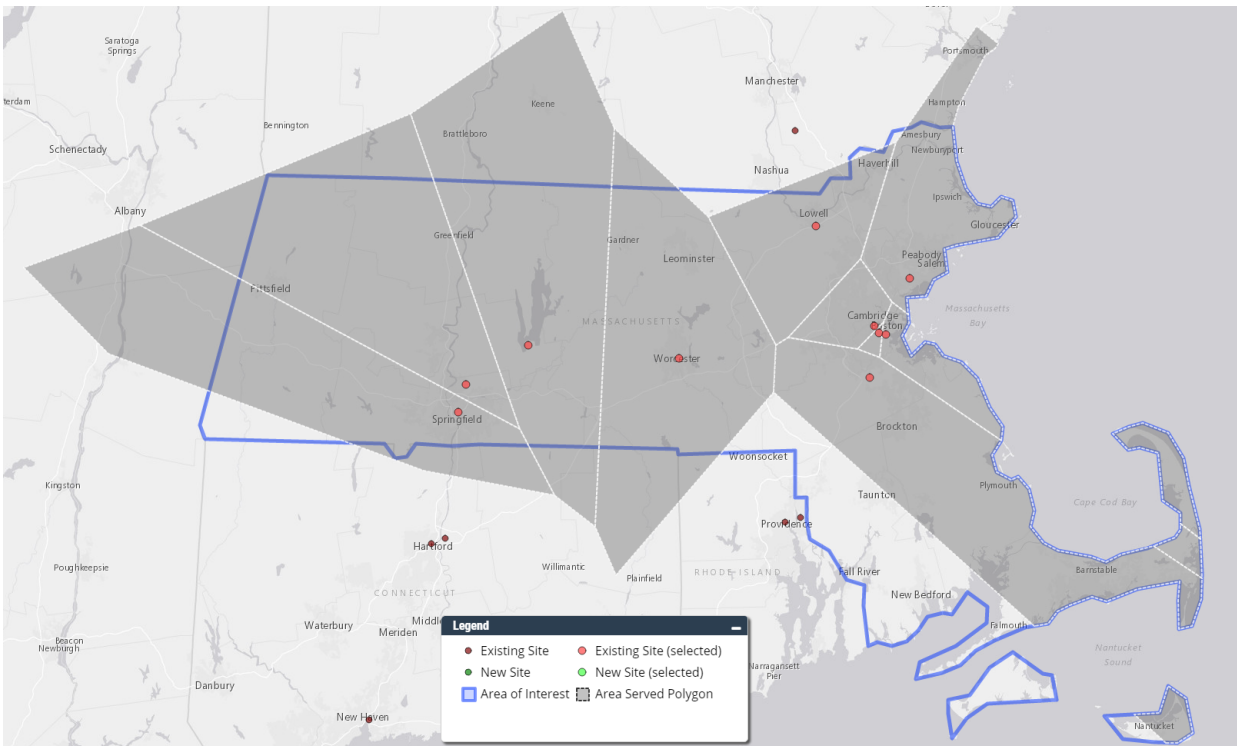
Figure 5-40
NO_2 Monitor Site Location, Description and Other Pollutants Monitored

Site ID	Site Name	Scale	Reason for Monitor	Date Established	MSA/MiSA
25-025-0002	Boston - Kenmore	Micro	Highest Concentration; Population Exposure	1/1/1965	Boston-Cambridge-Newton MSA
25-025-0042	Boston - Harrison Ave	Neighborhood	Population Exposure	12/15/1998	Boston-Cambridge-Newton MSA
25-025-0044	Boston - Von Hillern St	Middle	Population Exposure; Max. Concentration; Near Road	6/15/2013	Boston-Cambridge-Newton MSA
25-017-0010	Chelmsford – Manning Rd	Middle	Population Exposure; Max. Concentration; Near Road	7/1/2018	Boston-Cambridge-Newton MSA
25-013-0008	Chicopee	Urban	Population Exposure	1/1/1983	Springfield MSA
25-009-2006	Lynn	Urban	PAMS - Max. Precursor O_3; Population Exposure	1/1/1992	Boston-Cambridge-Newton MSA
25-021-3003	Milton - Blue Hill	Regional	Upwind Background $PM_{2.5}$; Maximum Ozone	4/2/2002	Boston-Cambridge-Newton MSA
25-013-0018	Springfield	Urban	Population Exposure; Highest Concentration	5/1/2018	Springfield MSA
25-015-4002	Ware	Urban	Max. O_3 Conc.; background for other pollutants	6/1/1985	Springfield MSA
25-027-0023	Worcester - Summer St	Urban	Population Exposure	1/1/2004	Worcester MSA

COVERAGE AREA

Figure 5-41 shows the area served by each NO_2 monitor as defined by Voronoi polygons. These polygons were developed using NetAssess2020. The NO_2 monitoring network provides adequate coverage for the state given that the largest sources of NO_2 are roadways, and the network has two near-road sites (Boston – Von Hillern Street and Chelmsford Manning Street) that are sited where the highest concentrations in the state are expected to be.

Figure 5-41
NO_2 Monitor Coverage Area



Source: NetAssess2020 v1.1

NO_2 DATA

2019 NO_2 Data Summary

A summary of the 2019 NO_2 data is shown in Figure 5-42. All levels are well below applicable NAAQS.

Figure 5-42
2019 NO_2 Monitoring Data Summary (ppb)

City	County	Address	1ST MAX 1-HR	2ND MAX 1-HR	98TH PERCENTILE VALUE	ARITH MEAN
Boston	Suffolk	Kenmore Square	49	48	44	12.42
Boston	Suffolk	Harrison Avenue	57	55	49	11.18
Boston	Suffolk	Von Hillern Street	56	53	49	14.17
Chelmsford	Middlesex	Manning Road	44	44	41	10.47
Chicopee	Hampden	Anderson Road	38	38	32	4.45
Lynn	Essex	Parkland Avenue	46	43	35	5.33
Milton	Norfolk	Canton Avenue	33	33	25	3.48
Springfield	Hampden	Liberty Street	46	46	44	10.41
Ware	Hampshire	Skyline Drive	26	26	20	1.83
Worcester	Worcester	Summer Street	51	49	48	10.49

Standards: 1-hour = 100 ppb
Annual Arithmetic Mean = 53 ppb

1ST, 2ND MAX 1-HR = First and Second Highest 1-hr Value
ARITH MEAN = Annual Arithmetic Mean

NO_2 Design Values

Figure 5-43 shows the 2019 design values for NO_2. The annual average NO_2 NAAQS is 53 ppb. The 1-hour NO_2 NAAQS is 100 ppb calculated as the 3-year average of the annual 98th percentile of the daily 1-hour maximum.

Figure 5-43
2019 Design Values for NO_2

City	County	Address	2017-2019 98th Percentile 1-hour Maximum Design Value	2017-2019 Average Annual Mean
Boston	Suffolk	Kenmore Square	45	12.93
Boston	Suffolk	Harrison Avenue	48	11.20
Boston	Suffolk	Von Hillern Street	46	13.78
Chelmsford	Middlesex	Manning Road	37	10.07
Chicopee	Hampden	Anderson Road	35	5.01
Lynn	Essex	Parkland Avenue	34	4.70
Milton	Norfolk	Canton Avenue	29	3.76
Springfield	Hampden	Liberty Street	38	10.33
Ware	Hampshire	Skyline Drive	21	2.09
Worcester	Worcester	Summer Street	46	11.13

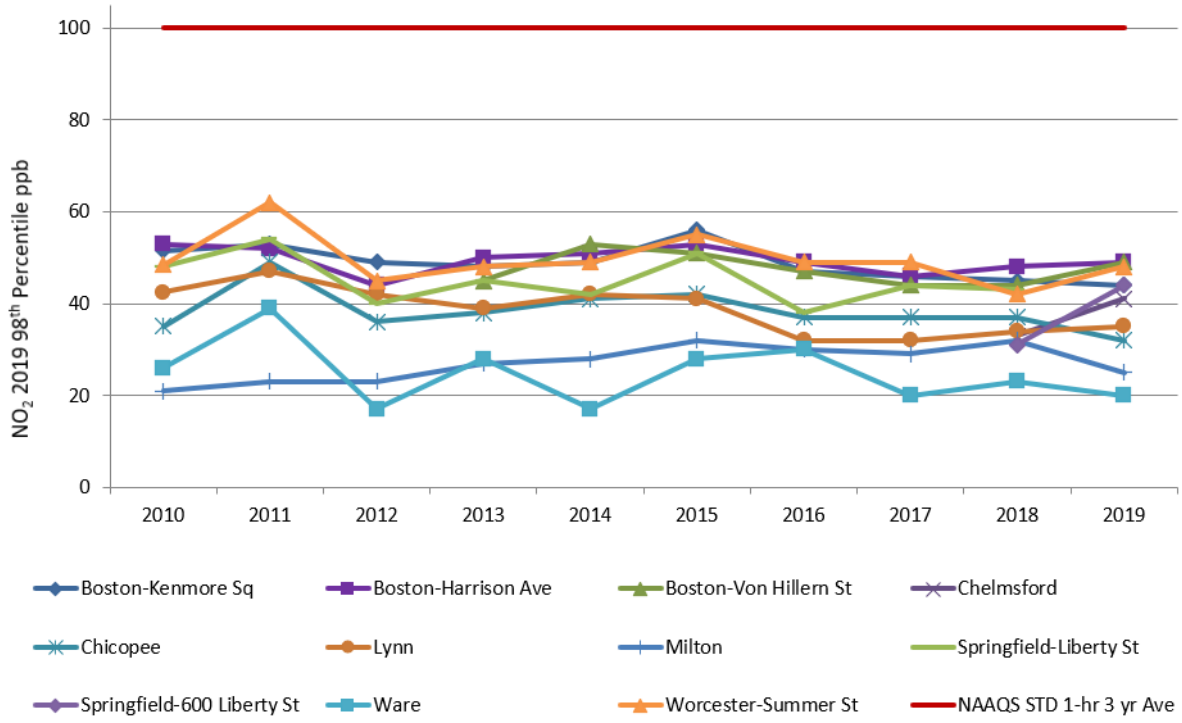
Standards: 1-hour = 100 ppb
Annual Arithmetic Mean = 53 ppb

Note: Chelmsford – Manning Road site does not yet have full three years of data.

NO_2 Trends Data

Figure 5-44 shows trends for each NO_2 monitor relative to the 1-hour standard of 100 ppb.

Figure 5-44
Nitrogen Dioxide Trends 2010 - 2019
1-hour 98th Percentile Annual Average



TECHNOLOGY

MassDEP uses continuous chemiluminescence-based instruments to measure NO_2, NO_x, NO_y and NOA. Chemilumenescent NO_x monitors measure NO_2 indirectly, by subtracting NO (Nitric Oxide) from NO_x (total oxides of nitrogen). Under some circumstances, this difference can include the inadvertent inclusion of other nitrogen compounds. In accordance with PAMS requirements, MassDEP uses one Cavity Attenuated Phase Shift (CAPS) analyzer at the Lynn PAMS site. The CAPS spectroscopy technique provides a direct absorption measurement and relies on producing very long optical paths (up to 2 km) using very high reflectivity mirrors in a sampling cell that is less than 30 cm in length.

ADEQUACY OF THE EXISTING MONITORING NETWORK

EPA Monitoring Requirements

In February 2010, EPA promulgated a 100 ppb 1-hour standard for NO_2 and established new near-road monitoring requirements for heavily traveled roadways, as well as area-wide monitoring. The number of roadway and area wide monitors required in each MSA depends upon the MSA's population and the Annual Average Daily Traffic counts (AADTs) for major roadways in the MSA. Figure 5-45 shows the number of NO_2 monitors required in each Massachusetts MSA.

Figure 5-45
EPA NO_2 Monitoring Requirements

MSA	MA County in MSA	County Population	MA Population in MSA	2019 AADT	Required for Near-Road Monitoring	Required for Area-Wide Monitoring	Near-Road Sites	Area-Wide Sites
Boston-Cambridge-Newton	Essex	790,638	4,436,124	329,265	2	1	2	4
	Middlesex	1,614,714						
	Suffolk	807,252						
	Norfolk	705,388						
	Plymouth	518,132						
Barnstable	Barnstable	213,413	213,413	58,879	0	0	0	0
Providence-Warwick	Bristol	564,022	564,022	77,414	0	0	0	0
Worcester	Worcester	830,839	830,839	63,865	0	0	0	1
Greenfield Town	Franklin	70,963	70,963	1,611	0	0	0	0
Springfield	Hampden	470,406	631,761	14,733	0	0	0	3
	Hampshire	161,355						
Pittsfield	Berkshire	126,348	126,348	16,381	0	0	0	0

Source: AADTs – MassDOT annual traffic data collection program. https://www.mass.gov/traffic-volume-and-classification
Population - US Census-Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2018.

Near-road requirements:

- One near-road NO_2 monitoring station in each MSA with a population of 1,000,000 or more persons.
- A second near-road NO_2 monitoring station is required for any MSA with a population of 2,500,000 persons or more, or in any MSA with a population of 1,000,000 or more persons that has one or more roadway segments with 250,000 or greater AADT counts

Area-wide NO_2 requirements:

- One monitoring station in each MSA with a population of 1,000,000 or more persons.
- PAMS sites that are situated in an area of expected high NO_2 concentrations may be used to satisfy this minimum requirement

ANALYSIS RESULTS

MassDEP's NO_2 monitoring network meets EPA monitoring requirements and objectives and provides good coverage for the state, and there is no need for NO_2 monitors at this time. While it is possible that some NO_2 monitors could be eliminated, MassDEP measures other pollutants at all NO_2 monitoring sites, providing additional benefit.

Lead (Pb)

NETWORK DESCRIPTION

MassDEP monitors lead at the Boston – Harrison Avenue NCore site using a low-volume PM_{10} method for non-NAAQS purposes under the National Air Toxics Trends Site (NATTS) program.

LEAD MONITORING DATA

2018 Pb Data Summary

A summary of the 2019 Pb data is shown in Figure 5-46. All values are well below the NAAQS.

Figure 5-46
2019 Pb Monitoring Data Summary (µg/m³)

City	County	Address	2019 MAX µg/m³	2019 MEAN µg/m³
Boston	Suffolk	Harrison Avenue	0.00460	0.00156

Standard: 0.15 µg/m³ (rolling 3-month average)

MAX = Maximum 24-hour value
MEAN = Annual Arithmetic Mean

TECHNOLOGY

MassDEP currently collects Teflon low volume PM_{10} samples at Boston – Harrison Avenue, which is analyzed via X-ray fluorescence by EPA contractors. The samples are collected every 6th day for 24 hours.

ADEQUACY OF THE MONITORING NETWORK

EPA Requirements

Because lead levels are well below the NAAQS, EPA no longer requires lead monitoring at MassDEP's Boston NCore site. EPA requires monitoring near lead sources that emit 0.5 tons or greater annually; however, Massachusetts does not have any sources of lead emissions that meet this level.

ANALYSIS RESULTS

MassDEP is not required to monitor lead for NAAQS purposes. However, MassDEP monitors toxics metals, including lead, at its Boston – Harrison Avenue as part of the National Air Toxics Trends Site program. Levels from this monitoring show lead levels are well below the lead NAAQS of 0.15 µg/m³.

Meteorology

NETWORK DESCRIPTION

MassDEP operates the following types of meteorological instruments at its monitoring sites:

- 13 – Barometric pressure (BP)
- 13 – Relative humidity (RH)
- 13 – Solar radiation (Solar)
- 13 – Temperature (TEMP)
- 13 – Wind speed/wind direction (WS/WD)
- 2 – Precipitation (PRECIP)

In addition, there are two acid rain monitors in Massachusetts that are part of the National Atmospheric Deposition Program (NADP):

- Ware – operated by MassDEP
- Truro – operated by the National Park Service

Figure 5-47 describes all the meteorological monitors MassDEP operates.

Figure 5-47
Description of Existing Meteorological Monitoring Network

Site ID	Site Name	Scale	Reason for Monitor	Parameters
25-025-0042	Boston - Harrison Ave	Neighborhood	Population Exposure	WS/WD, TEMP, RH, BP, SOLAR
25-025-0044	Boston - Von Hillern	Middle	Population Exposure; Max. Concentration; Near Road	WS/WD, TEMP, RH, BP, SOLAR
25-013-0008	Chicopee	Urban	Population Exposure	WS/WD, TEMP, RH, BP, SOLAR
25-005-1006	Fairhaven	Regional	Population Exposure	WS/WD, TEMP, RH, BP, SOLAR
25-011-2005	Greenfield	Regional / Neighborhood	Population Exposure	WS/WD, TEMP, RH, BP, SOLAR
25-009-5005	Haverhill	Urban	Population Exposure	WS/WD, TEMP, RH, BP, SOLAR
25-009-2006	Lynn	Urban / Neighborhood	PAMS - Max. Precursor O_3; Population Exposure	WS/WD, TEMP, RH, BP, SOLAR, PRECIP
25-021-3003	Milton - Blue Hill	Regional	Upwind Background $PM_{2.5}$; Maximum Ozone	WS/WD, TEMP, RH, BP, SOLAR
25-003-0008	Pittsfield	Urban / Neighborhood	Population Exposure	WS/WD, TEMP, RH, BP, SOLAR
25-001-0002	Truro	Regional	General Background	WS/WD, TEMP, RH, BP, SOLAR
25-027-0024	Uxbridge	Regional	Ozone Transport; Population Exposure	WS/WD, TEMP, RH, BP, SOLAR
25-015-4002	Ware	Urban	Max. O_3 Conc.; background for other pollutants	WS/WD, TEMP, RH, BP, SOLAR, PRECIP
25-027-0015	Worcester - Airport	Urban	Population Exposure	WS/WD, TEMP, RH, BP, SOLAR

TECHNOLOGY

The Figure 5-48 below summarizes the technology MassDEP uses to measure meteorology. There are no plans to change existing technology.

Figure 5-48
Meteorological Monitoring Technology

Parameter	Analytical Method	Sample Frequency	Location
Wind Speed/Direction	Ultrasonic Sensors	Hourly	All Meteorological Sites
Solar	Pyranometer	Hourly	All Meteorological Sites
Relative Humidity	Electronic Sensor	Hourly	All Meteorological Sites
Ambient Temperature	Electronic Thermistor	Hourly	All Meteorological Sites
Barometric Pressure	Electronic Sensor	Hourly	All Meteorological Sites
Precipitation	Tipping Bucket	Hourly	Ware and Lynn Only

ANALYSIS RESULTS

MassDEP has access to adequate meteorological information to forecast air quality, including predicting ozone and $PM_{2.5}$ episodes, modeling emissions from individual sources, evaluating the transport of pollution (particularly ozone and its precursors), and creating wind roses. MassDEP is planning to obtain a ceilometer for the Lynn PAMS site.

Technology Issues

Key technology issues that MassDEP must address as part of operating the air monitoring network are listed below.

Calibration

- MassDEP's field calibrators are suitable for ozone and trace-level dilution as appropriate. The equipment is capable of automated quality control checks. MassDEP has an internal ozone generator–photometer.

- MassDEP's lab and field calibrators can generate Minimum Detection Level (MDL) concentrations (CO, SO_2, and NO_y).

Zero Air Source

- MassDEP's zero air source is compliant with NCore TAD recommendations. An ultra-pure air cylinder is used for occasional comparison to zero air source. The equipment has the capacity for 20+ LPM of dilution air.

Data Acquisition System

- MassDEP's data system is capable of a digital system, remote diagnostics, and remotely enabled checks. MassDEP has invested in a new, upgraded Data Acquisition System and remote communications capabilities, which has improved data polling times and quality and will significantly improve ongoing quality control assessments through real-time and near real-time communications with fields analyzers.

Gas Cylinder Standards

- MassDEP's gas cylinders are suitable for trace-level dilutions in accordance with Appendix A of 40 CFR Part 58 audit concentrations and EPA protocol certifications, and meet the special low-level standards needed for MDL concentrations (CO, SO_2, and NOy).

Meteorological Calibration Devices

- MassDEP's meteorological calibration devices have NIST (National Institute of Standards) traceability for required meteorological parameters. Sonic wind instruments must be shipped to the manufacturer annually for factory calibration.

Sampling Manifold

- MassDEP's sampling meets the standards of Appendix E of 40 CFR Part 58, including residence time <20 seconds, only glass or Teflon materials, and probe and monitor inlets of acceptable heights.

Auditing Equipment

MassDEP has the following auditing equipment:
- Independent calibrators
- Zero air source and gas standards compatible with trace-level specifications
- Independent meteorological and flow standards
- A new dilution system capable of generating EPA-required concentration levels

Other

MassDEP has:
- Automated Gas Chromatograph systems for measuring VOC ozone precursors at the PAMS site and at its laboratory for analyzing field-procured VOC canister samples
- An environmental chamber that houses a robotic weighing device for $PM_{2.5}$ filters
- A real-time website for displaying current air pollution concentrations to the public