2011

AIR QUALITY SUMMARY

STATE OF RHODE ISLAND

INTRODUCTION

Ambient air quality has been monitored at a network of stations in the State of Rhode Island since 1968. The monitoring network is operated and maintained by the Rhode Island Department of Environmental Management (RI DEM) Office of Air Resources (OAR) and by the Rhode Island Department of Health (RI HEALTH) Air Pollution Laboratory via an interagency contract agreement. The ambient air quality data collected are entered quarterly in the U.S. Environmental Protection Agency's (US EPA's) Air Quality System (AQS).

PURPOSE

Monitoring data collected are used for the following purposes:

1. Determining whether the State is in attainment of national and State ambient air quality standards;
2. Tracking progress toward meeting national and State ambient air quality standards for which the State is in nonattainment;
3. Documenting maintenance of air quality standards for which the State is in attainment;
4. Providing a daily report of air quality and a forecast of the next day's air quality with appropriate health warnings, when required;
5. Providing real-time data for regional air quality maps;
6. Identifying pollution patterns and trends;
7. Assessing health and welfare effects and land use and transportation plans and evaluating the effectiveness of abatement strategies and enforcement of control regulations; and,
8. Activating emergency control procedures intended to prevent air pollution episodes.

This summary of 2011 ambient air quality data is intended to provide general information about air quality in Rhode Island and to be used as a source of statistics to support modeling studies and other air quality analyses.

AMBIENT AIR QUALITY STANDARDS AND ATTAINMENT

The US EPA has set National Ambient Air Quality Standards (NAAQS) for six air pollutants: lead (Pb), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) and particulate matter (PM). Two size classes of PM are regulated: particulate matter with diameters less than or equal to 10 micrometers (PM_{10}) and particulate matter with diameters less than or equal to 2.5 micrometers ($PM_{2.5}$). Pollutants with adopted NAAQS are referred to as "criteria pollutants."

There are two types of NAAQS; primary NAAQS are designed to protect human health and secondary NAAQS are designed to protect the environment, property and aesthetics. The derivations of the NAAQS, as well as background information about the sources, chemistry and deleterious effects of the criteria pollutants, are documented in the US EPA's air quality criteria documents. The NAAQS that are currently in effect are listed in Table 1. Note that the US EPA promulgated new one-hour average NAAQS for NO_2 and SO_2 in 2010.

Areas that do not meet air quality standards are called nonattainment areas. The Federal Clean Air Act requires each state with a nonattainment area to submit and implement a State Implementation Plan (SIP) which documents the measures that the State plans to take to come into attainment with the standard. The entire State of Rhode Island was a nonattainment area for ozone in 2011. The US EPA has designated Rhode Island as an unclassifiable/attainment area for the revised lead NAAQS, which was promulgated in 2008, and the new one-hour NO_2 NAAQS, which was promulgated in 2010, pending the collection of additional monitoring data. A similar designation is expected for the one-hour SO_2 NAAQS. The State is in attainment of all other NAAQS.

The Clean Air Act Amendments of 1990 required ozone nonattainment areas, like Rhode Island, to implement a variety of measures to limit emissions of two classes of ozone precursors, volatile organic compounds (VOC) and oxides of nitrogen (NOx), from mobile sources (motor vehicles) and from industrial and commercial sources such as surface coating facilities, power plants and gasoline stations. Although implementation of these measures has reduced ozone levels in the State, levels continue to exceed the NAAQS level during the summer months. Since Rhode Island's air quality is substantially affected by transport of pollutants into the State, further reductions in emissions in upwind states will be necessary for Rhode Island to ensure that ozone levels are safe for the State's residents.

TABLE 1: NATIONAL AMBIENT AIR QUALITY STANDARDS

POLLUTANT	AVERAGING TIME	PRIMARY STANDARD	SECONDARY STANDARD
Sulfur Dioxide (SO_2)	3-Hour[A]	None	0.5 ppm (1300 µg/m³)
	1-Hour[B]	75 ppb (196 µg/m³)	None
	Annual Arithmetic Mean[B]	0.03 ppm (80 µg/m³)	None
	24-Hour[AB]	0.14 ppm (365 µg/m³)	None
Carbon Monoxide (CO)	8-Hour[A]	9 ppm (10 mg/m³)	None
	1-Hour[A]	35 ppm (40 mg/m³)	None
Ozone (O_3)	8-Hour[C]	0.075 ppm (157 µg/m³)	Same as Primary Standard
Nitrogen Dioxide (NO_2)	Annual Arithmetic Mean	0.053 ppm (100 µg/m³)	Same as Primary Standard
	1-Hour[D]	100 ppb (188 µg/m³)	None
Particulate Matter ≤ 10 micrometers (PM_{10})	24-Hour[E]	150 µg/m³	Same as Primary Standard
Particulate Matter ≤ 2.5 micrometers ($PM_{2.5}$)	Annual Arithmetic Mean[F]	15.0 µg/m³	Same as Primary Standard
	24-Hour[G]	35 µg/m³	Same as Primary Standard
Lead (Pb)	Rolling 3-Month Average[H]	0.15 µg/m³[F]	Same as Primary Standard

Primary standards protect against adverse health effects. **Secondary standards** protect against welfare effects such as damage to crops, vegetation, and buildings.

[A]Not be exceeded more than once a year.

[B] A rule promulgating a 1-hour SO_2 NAAQS was signed on June 2, 2010. The rule revokes the annual and 24-hour SO_2 NAAQS one year after designations for the 1-hour NAAQS are final. To attain the 1-hour NAAQS, the 3-year average of the 99th percentile of the daily maximum 1-hour average SO_2 level at each monitor must not exceed 75 ppb.

[C] The ozone NAAQS is violated when the average of the 4th highest daily eight-hour concentration measured in 3 consecutive years exceeds 0.075 ppm (the 0.075 ppm NAAQS became effective in May 2008)

[D] To attain the 1-hour NO_2 NAAQS, effective January 22, 2010, the 3-year average of the 98th percentile of the daily maximum 1-hour average NO_2 concentration at each monitor must not exceed 100 ppb.

[E] To attain the PM_{10} standard, the 24-hour concentration at each site must not exceed 150 µg/m³ more than once per year, on average over 3 years.

[F] To attain the $PM_{2.5}$ annual standard, the 3-year average of the weighted annual means of 24-hour concentrations must not exceed 15 µg/m^3.

[G] To attain the $PM_{2.5}$ 24-hour standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-based monitor must not exceed 35 µg/m^3.

[H]On October 15, 2008, the Pb NAAQS was changed to 0.15 μg/m^3 as a rolling 3-month average, not to be exceeded in a 3-year period.

μg/m³ = micrograms per cubic meter **mg/m³** = milligrams per cubic meter
ppb = parts per billion **ppm** = parts per million

RHODE ISLAND AMBIENT AIR QUALITY MONITORING NETWORK

During 2011, Rhode Island conducted monitoring to determine compliance with the NAAQS for all of the criteria pollutants. The State discontinued NAAQS lead monitoring in 1992 because airborne lead concentrations in the State dropped to levels substantially lower than the NAAQS for that pollutant in 1986, when lead was removed from gasoline. However, the US EPA promulgated a considerably more stringent lead NAAQS in October 2008 and Rhode Island resumed lead monitoring in 2011 to determine whether the State is in attainment of the revised NAAQS. The criteria pollutant monitoring sites are part of the US EPA's State or Local Air Monitoring Stations network (SLAMS).

In addition, Rhode Island monitors toxic air pollutants and ozone precursors, which are substances that react in the atmosphere to form ground-level ozone. The State operates one monitoring site that is part of the National Air Toxics Trends Sites (NATTS) network, two that are part of the Photochemical Assessment Monitoring Stations (PAMS) network and one that is part of the $PM_{2.5}$ Speciation Trends Network (STN). A site that is part of a new national network, the network of core multipollutant monitoring (NCore) stations, began operating in 2011.

The locations of the criteria pollutant and air toxics monitoring sites operating in 2011 are shown in Figures I - IV. Table 2 lists the parameters measured and the sampling methods employed at each of those sites.

Figure 1
Air Quality Monitoring Network
Continuous Monitors
Site Locations

Figure 2
PM-10 Air Pollution Monitoring Network
Site Locations

Figure 3
PM-2.5 Air Pollution Monitoring Network
Site Locations

Figure 4
Air Toxics Monitoring Network
Site Locations

TABLE 2: MONITORING SITES (2011)

Site	AQS ID	Latitude Longitude	Parameter Measured	Method Of Sampling	EPA Method Designation
Vernon Trailer Vernon Street Pawtucket	440070026	41.874675 -71.379953	$PM_{2.5}$	Lo Vol	Reference
			PM_{10}	Hi Vol	Reference
			VOC	Canisters, GC/FID/MS	Reference
Johnson & Wales 111 Dorrance Street Providence	440070027	41.822686 -71.411089	PM_{10}	Hi Vol	Reference
Hallmark Building 695 Eddy Street Providence	440070028	41.80933 -71.40743	$PM_{2.5}$	Lo Vol	Reference
Brown University 10 Prospect Street	440070012	41.825556 -71.405278	Oxides of Nitrogen	Chemiluminescence	Reference
			Nitrogen Dioxide	Chemiluminescence	Reference

Site	AQS ID	Latitude Longitude	Parameter Measured	Method Of Sampling	EPA Method Designation
Providence			Sulfur Dioxide	Simulated Fluorescence	Equivalent
USEPA Laboratory 27 Tarzwell Drive Narragansett	440090007	41.4950779 -71.4236587	Ozone	U.V. Photometric	Reference
			$PM_{2.5}$	Beta Attenuation/Cont	N/A
			Wind Speed	Anemometer	N/A
			Wind Direction	Wind Vane	N/A
			Temperature	Spot Reading	N/A
Francis School 64 Bourne Avenue E. Providence	440071010	41.840920 -71.36094	Oxides of Nitrogen	Chemiluminescence	Reference
			Nitrogen Dioxide	Chemiluminescence	Reference
			NO/NO_y	Chemiluminescence (low range)	Reference
			Carbon Monoxide	Gas Filter Correlation (low range)	Equivalent
			Sulfur dioxide	Pulsed Fluorescence (low range)	Equivalent
			Ozone	U.V. Photometric	Reference
			$PM_{2.5}$	Lo Vol	Reference
			$PM_{2.5}$	Beta Attenuation/Cont	Equivalent
			Speciated $PM_{2.5}$	Speciation Monitor	N/A
			Coarse PM ($PM_{10-2.5}$)	Dichotomous Lo Vol	Equivalent
			Black Carbon	Aethalometer	N/A
			Lead	Lo Vol PM_{10}, XRF	Equivalent
			VOC	Canisters, GC/FID/MS	Reference
			Carbonyls	HPLC Cartridges	Reference
			Wind Speed	Anemometer	N/A
			Wind Direction	Wind Vane	N/A
			Barometric Pressure	Barometer	N/A
			Temperature	Spot Reading	N/A
			Relative Humidity	Plastic Film	N/A
			Solar Radiation	Pyranometric	N/A
			UV Radiation	UV Photometric	N/A
			Precipitation	Bucket/Continuous	N/A
Urban League 212 Prairie Avenue Providence	440070022	41.807949 -71.415103	$PM_{2.5}$	Lo Vol	Reference
			$PM_{2.5}$	Beta Attenuation/Cont	N/A
			PM_{10}/Metals	Hi Vol	Reference
			VOC	Canisters, GC/FID/MS	Reference
			Carbonyls	HPLC Cartridges	Reference
			Black Carbon	Aethalometer	N/A
			Semi-volatiles	PUF/XAD, GC/MS	N/A
			Wind Speed	Anemometer	N/A
			Wind Direction	Wind Vane	N/A
			Temperature	Spot Reading	N/A
			Relative Humidity	Plastic Film	N/A
Alton Jones Campus Victory Highway West Greenwich	440030002	41.615600 -71.719900	Ozone	U.V. Photometric	Reference
			Nitrogen Dioxide	Chemiluminescence	Reference
			Oxides Of Nitrogen	Chemiluminescence	Reference
			VOC	Canisters, GC/FID/MS	Reference
			PM_{10}	Hi Vol	Reference

Site	AQS ID	Latitude Longitude	Parameter Measured	Method Of Sampling	EPA Method Designation
			$PM_{2.5}$	Lo Vol	Reference
			$PM_{2.5}$	Beta Attenuation/Cont	N/A
			Wind Speed	Anemometer	N/A
			Wind Direction	Wind Vane	N/A
			Barometric Pressure	Barometer	N/A
			Temperature	Spot Reading	N/A
			Relative Humidity	Plastic Film	N/A
			Solar Radiation	Pyranometric	N/A

AIR QUALITY INDEX

In 1976, the US EPA developed the Pollutant Standards Index (PSI), a readily understandable way of communicating monitored air pollutant concentrations and associated health implications to the public. In June 2000, the US EPA updated the index and renamed it the Air Quality Index (AQI). The AQI converts monitored ambient concentrations of criteria pollutants to a scale of 0 to 500. An AQI level of 100 means that the monitored concentration is at the level of the short-term standard for the pollutant. The US EPA characterizes levels just above the standard (AQI of 101 –150) as “unhealthy for sensitive groups” and higher levels (AQI of 151-200) as “unhealthy.” To avoid misinterpretation of the term “sensitive groups,” Rhode Island describes all AQI levels between 100 and 200 as “unhealthy” in its health advisories.

In 2011, AQI subindices were calculated every day for the highest 8-hour average concentrations of ozone (O_3) and carbon monoxide (CO), for the 24-hour average concentrations of sulfur dioxide (SO_2) and $PM_{2.5}$, and for the highest 1-hour average concentrations of SO_2 and NO_2 recorded on the previous day. The highest of the subindices is then reported as the AQI. During the summer, the AQI is driven by the ozone and $PM_{2.5}$ subindices, while during the cooler months the AQI is based on CO, SO_2, NO_2 and $PM_{2.5}$.

Rhode Island DEM reports the AQI to the local news media, accompanied by an easily understood descriptor word. A forecast for the next day’s pollutant levels, consisting only of a descriptor word, is also reported.

The Rhode Island AQI descriptors are as follows:

AQI	Descriptor
0 to 50	Good
51 to 100	Moderate
101 to 200	Unhealthy
201-300	Very Unhealthy

Pollutant levels measured at five monitoring sites were used for AQI reporting in 2011. The AQI pollutants measured at those sites are as follows:

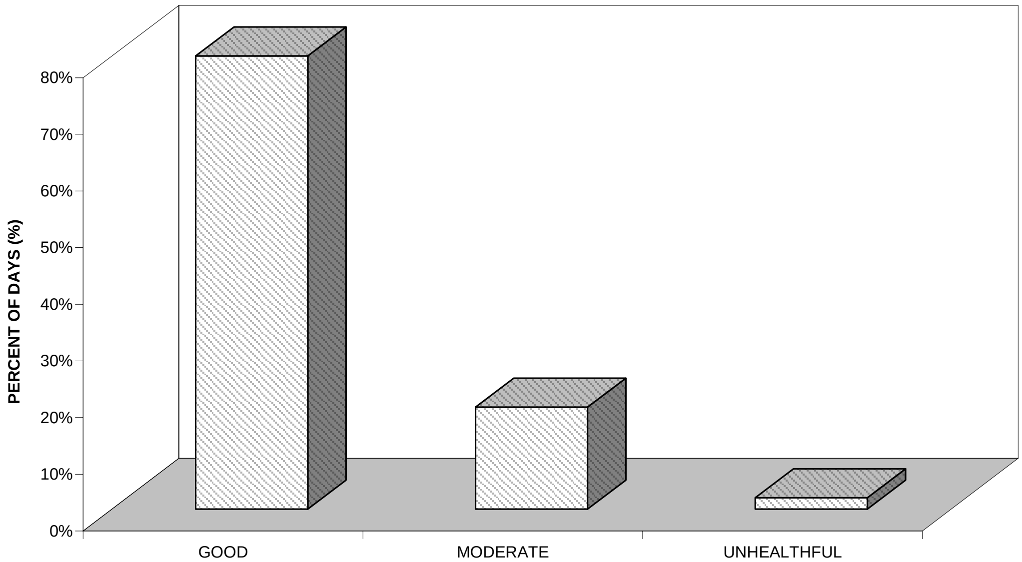
Site Location	AQI Pollutants Monitored
Brown University, 10 Prospect Street, Providence	Sulfur dioxide Nitrogen dioxide
Myron Francis School, 64 Bourne Avenue, E. Providence	Ozone Carbon monoxide Sulfur dioxide
Alton Jones Campus of URI, Victory Highway. Greenwich	Ozone $PM_{2.5}$
US EPA Research Laboratory 72 Tarzwell Drive, Narragansett	Ozone $PM_{2.5}$
Urban League 212 Prairie Avenue, Providence	$PM_{2.5}$

Note that, due to the new NAAQS for NO_2 and SO_2, one-hour average concentrations of those pollutants were used in AQI calculations for the first time in 2010. Subindices for the one-hour concentrations of both of those pollutants were in the "good" category on all days in 2011.

PM_{10} levels are not used in the AQI calculations, because the monitoring results for that pollutant are not available the day after the samples are taken. Similarly, $PM_{2.5}$ concentrations measured using the filter-based Federal Reference Method are not used for calculating the AQI because those values are not immediately available; only $PM_{2.5}$ concentrations measured by continuous instruments are used for the AQI.

In 2011, the AQI in Rhode Island was good on 80% of the reporting days, moderate on 18% and unhealthful on 2.0% (see Figure V). A daily air quality report is available on the RI DEM web site at http://www.dem.ri.gov/programs/benviron/air/pm.htm. Additional information on the AQI and the health effects associated with various index levels is available from the OAR.

Figure V
Air Quality Index (AQI)
2011
Air Quality Levels



2011 AIR QUALITY SUMMARY

The spring of 2011 started out warm and wet and continued into June with wet and cooler conditions. July was hot and dry and then August was warm, wet and windy, due to Tropical Storm Irene, which occurred on August 28th. September was warmer but again wet. In the summer of 2010, temperatures were at or above 90 degrees F on 18 days and elevated temperatures continued through September. In 2011, temperatures were at or above 90 degrees on 7 days. Although there were fewer hot sunny days with west to southwest winds, conditions that are conducive to ozone formation, in 2011 than in 2010, the current 8-hour ozone standard (0.075 ppm) was exceeded on six days in 2011, as compared to four days in 2010. Ambient concentrations of the other criteria pollutants continued to comply with the National Ambient Air Quality Standards (NAAQS). A more detailed discussion of the properties of the criteria pollutants, the concentrations of pollutants measured in 2011 and ambient air quality trends follows.

CARBON MONOXIDE (CO)

Carbon monoxide (CO) is a colorless, odorless, poisonous gas formed by the incomplete combustion of fuels in motor vehicles, aircraft, boilers, power plants, incinerators, industrial processes and other fuel-burning sources. Elevated CO levels in outdoor air are most often found in downtown areas with heavy traffic and poor dispersion characteristics.

CO binds to the hemoglobin in blood, reducing the amount of oxygen that is delivered to the body's organs and tissues. While CO exposure is most dangerous to those who suffer from cardiovascular disease, healthy individuals are also affected at higher concentrations. Exposure to elevated CO levels can cause shortness of breath, chest pain, headache, confusion, visual impairment, reduced work capacity, reduced coordination, poor learning ability, and difficulty in performing complex tasks.

The primary and secondary NAAQS for CO are the same, 9 ppm as an 8-hour average and 35 ppm as a 1-hour average. The City of Providence was designated as a non-attainment area for CO in 1978 because levels measured at a site on Dorrance Street in downtown Providence were, at that time, higher than the 8-hour CO NAAQS. All monitors have been in compliance with the 8-hour NAAQS since 1986 and Providence was redesignated to attainment status in 1991. The 1-hour average NAAQS has never been exceeded in Rhode Island.

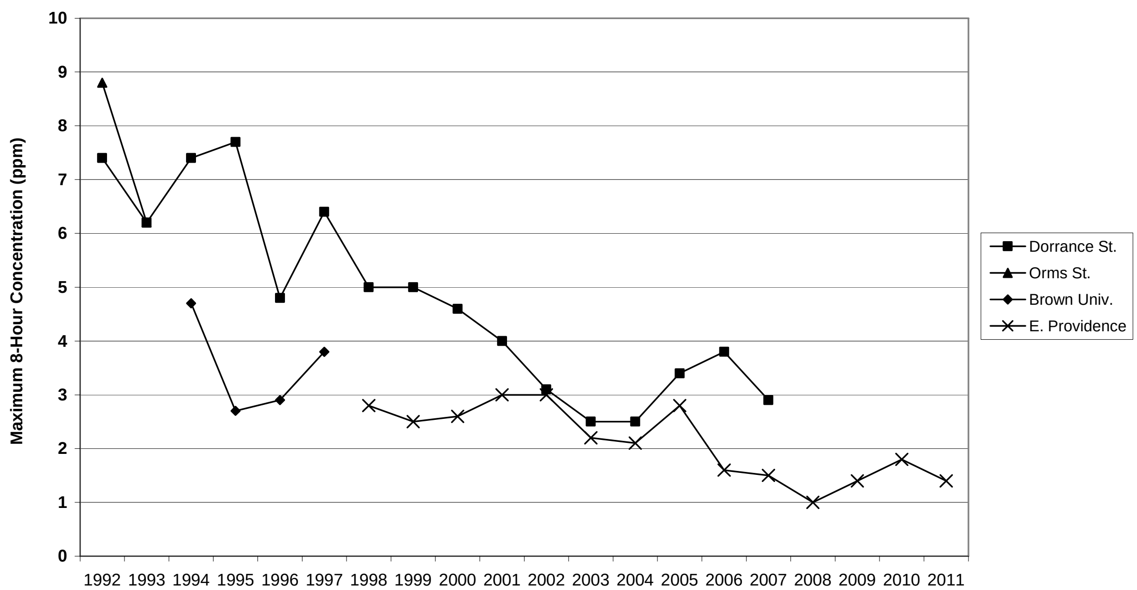
As a condition of redesignation of Providence to an attainment area for the CO standard, the US EPA required Rhode Island to monitor CO levels at the Dorrance Street site for 20 years to ensure that the air quality in downtown Providence did not again exceed the 8-hour average CO NAAQS. However, Rhode Island was allowed to discontinue monitoring at the Dorrance Street site in 2007 because CO levels were substantially below the standard and on a downward trend; RI DEM agreed to use alternative methods to track CO levels to ensure continued compliance with the NAAQS.

In 2011, CO was measured at one site in the State, the Francis School in East Providence. The highest CO concentrations recorded in 2011 were 15.6% and 5% of the 8-hour and 1-hour NAAQS respectively, (See Table 3). Figure VI shows CO trends in Rhode Island between 1992 and 2011. CO concentrations decreased substantially in that period. The 2011 maximum 8-hour average CO concentration at the East Providence site was lower than in 2010 and equal to the 2009 level.

Table 3 Carbon Monoxide (CO) Levels Measured in Rhode Island in 2011 (ppm)

	1-Hour Values (NAAQS is 35 ppm)				**8-Hour Values (NAAQS is 9 ppm)**		
Stations	**# of Observations**	**1st Maximum**	**2nd Maximum**	**# of Exceedances**	**1st Maximum**	**2hd Maximum**	**# of Exceedances**
Francis School 64 Bourne Ave. E. Providence	8,045	1.8	1.8	0	1.4	1.3	0
Totals				0			0

Figure VI
CARBON MONOXIDE (CO)
Maximum 8-Hour Concentrations
Standard = 9 ppm



LEAD (Pb)

Lead can enter the body through inhalation of lead dust or fumes and by ingestion of lead paint chips and lead-contaminated dust, water, soil, or food. Lead accumulates in blood, bone, and soft tissue. Fetuses and small children are particularly susceptible to the toxic effects of lead, which include brain damage, behavioral alterations, decreased intelligence and slowed growth. At higher levels, exposure to lead can damage the kidneys, liver, and nervous system, and cause reproductive disorders and anemia.

Rhode Island did not monitor for lead as a criteria pollutant during the years 1993-2010 because, after the removal of lead from gasoline, airborne lead concentrations in the State were substantially lower than the NAAQS for that pollutant. However, in October 2008, the US EPA's health-based NAAQS for lead was changed to 0.15 $\mu g/m^3$ as a rolling three-month average, as measured in Total Suspended Particulate (TSP), a level that is ten times more stringent than the standard it replaced. Since Rhode Island had not measured lead levels using the procedures specified in the NAAQS for many years, no data were available to definitively determine whether the ambient air in the State is in compliance with that standard. In 2011, Rhode Island began monitoring to determine whether lead levels in the State comply with the revised standard; those monitoring results are not yet available but will be presented in future years' Air Quality Data Summaries.

As part of the air toxics program, Rhode Island measures lead in PM_{10}, particles that are 10 micrometers or smaller, at the Urban League monitoring site in Providence. The highest 3-month average concentration of lead in PM_{10} measured at that site since 2007 is 0.005 $\mu g/m^3$, which is 3% of the new NAAQS. Therefore, TSP lead levels would have to be more than 30 times higher than the lead levels in PM_{10} for the Providence site to violate the NAAQS.

Rhode Island measured lead in both PM_{10} and TSP at the Urban League site during 2001 and 2002. During that period, 3-month average TSP lead levels were no more than twice as high as the PM_{10} lead levels. Therefore, it is unlikely that TSP lead levels at that site are now 30 times higher than the PM_{10} lead levels and would, therefore, exceed the new standard. Further, since there are no significant lead emissions sources in the State, it is unlikely that lead levels measured in other areas of the State would be substantially higher than at the Providence site. Therefore, RI DEM expects that the lead measurements which began in 2011 will show that Rhode Island is in attainment of the updated NAAQS

As discussed above, lead is one of the metals monitored in PM_{10} at the Urban League site in Providence as part of the National Air Toxics Trends Sites (NATTS) network. In addition, as part of the national $PM_{2.5}$ Speciation program, lead in fine particulate matter ($PM_{2.5}$) was measured at Urban League site until September 2010 and at the East Providence NCore site thereafter. A summary of Rhode Island PM_{10} and $PM_{2.5}$ metals data is included in the Air Toxics section of this document.

NITROGEN DIOXIDE (NO_2) and OXIDES of NITROGEN (NOx)

Nitrogen dioxide (NO_2) belongs to a family of highly reactive gases called oxides of nitrogen (NOx). NOx forms when fuel is burned at high temperatures, and is found in exhaust emitted by motor vehicles and stationary sources such as power plants and industrial boilers. A suffocating, brownish gas, NO_2 is a strong oxidizing agent that reacts in the air to form corrosive nitric acid, as well as toxic organic nitrates.

Breathing air with elevated NO_2 levels irritates the lungs and lowers the body's resistance to respiratory infections such as influenza. Continued or frequent exposure to high concentrations of NO_2 may cause acute respiratory illness in children. Emissions of NO_2, as well as other oxides of nitrogen (NOx), contribute to the formation of ground level ozone and to other adverse environmental effects, such as acid rain and the eutrophication of coastal waters.

In 2011, Rhode Island monitored NO_2 and NOx at three sites. The East Providence and West Greenwich NO_2/ NOx monitors are located at sites that are part of the Photochemical Assessment Monitoring Sites (PAMS) network. The PAMS network is designed to track the movement of ozone and its precursors (like NOx) through the region, so NOx monitoring at those locations is required only during June, July and August, when ozone levels tend to be highest. NO_2/ NOx monitors in West Greenwich and East Providence were operated from June through October in 2011. The monitor at the third site, which is located at Brown University in Providence, operated throughout the year.

The long-term NAAQS for NO_2 is 0.053 ppm as an annual arithmetic mean. That standard has not been exceeded in Rhode Island since monitoring for NO_2 began in 1980. In 2011, the annual arithmetic mean NO_2 concentration at the Brown University site was 0.0113 ppm, 21% of the NAAQS. There is no NAAQS for NOx. 2011 NO_2 and NOx levels are summarized in Tables 4 and 5, respectively. As can be seen in Figure VII, annual average levels of NO_2 and NOx in the State have declined over the past ten years. Average NO_2 and NOx levels in 2011 were higher than those in 2010 and similar to those in 2010.

In addition to the annual average NO_2 NAAQS, the US EPA promulgated a 1-hour average NAAQS for NO_2 effective on January 22, 2010. For an area to comply with the new NAAQS, the 1-hour design value, which is the 3-year average of the 98th percentile of the daily maximum 1-hour average values measured at each site in the area, must not exceed 100 ppb (0.1 ppm). Since the 1-hour design value for the Providence NO_2 monitor for the 2009-2011 period is 44 ppb, less than half of the NAAQS, that monitor is in compliance with the new standard. Figure VIII shows trends in the 1-hour design value for NO_2 from 1991 through 2011; 1-hour NO_2 levels decreased by 38% over that period.

However, the new NAAQS also requires states with large metropolitan areas to monitor for NO_2 at a site near a busy roadway and stipulates that the data collected at all sites, including the near-road location, will be used to determine whether the area is in compliance with the NAAQS. Therefore, until sufficient near-road monitoring data for NO_2 has been collected, Rhode Island has been designated as unclassifiable/attainment for the 1-hour NAAQS. Rhode Island will begin monitoring at a near-road site in 2013.

Table 4 Nitrogen Dioxide (NO_2) Levels Measured in Rhode Island in 2011 (ppm)

Stations	1-hour Values				Annual Mean (NAAQS = 0.053 ppm)	
	# of Observations	1st Maximum	2nd Maximum	98th Percentile	Observed Mean	# of Exceedances
Alton Jones W. Greenwich	3,218	0.018	0.010	N/A*	N/A*	N/A
Brown University 10 Prospect St. Providence	7,970	0.063	0.052	0.045	0.00113	0
Francis School 64 Bourne Ave. E. Providence	3,438	0.031	0.030	N/A*	N/A*	N/A
Total						0

Table 5 Levels of Oxides of Nitrogen (NOx) Measured in Rhode Island in 2011 (ppm)

Stations	1-hour Values			Annual Mean
	# of Observations	1st Maximum	2nd Maximum	
Alton Jones W. Greenwich	3,218	0.020	0.013	N/A*
Brown University 10 Prospect St. Providence	8,014	0.328	0.321	0.00167
Francis School 65 Bourne Ave. E. Providence	3,438	0.016	0.013	N/A*

* N/A = Not applicable. The W. Greenwich and E. Providence NO_2/NOx monitors were operated only in June - October. Since those monitors did not operate for the whole year, 98th percentile values and annual means cannot be calculated for those sites.

Figure VII
NITROGEN DIOXIDE (NO_2) and OXIDES OF NITROGEN (NOx)
Annual Average Concentrations at Brown University, Providence
NO_2 Standard = 0.053 ppm

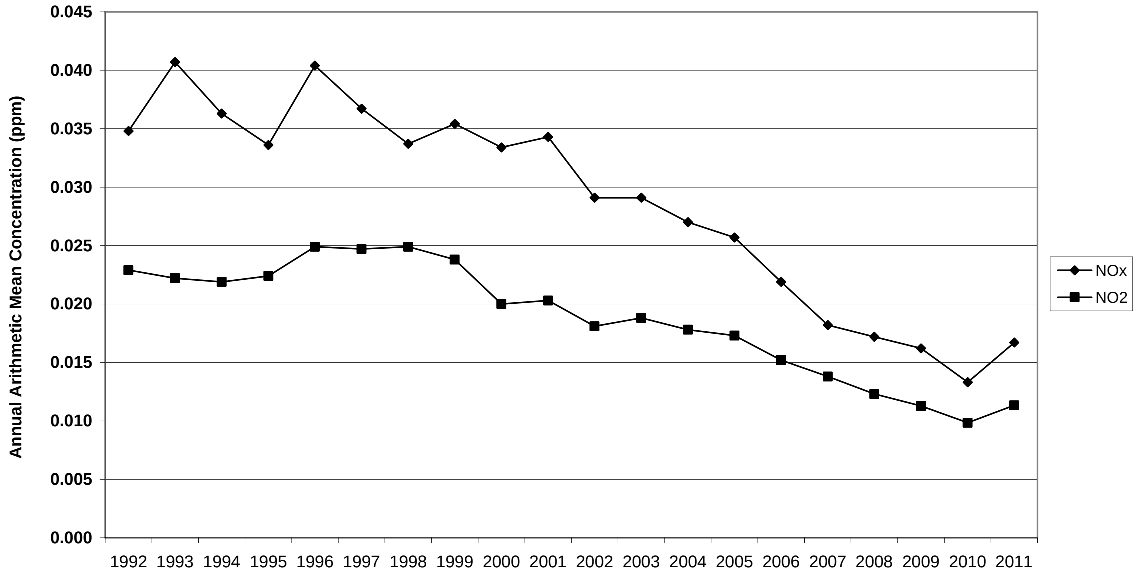
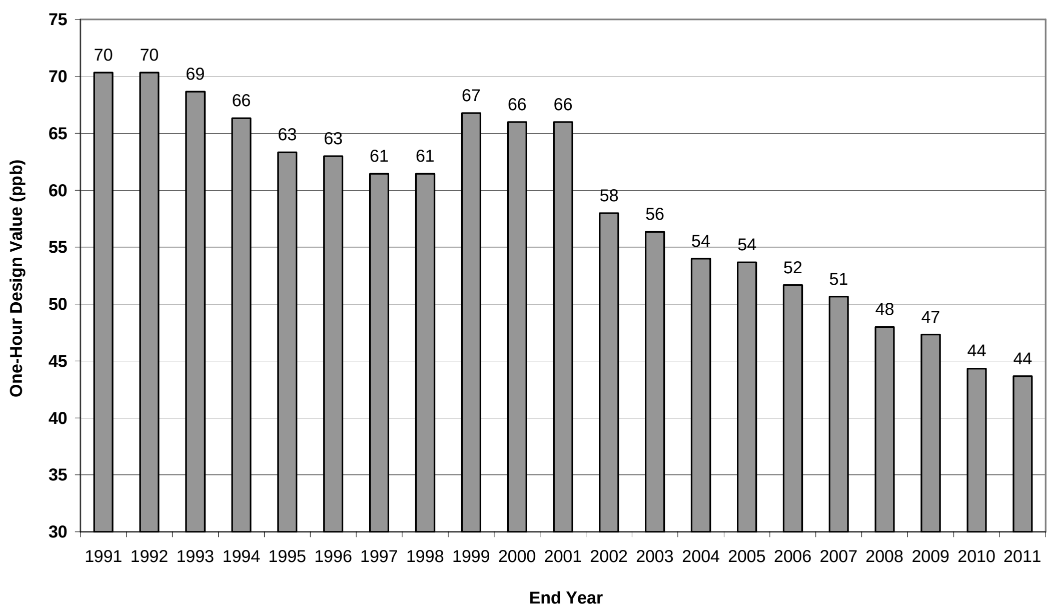


Figure VIII
NITROGEN DIOXIDE (NO_2)
One-Hour Concentrations at Brown University, Providence
2010 One-Hour NO_2 Standard =100 ppb



OZONE (O_3)

Ozone (O_3) is a photochemical oxidant and is the major component of smog. Elevated concentrations of ground level ozone are a major health and environmental concern. Ozone is formed in the atmosphere when volatile organic compounds (VOC) and oxides of nitrogen (NOx) emitted by mobile and stationary sources react in the presence of elevated temperatures and sunlight; therefore, VOCs and NOx are called "ozone precursors". Because airborne VOCs and NOx, as well as ozone itself, are transported over long distances, sources emitting ozone precursors in states upwind of Rhode Island contribute to the State's ozone problem. Ozone levels in Rhode Island generally are highest on hot sunny summer days when the winds are from the west or southwest.

Exposure to elevated ozone levels causes eye, nose and throat irritation; coughing; chest pain; shortness of breath; decreased lung function; headache; and fatigue. Repeated exposures can increase susceptibility to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Long-term exposures can cause irreversible changes in the lungs, leading to chronic respiratory illnesses such as emphysema and chronic bronchitis and to premature aging of the lungs.

Children are at a high risk for ozone-related health effects because they have developing lungs and relatively high respiration rates and because they are often active outdoors during the summer months, when ozone levels are highest. Adults who work or exercise outside and people with respiratory and heart diseases are also at an increased risk. Elevated ozone levels also reduce agricultural and commercial forest yields; reduce the growth and survivability rates of tree seedlings; increase tree and plant susceptibility to disease, pests and other environmental stresses; and have long-term effects on forests and ecosystems.

In 1977 the US EPA determined that the ozone NAAQS applicable at that time, a 1-hour average NAAQS of 0.12 ppm, was not sufficiently stringent to protect public health and the environment and promulgated a new ozone standard of 0.08 ppm as an 8-hour average. The 8-hour standard was further strengthened to 0.075 ppm in May 2008. Although the 1-hour standard was revoked as of June 1, 2005 and is no longer effective in Rhode Island, 1-hour average ozone concentrations are shown in Table 6a for information purposes. Rhode Island was classified as a serious nonattainment area for the one-hour average NAAQS for ozone and is classified as a moderate nonattainment area for the 1997 8-hour average ozone standard.

Ozone monitors were operated at three Rhode Island sites, the Alton Jones campus of the University of Rhode Island in West Greenwich, the Francis School in East Providence and the US EPA Laboratory in Narragansett, in 2011. The monitors a the West Greenwich and Narragansett sites were operated from March – October, while the monitor at the East Providence site was operated the entire year, consistent with NCore requirements. The 8-hour ozone NAAQS (0.075 ppm) was exceeded at one or more of the Rhode Island sites in 2011 on six days (four days at the Alton Jones site, three days at the East Providence site and three days at the Narragansett site). The highest 8-hour concentration, which was recorded at the East Providence site and the Narragansett site, was 0.084 ppm, 112% of the NAAQS. 2011 8-hour average ozone levels are summarized in Table 6b.

A monitor is in violation of the 8-hour ozone NAAQS if the design value, which is the average of the fourth highest daily maximum 8-hour concentrations for each year in a three-year period, is greater than 0.075 ppm. The ozone design values for the 2009 – 2011 period for the Alton Jones, Narragansett and East Providence sites were 0.073, 0.073 and 0.071 ppm, respectively, values below the 8-hour ozone NAAQS of 0.075 ppm. As shown in Figure IX, ozone design values have declined over the period between1978 and 2011; that trend continued in 2011.

Although the number of days per year with ozone levels that exceed the 0.075 ppm standard has also shown a downward trend, the number of exceedances in any given year is highly weather-dependent (see Figure X). As discussed above, although there were fewer hot sunny days in 2011 than in 2010, the NAAQS was exceeded on six days in 2011, as compared to four days in 2010.

Table 6a One-Hour Average Ozone Levels Measured in Rhode Island in 2011 (ppm) (No One-Hour NAAQS)

Stations	# of Observations	1st Maximum	2nd Maximum	3rd Maximum	4th Maximum
Alton Jones W. Greenwich	175	0.110	0.102	0.090	0.089
Francis School 10 Prospect St. E. Providence	179	0.099	0.092	0.087	0.083
EPA Laboratory 27 Tarzwell Dr. Narragansett	167	0.095	0.092	0.089	0.083

Table 6b Eight-Hour Average Ozone Levels Measured in Rhode Island in 2011 (ppm) (NAAQS = 0.075 ppm)

Stations	# of Observations	1st Maximum	2nd Maximum	3rd Maximum	4th Maximum	# of Exceedances
Alton Jones W. Greenwich	173	0.084	0.081	0.079	0.078	4
Francis School 10 Prospect St. E. Providence	178	0.078	0.078	0.076	0.073	3
EPA Laboratory 27 Tarzwell Dr. Narragansett	166	0.084	0.084	0.083	0.074	3
Total						10

Figure IX
Ozone
Trends in 8-Hour Average Concentrations
8-Hour NAAQS = 0.075 ppm

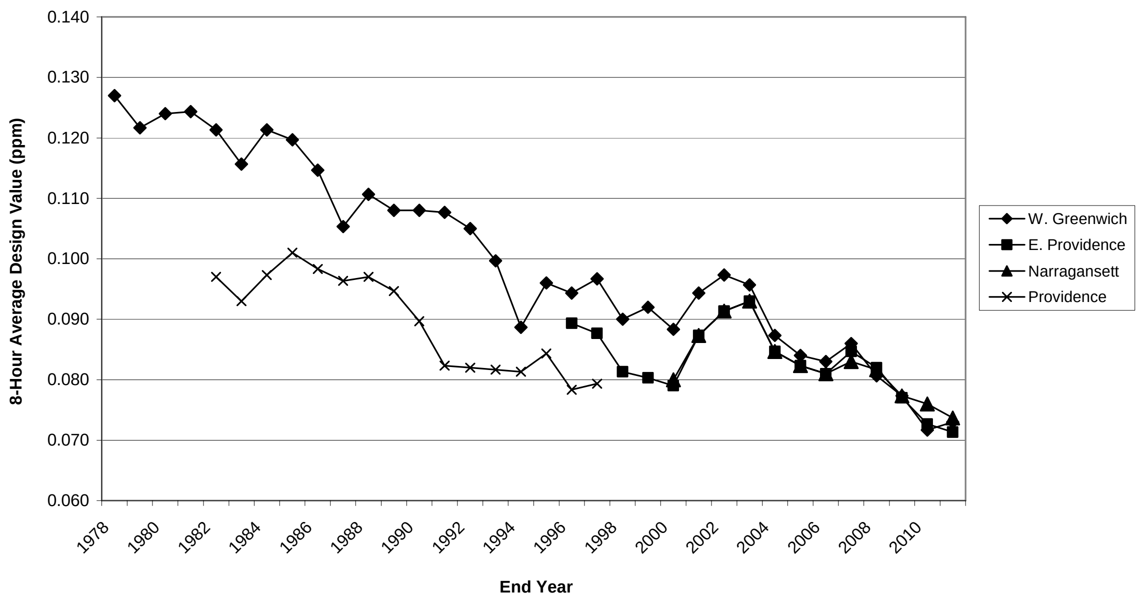
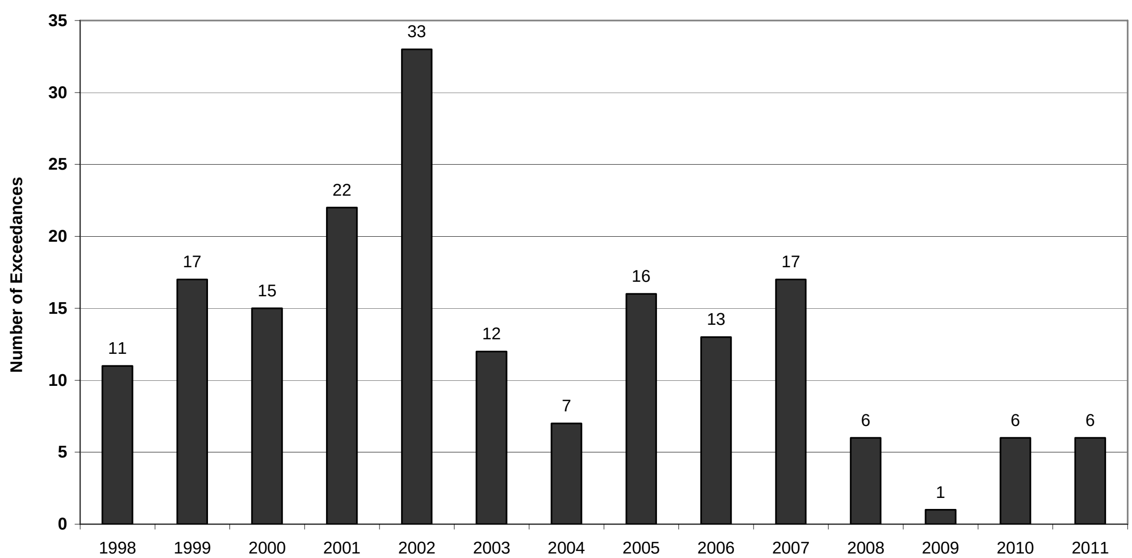


Figure X
OZONE (O3)
Number of Days per Year with Ozone Levels Higher than the Current 8-Hour Standard at Any Rhode Island Site
8-Hour Standard = 0.075 ppm



PARTICULATE MATTER

Airborne particulate matter (PM) is emitted by mobile and stationary sources, including diesel trucks, wood stoves, power plants, and industrial processes, as well as by natural occurrences and human activities. Primary PM is emitted directly from sources, while secondary PM is formed in the atmosphere as the product of chemical reactions of gaseous pollutants. The chemical and physical compositions of airborne particles vary widely.

The NAAQS for PM focus on small particles, because small particles, when inhaled, travel to the lower regions of the respiratory tract and can cause significant respiratory and cardiovascular health effects. The PM_{10} standard regulates particles with diameters of 10 micrometers (one-seventh the width of a human hair) or less and the $PM_{2.5}$ or fine particulate standard regulates particles with diameters equal to or smaller than 2.5 micrometers.

Exposure to PM is linked to a variety of health effects, including coughing, difficult or painful breathing, chronic bronchitis, aggravated asthma, increased respiratory-related hospital admissions and emergency room visits, and premature death. The elderly, children, and people with heart or lung diseases like emphysema, bronchitis and asthma are at particular risk for those effects. Airborne PM also impairs visibility and can soil and damage materials.

Rhode Island has monitored PM_{10} since 1985 and $PM_{2.5}$ since 1999.

PM_{10}

In 2011, Rhode Island operated a network of four PM_{10} monitoring sites located at: the Johnson and Wales library on Dorrance Street in downtown Providence; the Vernon Street, Pawtucket site adjacent to Route I-95*;* the Urban League building in urban South Providence and the Alton Jones campus of the University of Rhode Island in West Greenwich, a background rural site. PM_{10} samples collected at the Urban League site, which is the State's NATTS site, are analyzed for metals; metals results are discussed in the air toxics section of this document.

The NAAQS for PM_{10} is 150 $\mu g/m^3$ as a 24-hour average. That standard is exceeded if the design value, which is the fourth highest 24-hour concentration recorded at a site in a three year period, is higher than 150 $\mu g/m^3$. The PM_{10} standard has never been exceeded in Rhode Island since PM_{10} monitoring began in 1985. As is shown in Table 7a, the maximum 24-hour PM_{10} concentration in 2011, which was recorded at the Vernon Street, Pawtucket and Dorrance Street, Providence sites, was 38 $\mu g/m^3$, 25% of the NAAQS, and the maximum annual average PM_{10} concentration, recorded at the Pawtucket site, was 16.5 $\mu g/m^3$.

Figures XI and XII show the annual average concentrations and 24-hour design value (4th highest value in a three year period) concentrations of PM_{10}, respectively, measured in the past ten years. Until 2002, the highest PM_{10} values in the State were recorded at a monitor on Allens Avenue in Providence, immediately adjacent to Route I-95 in Providence. That site reflected worst-case PM_{10} levels and was not representative of neighborhood exposures. Monitoring at the Allens Avenue site was discontinued in 2002 due to extensive construction and demolition activity in the area associated with a highway relocation project.

Since the discontinuation of monitoring at the Allens Avenue site, the highest annual mean and 24-hour design value PM_{10} concentrations in the State often occur at the Vernon Street, Pawtucket site, which is adjacent to Rte. I-95 in Pawtucket. In 2011, the annual mean PM_{10} concentration at the Vernon Street site was 2 - 4 $\mu g/m^3$ higher than at the two other urban sites and 8 $\mu g/m^3$ higher than at the rural site in W. Greenwich. The 2009 - 2011 24-hour design value for PM_{10} was also highest at the Vernon Street site; the design value at that site was 10 $\mu g/m^3$ higher than at the Dorrance Street site, 13 $\mu g/m^3$ higher than at the Urban League site and 18 $\mu g/m^3$ higher than that in W. Greenwich. Note, however, that the highest PM_{10} 24-hour design value recorded, 43 $\mu g/m^3$, was only 29% of the NAAQS.

As can be seen in Figures XI and XII, annual and 24-hour average PM_{10} concentrations at the Rhode Island sites have gradually decreased over the past ten years. In 2011, the annual average levels at all of the sites except for the Dorrance Street site were lower than in 2010. The 24-hour design values for 2011 were similar to those for 2010.

Table 7a PM_{10} Concentrations in Rhode Island in 2011 (ug/m3)
NAAQS = 150 ug/m3 (24-hour average)

Stations	24-hour Values						Annual Mean
	# Of Observations.	1st Maximum	2nd Maximum	3rd Maximum	4th Maximum	# of Exceedances	
Vernon St. Pawtucket	56	38	34	33	29	0	16.5
Alton Jones W. Greenwich	60	24	23	22	18	0	8.7
212 Prairie Ave. Providence	58	27	25	23	23	0	12.4
111 Dorrance St. Providence	59	38	35	28	27	0	15.0
Totals						0	

Figure XI
PARTICULATE MATTER (PM-10)
Annual Average Concentrations

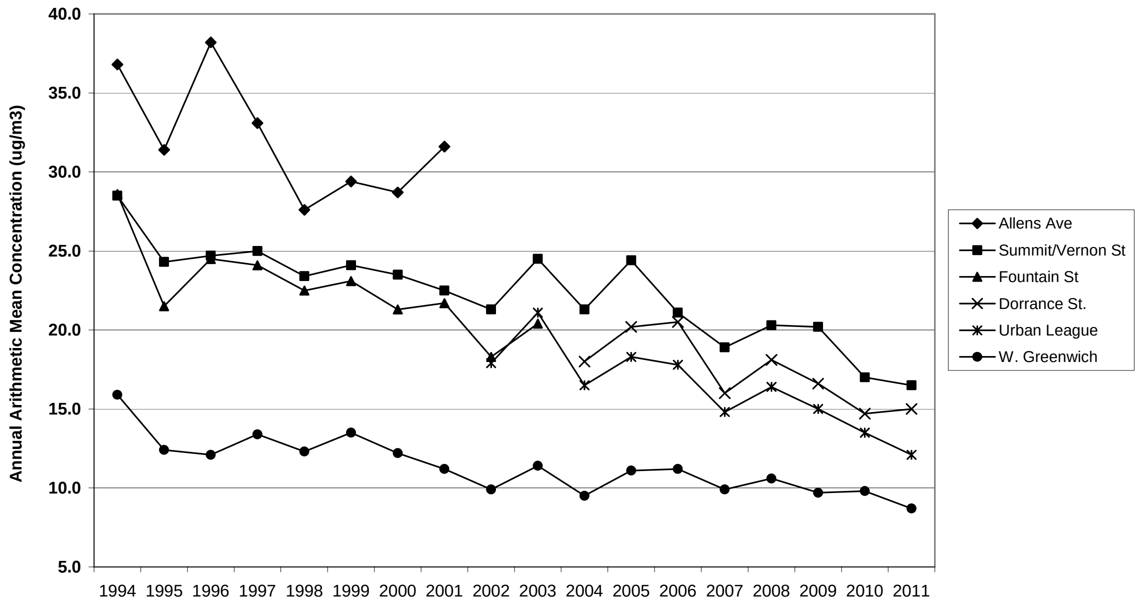
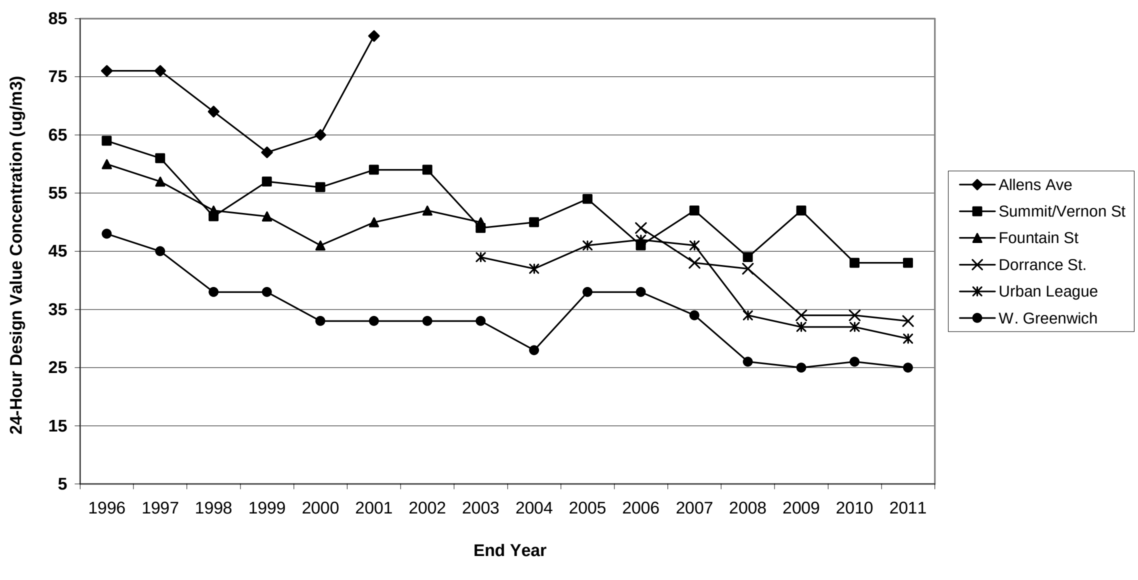


Figure XII
PARTICULATE MATTER (PM-10)
24-Hour Average Concentrations
Standard = 150 ug/m3



FINE PARTICULATE MATTER ($PM_{2.5}$)

As discussed above, the US EPA promulgated an NAAQS for $PM_{2.5}$ in July 1997 and, in 1999, RI DEM began operating a network of $PM_{2.5}$ monitors to determine whether Rhode Island was in compliance with that standard. The 24-hour $PM_{2.5}$ NAAQS was updated in December 2006.

$PM_{2.5}$ was measured using Federal Reference Method (FRM) or Federal Equivalent Method (FEM) monitors to determine compliance with the NAAQS at five sites in the State in 2010. Urban core sites, which reflect population exposure in urban areas, are located at the Urban League building on Prairie Avenue in Providence; at the Vernon Street site in Pawtucket, adjacent to Route I-95; at the Hallmark building on Eddy Street in Providence and at the Francis School in East Providence, which is in a suburban neighborhood frequently downwind of the Providence metropolitan area. A background/transport rural site is located at the Alton Jones campus of the University of Rhode Island in West Greenwich. $PM_{2.5}$ samples are collected daily at the Urban League and East Providence sites and every 3rd day at the Eddy Street and Vernon Street sites. A continuous FEM monitor is used to measure compliance with the $PM_{2.5}$ NAAQS at the West Greenwich site. To verify the results of the FEM monitor, a FRM monitor is also operated every sixth day at that site.

In 2011, Rhode Island operated continuous FEM $PM_{2.5}$ monitors, at three sites - the Urban League site in Providence, the West Greenwich site and the US EPA laboratory in Narragansett, a coastal site where ozone is also measured. The continuous monitors at the Narragansett and Providence sites are not used for determining compliance with the NAAQS. However, all of the continuous monitors provide vital real-time data important for forecasting $PM_{2.5}$ levels, for issuing health alerts, for calculating the AQI and for tracking hourly $PM_{2.5}$ levels.

$PM_{2.5}$ speciation monitors have been operated in Rhode Island since June 2002. Speciation monitors provide data on the composition of $PM_{2.5}$; that information is useful for identifying sources and for characterizing the toxicity of this pollutant. Speciated $PM_{2.5}$ samples were collected at the East Providence site every 6th day from June 2002 until May 2004. Speciation sampling at the Urban League site also began in June 2002 on the same one in six day schedule, but the frequency was increased to one in three days in May 2004, when the East Providence speciation measurements were discontinued. In September 2010, the one in three day speciation sampling was moved from the Urban League to the East Providence site, to conform to NCore requirements.

The 24-hour average NAAQS for $PM_{2.5}$ is 35 $\mu g/m^3$. A monitor is in attainment if the design value, which is the 98th percentile value of the 24-hour average concentrations measured at the site averaged over a 3-year period, does not exceed the NAAQS level. The annual average NAAQS for $PM_{2.5}$ is 15 $\mu g/m^3$. $PM_{2.5}$ levels measured at all sites have been below both the 24-hour and the annual $PM_{2.5}$ standards since the initiation of monitoring for that pollutant. As can be seen in Table 7b, in 2011 the highest 98th percentile 24-hour concentration, recorded at the Urban League, Providence site, was

25.1 μg/ m^3, 72% of the NAAQS, and the highest annual average, recorded at the Vernon Street site, was 9.94 μg/m^3, 66% of the annual NAAQS.

A number of experts have recommended adoption of a more stringent $PM_{2.5}$ standard, e.g. 30 μg/m^3, to protect sensitive members of the public. As discussed above, Rhode Island is in attainment of the NAAQS; however, on some days elevated levels of $PM_{2.5}$ occur that may pose health threats to sensitive individuals. Unlike ozone, elevated $PM_{2.5}$ levels occur in the cooler months as well as during the summer. In 2011, 24-hour $PM_{2.5}$ levels above 30 μg/m^3 were recorded in Rhode Island on four days, all in the month of January.

The 2011 annual average $PM_{2.5}$ level at the Vernon Street site, which is adjacent to I-95, was more than 1 μg/m^3 higher than at the other urban core sites and 3.5 μg/m^3 higher than at the rural site in W. Greenwich. The 98th percentile 24-hour concentration at the Urban League site was 2 - 6 μg/m^3 higher than at the other urban sites and 9 μg/m^3 higher than at the rural site.

As can been seen in Figure XIII, annual average $PM_{2.5}$ concentrations at the Rhode Island sites have been consistently lower than the annual average NAAQS since measurement of that pollutant began in 1999 and have shown a slight downward trend in that period. However, 2011 annual average levels at all sites were higher than those in the previous year. The 24-hour concentrations measured since 1999 at all of the currently operating sites, except at the Vernon Street site in 2003, have been consistently below the short-term $PM_{2.5}$ standard, as shown in Figure XIV and have shown a downward trend over that period. The 98th percentile 24-hour average concentrations at all sites except for the Urban League were lower in 2011 than in 2010.

Table 7b $PM_{2.5}$ Concentrations in Rhode Island in 2011 (ug/m3)
NAAQS = 35 ug/m3 (24-hour average), 15ug/m3 (annual mean)
FRM/FEM DATA SUMMARY

Stations	24-hour Values							Annual Mean
	# of Observations	1st Maximum	2nd Maximum	3rd Maximum	4th Maximum	98th Percentile	# of Exceedances of 2007 24-hr NAAQS	
Francis School E. Providence	348*	43.3	31.4	31.0	30.2	23.1	0	8.72
Vernon St Pawtucket	111**	23.5	22.8	22.1	22.0	22.1	0	9.94
Alton Jones W. Greenwich	8182***	24.5	18.2	17.5	17.4	16.1	0	6.43
Prairie Avenue Providence	344*	38.2	33.7	31.7	27.5	25.1	0	8.66
695 Eddy St Providence	110**	23.2	21.3	18.8	18.5	18.8	0	8.71

*Samples collected daily at this site.
**Samples collected every 3rd day at this site.

***A continuous FEM monitor producing hourly measurements is operated at the Alton Jones site. A sufficient number of valid hourly measurements needed to calculate a 24-hour average were collected at this site on 336 days in 2011.

Figure XIII
FINE PARTICULATE MATTER (PM-2.5)
Annual Average Concentrations
Stamdard = 15 ug/m^3

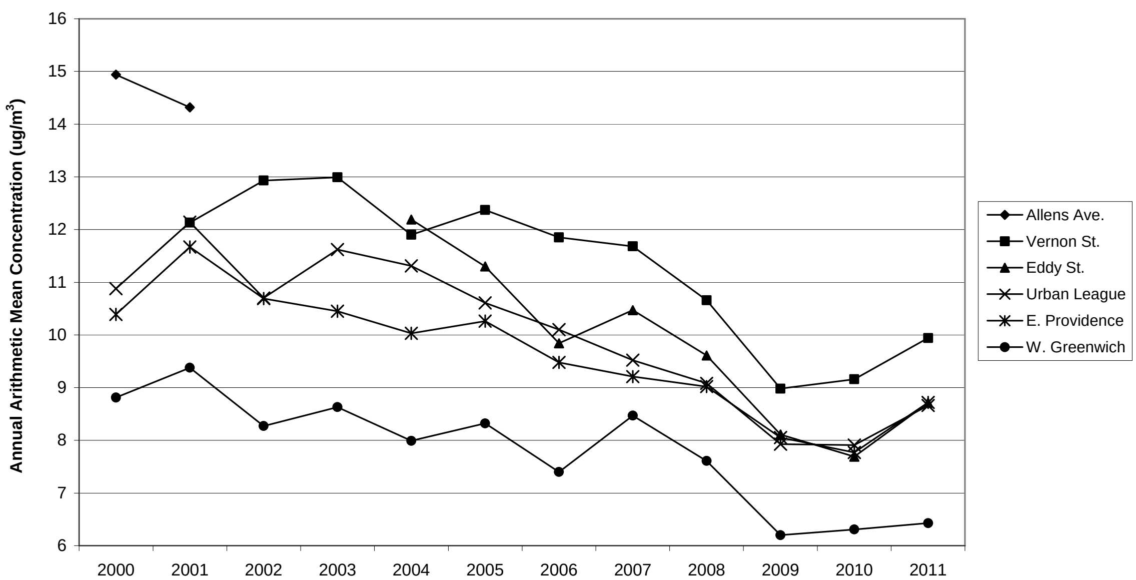
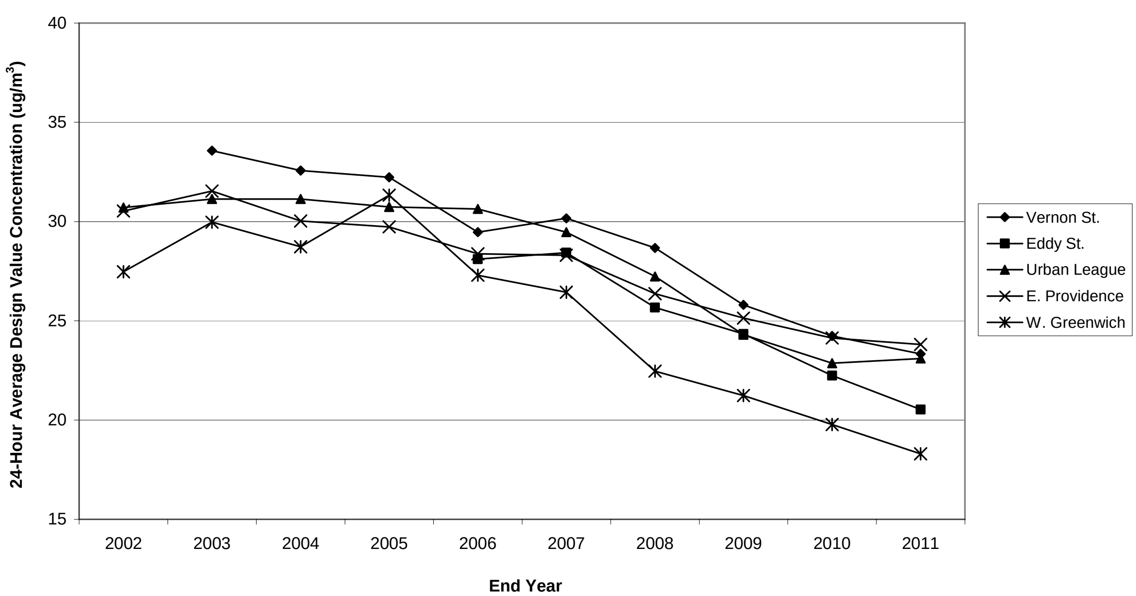


Figure XIV
FINE PARTICULATE MATTER (PM-2.5)
24-Hour Concentrations
Standard = 35 ug/m^3



PM-coarse

In 2007, Rhode Island began operating a modified low-volume $PM_{2.5}$ Federal Reference Method (FRM) monitor to measure PM_{10} at the Urban League site. Operation of that monitor, alongside a non-modified $PM_{2.5}$ FRM monitor, allowed RI DEM to calculate concentrations of PM-coarse, which is particulate matter with diameters between 2.5 and 10 microns, as the difference between the low-volume PM_{10} and the low-volume $PM_{2.5}$ measurements. Currently, there is no NAAQS for PM-coarse, but, since health effects have been linked to exposure to PM in that size category, a standard may be promulgated in the future.

Since the monitor was needed elsewhere, operation of the low-volume PM_{10} monitor was discontinued at the end of September 2009. During the 2 ¾ years of operation of that monitor, the PM_{10} concentrations measured by the low-volume monitor correlated well with and were, on average, approximately 1.3 $\mu g/m^3$ higher than the concentrations measured concurrently by the high volume PM_{10} sampler at that site. The average $PM_{2.5}$ concentration at the Urban League site was approximately 55% of the low-volume PM_{10} concentration, so the PM-coarse fraction accounted for, on average, approximately 45% of the low-volume PM_{10} levels.

In January 2011, Rhode Island began measuring PM-coarse at the East Providence site, to fulfill NCore requirements. 2011 PM-coarse measurements were taken using a Partisol Dichotomous Air Sampler. On days that both PM-coarse and $PM_{2.5}$ measurements were available, the PM-coarse fraction accounted for, on average, approximately 37% of total PM_{10} mass ($PM_{2.5}$ plus PM-coarse).

SULFUR DIOXIDE (SO_2)

Sulfur dioxide (SO_2) is emitted primarily by sources burning fossil fuels to produce heat or electricity. Exposure to high concentrations of SO_2 causes respiratory illness, alterations in pulmonary defenses, and aggravation of existing cardiovascular disease. Children, the elderly, and people with asthma, cardiovascular disease or chronic lung disease such as bronchitis or emphysema are most susceptible to the adverse health effects of SO_2.

SO_2 combines with water in the atmosphere to form sulfates, which can cause acidification of lakes and streams, accelerated corrosion of buildings and monuments, reduced visibility, and adverse health effects.

The primary (health-based) NAAQS for SO_2 are 0.03 ppm as an annual arithmetic mean, 0.14 ppm as a 24-hour average and, beginning in June 2010, 75 ppb (0.075 ppm) as a one-hour average. EPA will revoke the annual and 24-hour SO_2 NAAQS one year after designations for the 1-hour NAAQS are final. The US EPA has also set a secondary NAAQS for SO_2, 0.50 ppm as a three- hour average, to protect the environment, property, and aesthetics. The State of Rhode Island has been in compliance with applicable SO_2 standards since monitoring began in1975.

SO_2 is monitored at two sites in Rhode Island – at the Brown University Rockefeller Library in Providence and, beginning in 2011, at the NCore site in East Providence. The SO_2 monitor at the NCore site is designed to measure low-range levels of that pollutant.
.
In 2011, the annual average SO_2 concentrations at the Brown University and East Providence sites were 0.00143 ppm (5% of the NAAQS) and 0.00104 ppm (3% of the NAAQS), respectively. The highest 24-hour concentration (recorded at Brown) was 0.0121 ppm, 9% of the NAAQS, and the highest 3-hour concentration (recorded at East Providence) was 0.025 ppm, 5% of the secondary NAAQS. (See Table 8) Figure XV shows annual arithmetic mean concentrations of SO_2 at Rhode Island monitoring sites between 1994 and 2011. Annual mean SO_2 concentrations have trended downward during that time period with the most substantial reductions occurring since 2004. The 2011 annual average SO_2 concentration recorded at the Brown monitor was slightly higher than then 2010 value and 20% of the 1994 level.

As discussed above, the EPA promulgated a new one-hour NAAQS for SO_2 in 2010. For an area to comply with the new standard, the design value, which is the 3-year average of the 99th percentile of the daily maximum 1-hour average at each monitor in the area, must not exceed 75 ppb (0.075 ppm). Since the 1-hour design value for the Providence SO_2 monitor for 2009-2011 is 23 ppb, 31% of the NAAQS, that monitor would be in compliance with the standard. The 99th percentile 1-hour value for 2011 at the East Providence site was higher 26 ppb, 5 ppb higher than at the Brown University site, but still substantially below the NAAQS. Figure XVI shows trends in the 1-hour design values for SO_2 from 1988 through 2011; 1-hour SO_2 levels decreased substantially in that period. The 2009-2011 1-hour design value at the Brown University site (23 ppb) was 35% of the design value for 1994 – 1996, when the site began operation (65 ppb).

However, the new NAAQS also requires states to use modeling data to determine whether an area is compliance with the standard. Therefore, Rhode Island's attainment status for the 1-hour SO_2 NAAQS will be designated as unclassifiable/attainment until RI DEM completes air quality modeling to predict maximum one-hour SO_2 concentrations around sources emitting that pollutant,.

Table 8 Rhode Island 2011 Sulfur Dioxide (SO_2) Levels (ppm)

1-Hour Values (NAAQS = 0.075 ppm)		
	East Providence	Brown University
1st Maximum	0.030	0.024
2nd Maximum	0.028	0.023
99th Percentile	0.026	0.021
3-Hour Values (NAAQS = 0.50 ppm)		
1st Maximum	0.025	0.022
2nd Maximum	0.024	0.020
24-Hour Values (NAAQS = 0.14 ppm)		
1st Maximum	0.0118	0.0121
2nd Maximum	0.0096	0.0105
Annual Mean (NAAQS = 0.03 ppm)		
2011 Value	0.00104	0.00143

Figure XV
SULFUR DIOXIDE (SO_2)
Annual Average Concentrations
Standard = 0.03 ppm

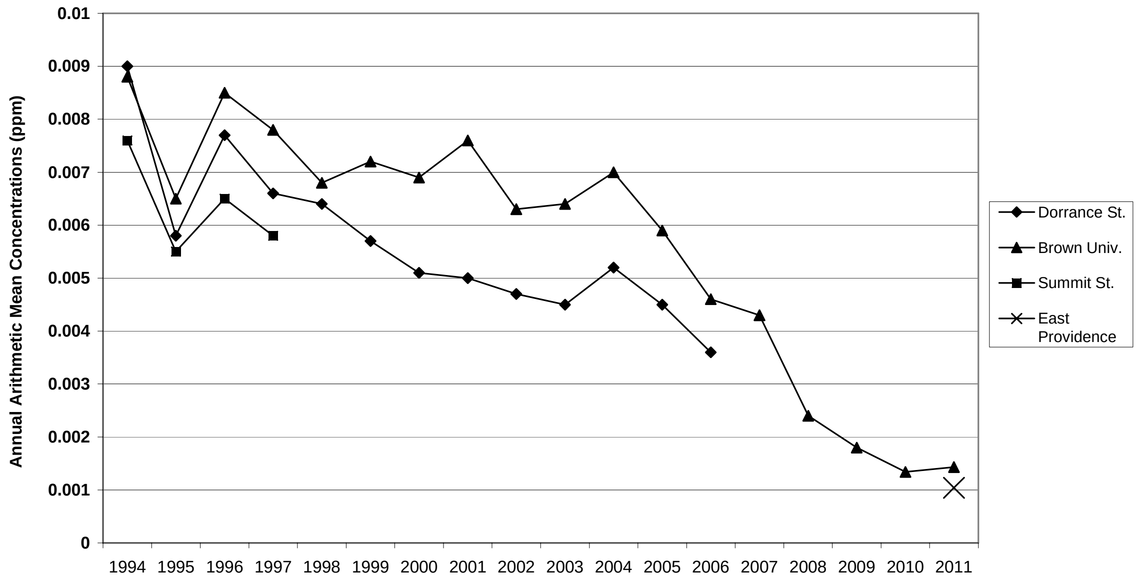
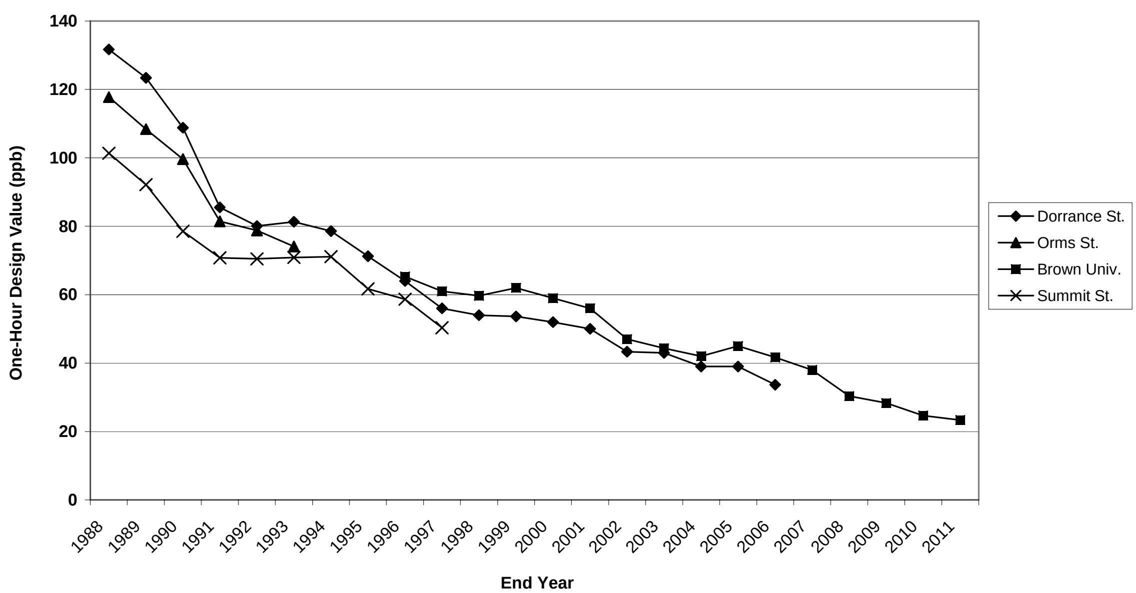


Figure XVI
SULFUR DIOXIDE (SO_2)
One-Hour Concentrations
2010 Standard = 75 ppb



PHOTOCHEMICAL ASSESSMENT MONITORING STATIONS (PAMS)

Although ground-level ozone concentrations in Rhode Island have decreased over the past twenty years, the ozone levels in the State, as well as in much of the rest of the Northeast, continue to exceed the NAAQS level on some hot summer days. Ground level ozone is a regional problem; ozone precursors (NOx and VOCs) emitted in one state contribute to elevated ozone levels in states that are many miles downwind. The photochemical reactions involved in ozone formation are influenced by a number of factors, including meteorology and the relative concentrations of various precursor chemicals in the atmosphere. Therefore, identifying emissions control strategies that effectively reduce ozone levels in nonattainment areas is a complex task.

In order to obtain ambient air quality data useful for evaluating control strategies, the Clean Air Act Amendments of 1990 (CAAA) required serious, severe and extreme ozone nonattainment areas to establish enhanced monitoring networks for ozone and ozone precursors. In response to that mandate, the US EPA promulgated rules in 1993 that required the establishment of a network of Photochemical Assessment Monitoring Stations (PAMS) to measure ozone, NOx, VOCs (including carbonyls), and meteorological parameters in nonattainment areas.

In 2011, Rhode Island's PAMS network consisted of three sites: one Type 1 site, one Type 2 site and one Type 3 site. Type 1 sites are located upwind of nonattainment areas and are used to measure concentrations of ozone and ozone precursors in air masses entering the area. Type 2 sites are located immediately downwind of the area of maximum precursor emissions, which in Rhode Island is the Providence metropolitan area. Type 3 sites are located 10-30 miles downwind of the urban area, and are used to track the movement of precursor pollutants and the resulting formation of ozone. Type 4 sites are located further downwind, and are used to track pollutants leaving the area.

Two of Rhode Island's PAMS sites are located within the State boundaries; the Type 1 site at the Alton Jones campus of the University of Rhode Island in West Greenwich and the Type 2 site at the Francis School in East Providence. Due to the proximity of the Providence metropolitan area to the Massachusetts border, the 2011 Type 3 site was located in Milton, Massachusetts on the Great Blue Hill.

At the West Greenwich Type I PAMS site, 24-hour VOC samples are collected every sixth day year round. At the Type 2 site in East Providence, eight three-hour VOC samples are collected daily and in 2011, eight three-hour carbonyl samples were collected every third day during June, July and August and 24-hour VOC and carbonyl samples are collected every sixth day year round. At the Milton, Massachusetts Type 3 site, eight three-hour VOC samples were collected every day during June, July and August 2011.

VOC samples are analyzed for approximately 90 substances which are ozone precursors and/or air toxics. The carbonyl samples are analyzed for formaldehyde, acetaldehyde and acetone. Ozone, NOx and surface meteorological conditions are also measured at the

PAMS sites during the summer months. PAMS monitoring began at the East Providence site in 1994 and at the West Greenwich site in 1995.

The data from the Rhode Island PAMS sites, combined with results from similar sites in other states, are used to identify sources of ozone precursors, to track migration of those pollutants, to determine the concentrations of various toxic air pollutants in the region, to track changes in ambient levels over time, and to verify the inputs and results of regional ozone modeling.

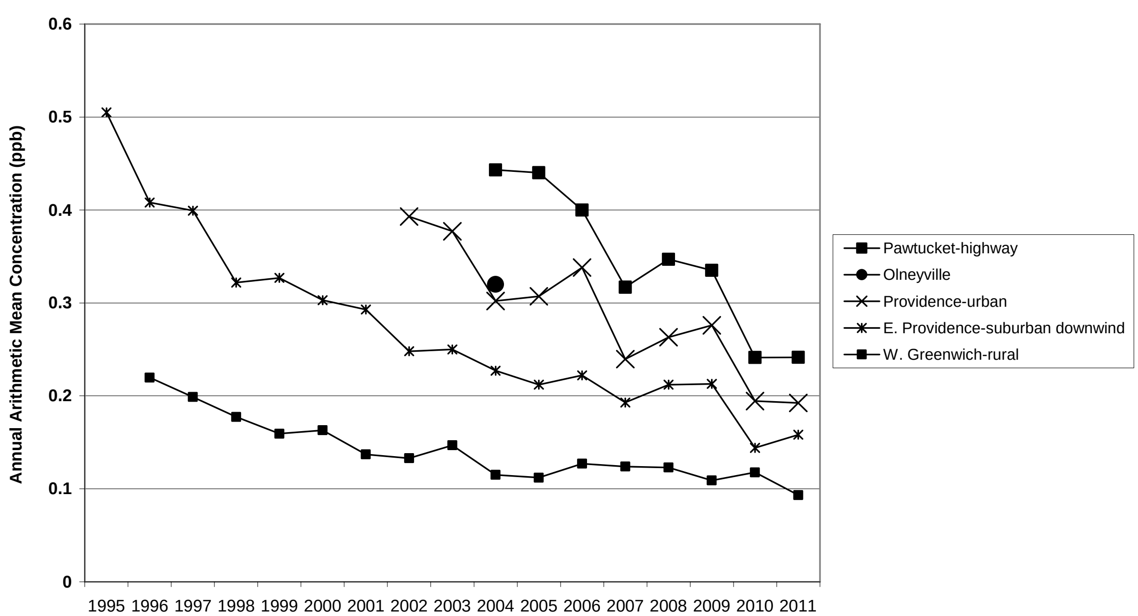
AIR TOXICS

Many of the substances measured at the PAMS sites are air toxics as well as ozone precursors. Since the PAMS sites have operated for well over a decade, data from those sites provide useful information about trends in ambient air toxics levels in Rhode Island. In addition, RI DEM has operated an air toxics monitoring site at the Urban League site in Providence since May 2001; that site became a National Air Toxics Trends Site (NATTS) in 2002. The Urban League site is in an urban residential area that is not immediately impacted by localized industrial or commercial sources. In addition to VOCs and carbonyls, black carbon, PM_{10}, PM_{10} metals, hexavalent chromium (Cr VI), semi-volatile compounds (SVOC), $PM_{2.5}$ and speciated $PM_{2.5}$ were monitored at that site in 2011. VOCs have also been monitored at the Vernon Street, Pawtucket site, adjacent to I-95, since 2001.

VOCs

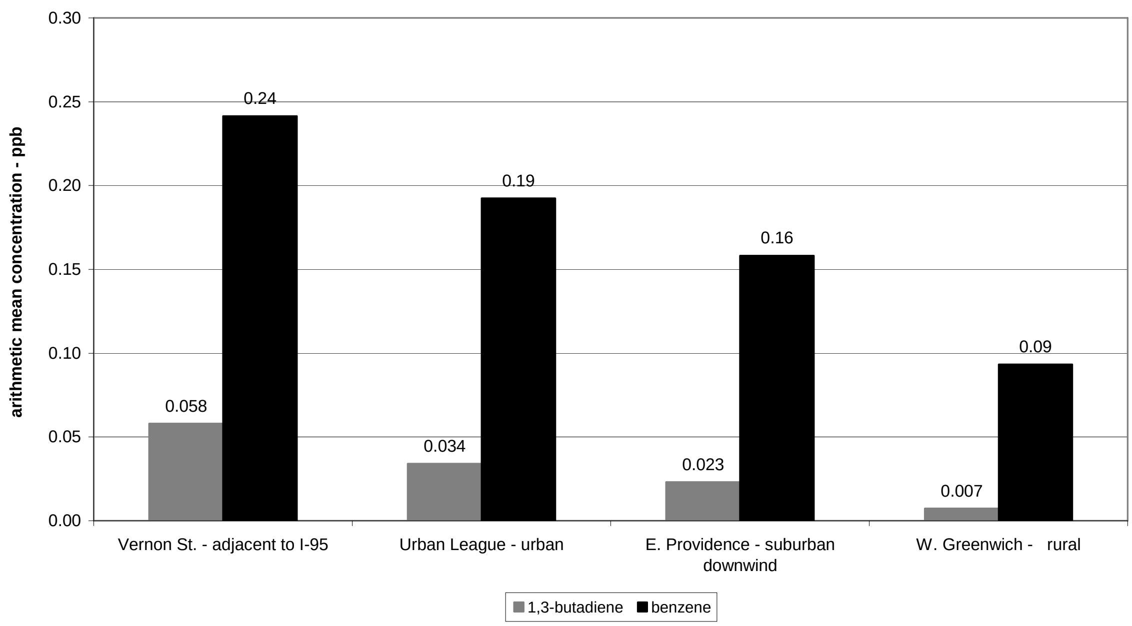
One of the toxics measured in VOC samples is benzene, a gasoline constituent known to cause leukemia in humans. The average benzene concentrations measured at the PAMS and toxics sites for the years 1995 –2011 are displayed in Figure XVII. Benzene levels dropped sharply between 1995 and 1996, probably due to the implementation of rules requiring the sale of reformulated gasoline with a reduced benzene content in late 1995. In the succeeding years, ambient benzene levels have shown a gradual downward trend. Average benzene levels at the Pawtucket, Providence and West Greenwich sites were slightly lower in 2011 than in the previous year.

Figure XVII
BENZENE
Annual Average Concentrations



Due to the ubiquitous nature of motor vehicle traffic, benzene, as well as other components of motor vehicle exhaust, including the carcinogen 1,3-butadiene, are present in the ambient air throughout the State. However, the concentrations of those pollutants are significantly higher in urban and highly trafficked areas than in more rural sections of the State. As can be seen in Figure XVIII, the average concentrations of both benzene and 1,3-butadiene in 2011 were highest at the Vernon Street, Pawtucket site, which is adjacent to the highway, next highest at the Urban League site in Providence, lower at the suburban East Providence site and lowest at the rural site in West Greenwich.

Figure XVIII
MOBILE SOURCE TOXIC VOLATILE ORGANICS
2011 Annual Average Concentrations of Benzene and 1,3-Butadiene



As shown in Figures XIX, concentrations of the industrial cleaning solvent trichloroethylene at all sites dropped sharply between 2003 and 2007 but have been fairly level since 2009 at all sites. Levels of perchloroethylene, a solvent used by dry cleaners and in industrial settings, have also decreased at the urban sites since 2003, although the annual average concentration of that pollutant at the Urban League site was higher in 2011 than in 2010 (see Figure XX). Levels are both solvents are highest at the urban sites (Pawtucket and Providence) and lowest at the rural West Greenwich site.

Figure XIX
Trends in Annual Average Trichloroethylene Levels

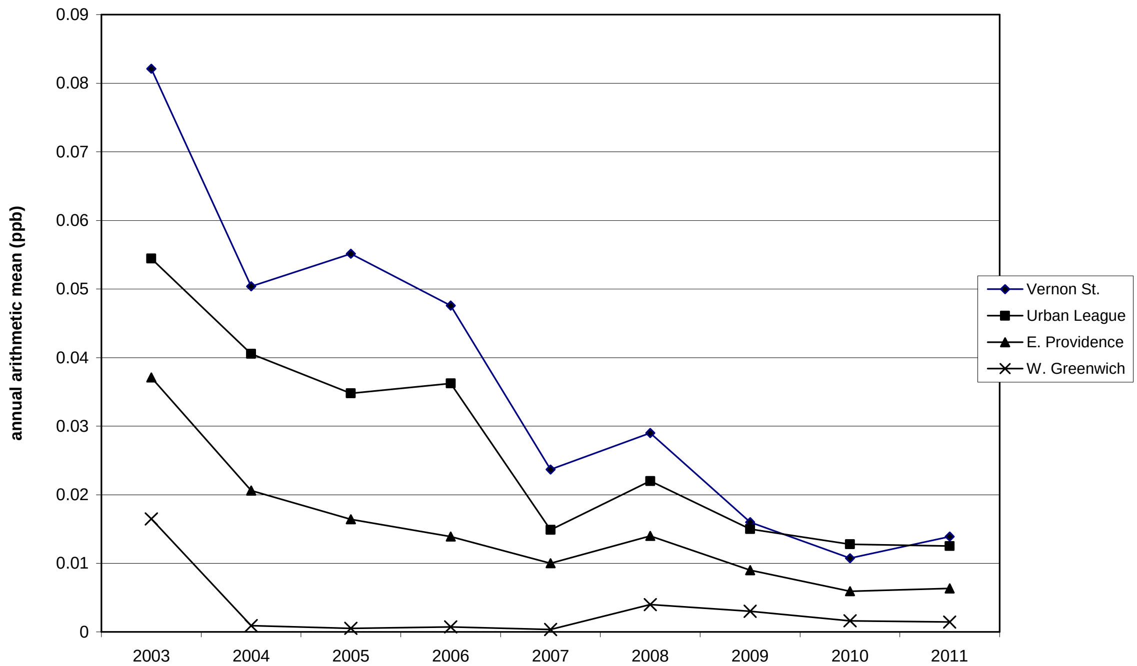
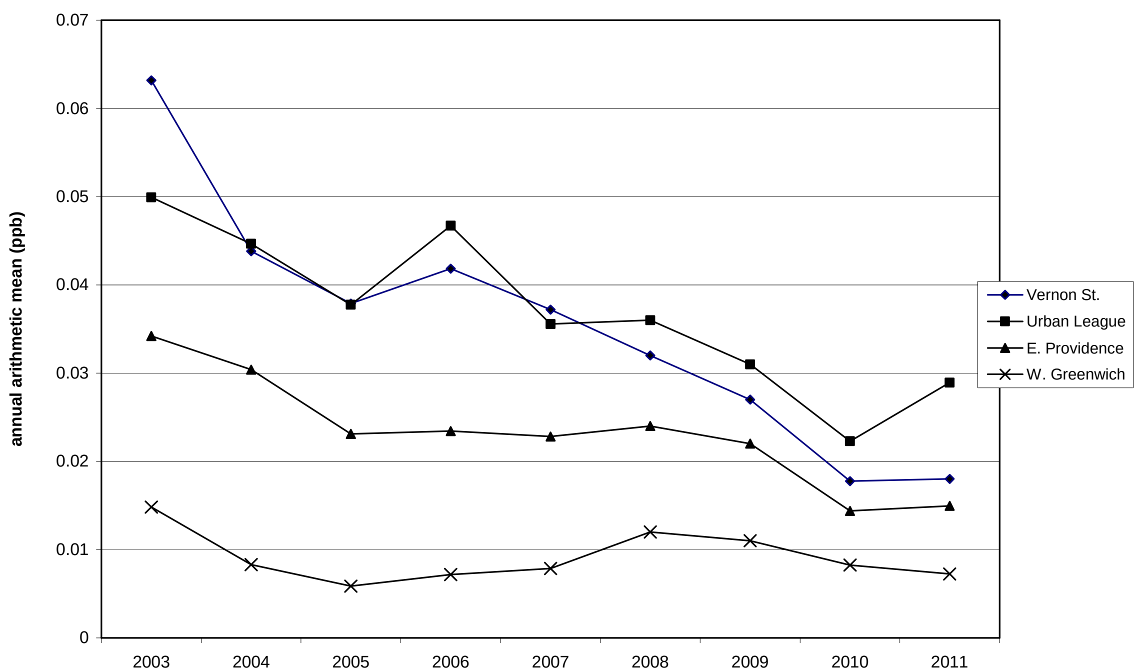


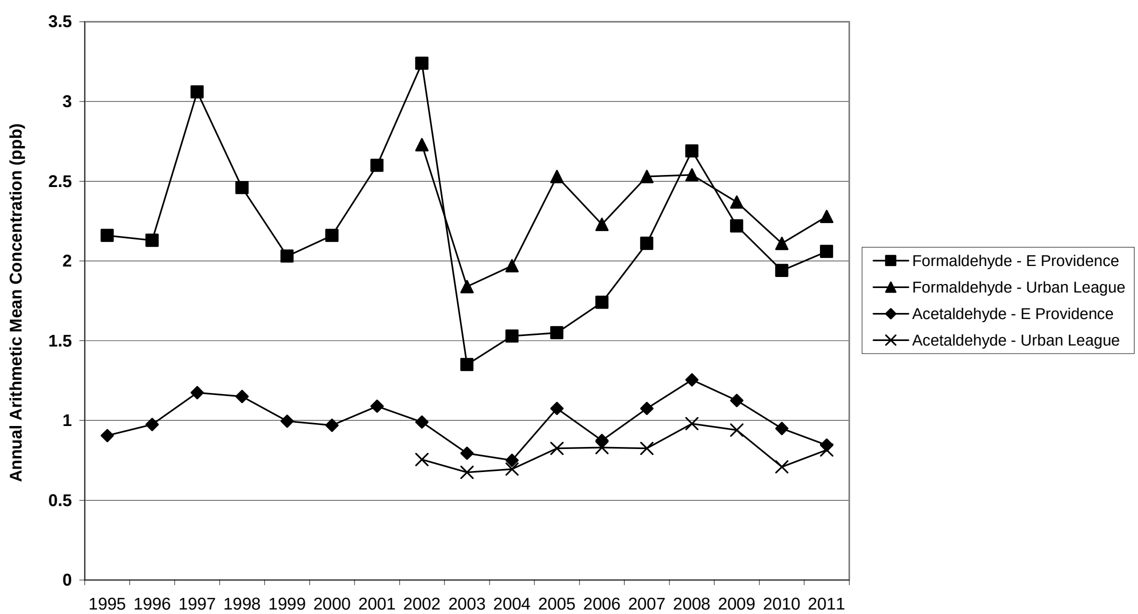
Figure XX
Trends in Annual Average Perchloroethylene Levels



Carbonyls

Average ambient concentrations of the carbonyl compounds formaldehyde and acetaldehyde at the East Providence site for 1995 –2011 and at the Urban League site for 2002- 2011 are displayed in Figure XXI. Carbonyls are emitted by combustion sources and, like ozone, are also formed via photochemical reactions in the atmosphere. Therefore, carbonyl levels tend to be highest in the summer and average carbonyl concentrations in years with hot summers tend to be higher than those in cooler years. The carbonyl levels measured to date do not show a clear trend. Average levels of both formaldehyde and acetaldehyde at the Urban League site and of formaldehyde at the East Providence site in 2011 were slightly higher than in 2010; ambient levels of these substances continue to pose a significant cancer risk.

Figure XXI
CARBONYLS
Annual Average Concentrations



Metals

Hi-volume PM_{10} samples are collected every sixth day at the Urban League NATTS site and analyzed for eight metals. Previously, that analysis was performed by the US EPA Region I laboratory but, since 2008, the metals analysis has been conducted by the Rhode Island Department of Health Laboratories. One of the metals, beryllium, is rarely detected at levels above the Minimum Detection Level. The remaining metals, antimony, arsenic, cadmium, chromium, lead, manganese and nickel, are frequently detected in the samples.

Since 2005, RI DEM has also sampled for hexavalent chromium (chromium VI) in total suspended particulate matter (TSP) samples collected at the Urban League site. Those samples are analyzed by a US EPA contractor. Chromium VI, the most toxic form of chromium, is a human carcinogen. Concentrations of that pollutant have been well below the corresponding health benchmark since sampling began.

The average concentrations of the detected metals in the Urban League PM_{10} samples for 2010 are shown in Table 9. Also listed in that table are health benchmarks for those metals. The health benchmarks for arsenic, cadmium, lead and nickel correspond to a lifetime cancer risk of one in one million and the health benchmarks for antimony, chromium III and manganese, which are not carcinogens, were developed by the US EPA to protect against other health effects.

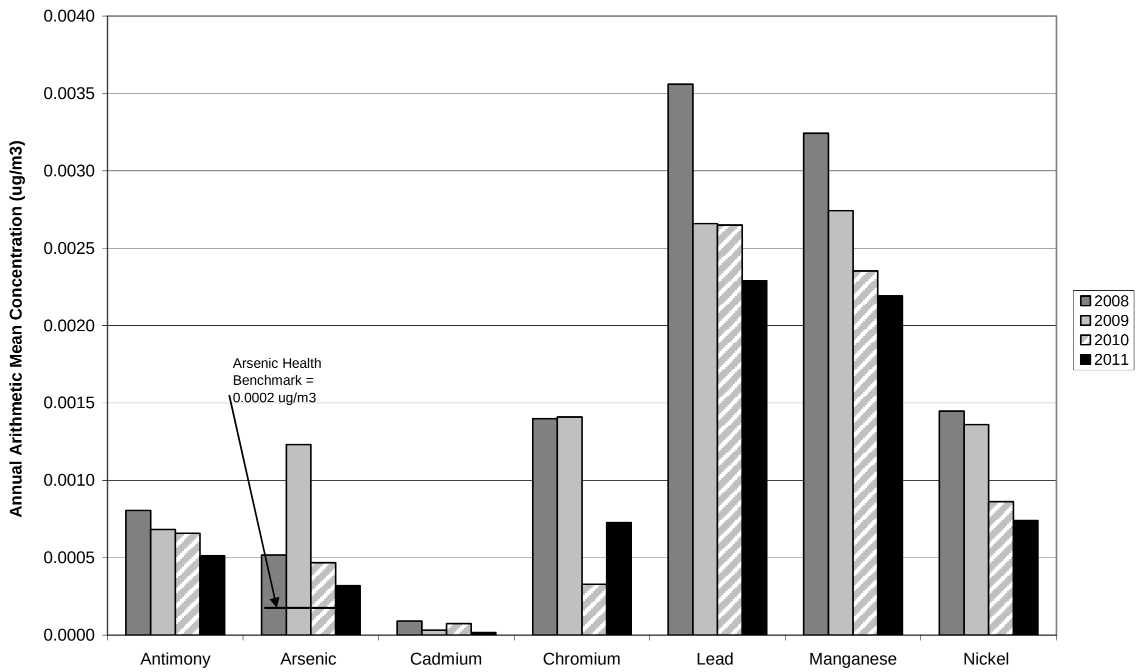
Table 9 Rhode Island 2011 Metals Levels

	2011 Mean ($\mu g/m^3$)	Health Benchmark ($\mu g/m^3$)	Above Benchmark?
Antimony (PM_{10})	0.0005	0.2	No
Arsenic (PM_{10})	0.0003	0.0002	Yes
Cadmium (PM_{10})	0.00002	0.0006	No
Chromium (PM_{10})	0.0007	5,000 (Chromium III)	No
Chromium VI (TSP)	0.00002	0.00008	No
Lead (PM_{10})	0.002	0.08	No
Manganese (PM_{10})	0.002	0.05	No
Nickel (PM_{10})	0.00079	0.004	No

For all of the metals listed in Table 9 except arsenic, the average concentrations measured were lower than the corresponding health benchmark, and thus would not be likely to present a significant health risk. The 2011 arsenic concentration measured was less than twice the benchmark, which is based on lung cancer, and thus long-term exposure to that level would be associated with an increased lung cancer risk of less than two cases in one-million people exposed. As shown in Figure XXII, concentrations of all metals in 2011 except chromium were lower than the 2010 levels.

As part of the federal $PM_{2.5}$ speciation program, a number of metals are also measured in $PM_{2.5}$. However, since $PM_{2.5}$ speciation monitoring was moved from the Urban League to the East Providence site in September 2010 to conform to NCore requirements, it is not possible to compare the metals levels measured in $PM_{2.5}$ and PM_{10} in 2011. Note that, in previous years, virtually all of the particulate nickel and most of the lead was present on fine particles ($PM_{2.5}$), while manganese was divided between the fine and the coarser particles (particles with diameters between 2.5 and 10 micrometers).

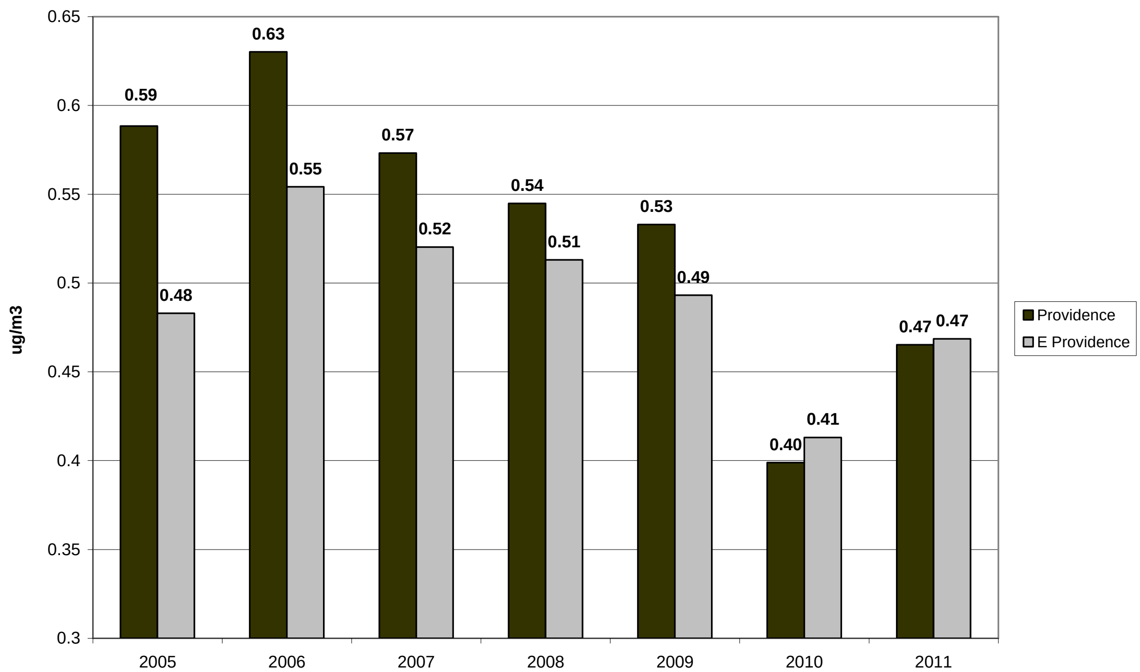
Figure XXII Metals in PM-10 at Urban League, Providence Site



Black Carbon

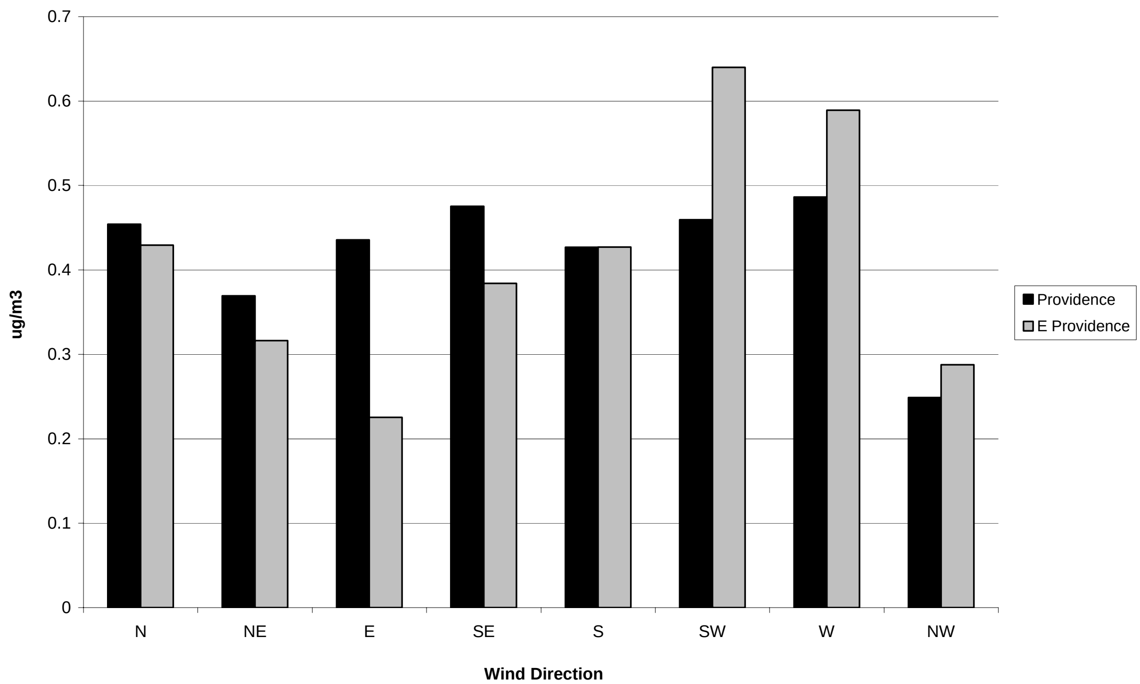
Black carbon, an indicator of diesel exhaust, has been measured at the Francis School, East Providence and Urban League, Providence sites since 2005 using a continuous reading instrument. As shown in Figure XXIII, annual average concentrations at both sites have generally decreased since 2006 but were higher in 2011 than in 2010. Prior 2010, average concentrations were higher at the urban Providence site than at the suburban East Providence site, but average levels at the East Providence site were slightly higher than at the Providence site in 2010 and 2011.

Figure XXIII Black Carbon Concentration - Annual Average



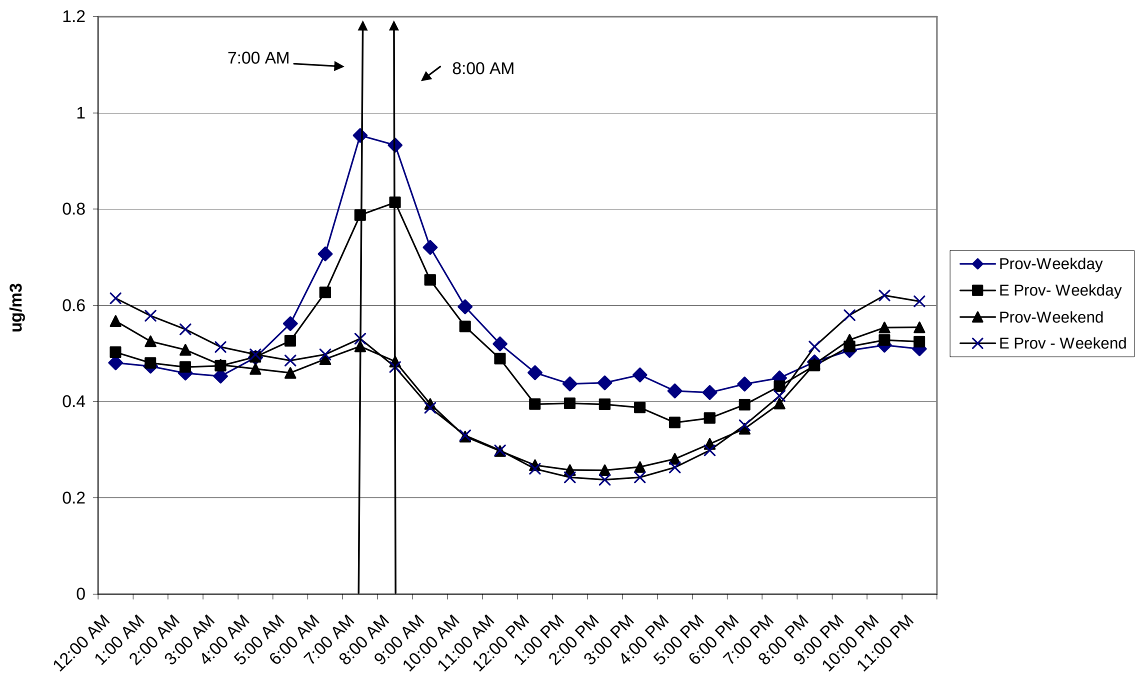
As can be seen in Figure XXIV, black carbon concentrations are influenced by wind direction. When the wind was from the west or southwest, average black carbon levels at the suburban East Providence site were higher than at the urban Providence site. This is likely due to the presence of industrial and/or mobile sources emitting that pollutant in the Providence metropolitan area, which is upwind of the East Providence site when the winds are from those directions. When the wind has an easterly component, the Providence levels were, on average, higher than those at the East Providence site. This discrepancy was particularly large when the wind was from the east, probably due to the influence of traffic on Interstate Rte. 95, which is east of the Providence site.

Figure XXIV   2011 Average Black Carbon Concentration by Wind Direction



As shown in Figure XXV, average black carbon levels peak between 7:00 and 8:00 AM on week days, due to high traffic activity and meteorological conditions that limit dilution of pollutants. Concentrations are considerably lower during the daytime hours on weekends than during the work week.

Figure XXV Black Carbon - Average Hourly Concentrations



Semi-Volatile Organic Compounds

Rhode Island began monitoring semi-volatile compounds (SVOCs), including polycyclic aromatic hydrocarbons (PAHs), at the Urban League NATTS site in July 2008. The following SVOCs are measured: 9-fluorenone, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, coronene, cyclopenta[cd]pyrene, dibenz(a,h)anthracene, fluoranthene, fluorine, indeno(1,2,3-cd)pyrene, naphthalene, perylene, phenanthrene, pyrene and retene. These substances are emitted during combustion of wood, coal, oil and other fuels.

RI DEM's Air Toxics Regulation establishes Acceptable Ambient Levels (AALs), which are based on health risk, for a number of substances, including naphthalene and PAHs. The average naphthalene level measured at the Urban League, Providence site in 2011 is in the middle of the acceptable range; lifetime exposure to naphthalene at the measured level would correspond to a cancer risk of about three cases in one million people exposed. Lifetime exposure to PAHs in total would correspond to a risk of about eight cases in one million people exposed. The PAHs that contribute most to the total risk are fluoranthene, benzo(a)pyrene and anthracene.