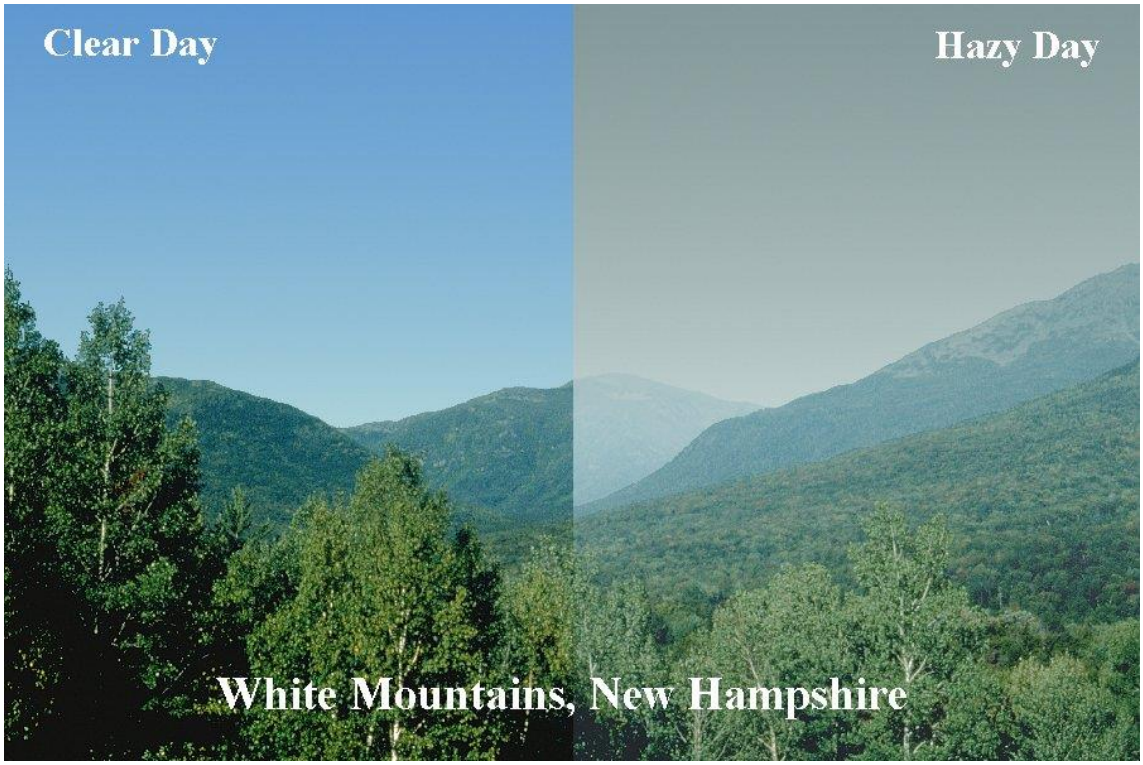
# Air Pollution Transport and How It Affects New Hampshire




**May 2004**

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

R-ARD 04-1

# Air Pollution Transport and How It Affects New Hampshire

**May 2004**

**Prepared by the**
**New Hampshire Department of Environmental Services**
**29 Hazen Drive, P.O. Box 95**
**Concord, New Hampshire 03302-0095**
**603-271-1370**
**www.des.nh.gov**

**Michael P. Nolin, Commissioner**
**Michael J. Walls, Assistant Commissioner**
**Robert R. Scott, Air Resources Division Director**

*Cover photo: Mount Jefferson, New Hampshire – Computer simulated split photograph demonstrating clear conditions and reduced visibility from small particle pollution*

Printed on 100% Recycled, Process Chlorine Free Paper

## A Message from the Governor

New Hampshire's environment is important to our quality of life and public health, as well as our economy. My administration has worked hard to preserve our natural resources in order to make this state a great place to live, work or simply take a vacation. Many people come to New Hampshire to enjoy our state's natural beauty, admire the breathtaking views of our mountains and breathe our fresh air. Though we have done much in this state to reduce pollution and ensure a healthy environment for all, keeping the air clean offers a particular challenge.

New Hampshire has been at the forefront of reducing emissions of air pollution within the state's borders, but research over the past few years has shown that most of the air pollution the state experiences comes from out of state sources. Some of these pollution sources are hundreds of miles away, but their emissions are transported into the state with the wind, even over these great distances. Though we are responsible for air pollution originating in New Hampshire, much of the responsibility for clearing the air is shared by other states and by the federal government. Air pollution does not respect geopolitical boundaries and it is for this reason that we have analyzed the effects on New Hampshire's citizens and businesses from this transported pollution.

This report presents an eye-opening assessment of the cost of air pollution from these far-away sources. Though many of us do not think of how air pollution affects our lives, the scientific analysis contained in this report estimates that the health-related impact of air pollution transported into our state exceeds $1 billion annually. Beyond that, are the increased costs of doing business, increased healthcare claims, and the loss of worker productivity due to respiratory illness which affect not only those people, but all of us. The health of many of New Hampshire's citizens has been greatly affected, thereby reducing their quality of life. When some of us suffer from the adverse health effects of air pollution, we all pay the price.

New Hampshire's businesses also feel the effects, and this is significant since the environment drives a big part of the state's economy. Failing to maintain a healthy environment will ultimately reduce business opportunities since many businesses will have to bear higher operational costs due to tighter federal regulations, along with higher energy costs. Tourism is also affected since much of the pollution originating from out of state also obscures the scenic views of our mountains and seacoast for which this state is noted.

This administration is committed to protecting our air and environment by working with regional and federal agencies to ensure that effective and reasonable legislation is passed to address this issue. The more that is known about the personal and economic impacts of air pollution, the stronger our case is to pass meaningful legislation. After all, the health of our citizens and the vitality of our state depend on it.

Craig R. Benson
Governor

# Air Pollution Transport and How It Affects New Hampshire

## Table of Contents


Report Highlights ..... *iii*

Section 1 Introduction ..... 1

Section 2 Assessment of New Hampshire's Air Quality
and the Air Pollutants That Are Most Subject to Transport ..... 2
Ozone ..... 2
Small Particle Pollution ..... 5
Acid Rain and Acid Deposition ..... 10
Mercury ..... 13

Section 3 Health Implications of Ozone and Small Particle Pollution at Levels
Below Federal Standards ..... 18

Section 4 Local and Transported Air Pollution Impacts on New Hampshire ..... 19

Section 5 Defining the Transport Problem ..... 22

Section 6 The Economic Impacts of Air Pollution Transport on New Hampshire ..... 26
Impacts on Health-Related Costs ..... 27
Particle Pollution ..... 27
Ozone ..... 30
Impacts of Air Pollution on New Hampshire's Business ..... 31

Section 7 Addressing Air Pollution Transport with Multi-Pollutant Control Strategies ..... 33
States' Rights ..... 37
Cap and Trade program and Mercury Considerations ..... 38
EPA's Clean Air Interstate Rule and Mercury MACT Rule ..... 39

Section 8 New Source Review and Its Impact on Air Pollution Transport ..... 41

Section 9 Conclusion ..... 43

**Technical Attachments**
A. Detailed Transport Mechanisms ..... A-1
B. $PM_{2.5}$ Health Valuation Calculations ..... B-1
C. Ozone health Valuation Calculations ..... C-1
D. Comparison of Federally Proposed Electric Generating Unit
Multi-Pollutant Legislation ..... D-1

Glossary – Terms and Acronyms ..... G-1

References ..... R-1

## List of Figures

Figure 2.1 Number of Unhealthy Ozone Days in New Hampshire ..... 2
Figure 2.2 Ozone Nonattainment Areas in New Hampshire - 2004 ..... 3
Figure 2.3 National Nitrogen Oxide (NOx) Emissions by Sector for 1996 ..... 4
Figure 2.4 Volatile Organic Compound (VOC) Emissions in NH by Sector On a Hot Summer Day, 1996 ..... 4
Figure 2.5 Wind Patterns and NOx Emissions on High Ozone Days in NH ..... 5
Figure 2.6 Size of Small Particle Pollution ..... 6
Figure 2.7 Annual $PM_{2.5}$ Concentrations by Location 2001-03 Average ..... 6
Figure 2.8 National Sulfur Dioxide Emissions, 1996 ..... 7
Figure 2.9 Total Sulfur Dioxide and Nitrogen Oxide Emissions by State ..... 7
Figure 2.10 Composition of $PM_{2.5}$ Concentrations at Class I Areas in the Northeast, Annual Averages 1996 – 1999 ..... 8
Figure 2.11 What Causes Haze? ..... 9
Figure 2.12 The Difference Haze Makes on Visibility ..... 10
Figure 2.13 How Acid Rain Forms ..... 10
Figure 2.14 Acid Neutralizing Capacity Classifications of New Hampshire Lakes and Remote Ponds ..... 11
Figure 2.15 Acidity Classification of New Hampshire Lakes and Remote Ponds ..... 12
Figure 2.16 New Hampshire Mercury Emissions by Source Sector - 2003 ..... 14
Figure 2.17 Total Mercury Emissions by State - 1996 ..... 14
Figure 2.18 Annual Average Mercury Deposition (2000 – 2003) ..... 16
Figure 2.19 Modeled Mercury Deposition Across the Northeast United States and Canada ..... 16
Figure 2.20 Local and Regional Mercury Impacts from Coal-fired Power Plants ..... 17
Figure 3.1 Vehicle Miles Traveled (VMT) and Level of Pollution Control ..... 20
Figure 5.1 How Upper-Level Transport Works ..... 24
Figure 5.2 Typical Widespread "Smog" Event in the Northeast ..... 24

## List of Tables

Table 2.1 Acidified Lakes and Remote Ponds in New Hampshire ..... 13
Table 5.1 Air Pollution Transport Characteristics ..... 22
Table 6.1 Health-Related Costs from Transport of Small Particle Pollution into NH ..... 29
Table 6.2 Health-Related Costs from Transport of Ozone Pollution into NH ..... 30
Table 7.1 Comparison of Federally Proposed EGU Multi-Pollutant Legislation ..... 38

# REPORT HIGHLIGHTS

- New Hampshire experiences an average of ten days per year where the air quality is officially categorized as unhealthy. This is enough to classify portions of the state as nonattainment for ozone (i.e., dirty air regions), prompting certain federally required actions to reduce air pollution from in-state sources.
- During periods of unhealthy air quality for ozone and small particles in New Hampshire, approximately 92 to nearly 100 percent of this pollution originates from sources located outside of New Hampshire. These pollutants are transported into the state with the wind over great distances.
- New Hampshire has taken steps to reduce pollution emissions on a local basis to ensure that the problem doesn't get worse for our own citizens or for those living downwind.
- Since the large majority of air pollution in New Hampshire comes from out-of-state sources, emission reductions are necessary in upwind states to bring New Hampshire into compliance with clean air regulations.
- Emissions from large power plants in the Midwest and urban areas to the south of New Hampshire provide the vast majority of the pollution that causes unhealthy air quality, impaired visibility, acidification of lakes and forests, and mercury contamination throughout New Hampshire.
- When acid rain forming pollutants and mercury are released into the air, they are chemically transformed into acidic compounds and toxic mercury and carried many miles before being deposited onto land and into water bodies. Some forms of mercury are more likely than others to deposit in areas near their source, creating local "hot spots."
- Small particles and ozone have been shown to produce adverse health effects even at levels below the current federal National Ambient Air Quality Standards (NAAQS).
- Failing to have a healthy environment will ultimately reduce business opportunities – which in turn will reduce jobs, lower income and jeopardize the economic outlook of affected communities.
- Direct health-related costs to New Hampshire from transported air pollution due to out-of-state sources are estimated to **exceed $1 billion per year** based on health-related cost data obtained from independent studies. Economic impacts beyond direct health-related costs that are not accounted for in this figure include:
    - Increased health claims and health risks for all New Hampshire residents.
    - Loss of worker productivity.
    - Higher electricity costs and operating costs for local power plants due to increased federal requirements for operation in dirty air regions.
    - Higher operating costs for certain businesses in the state due to increased federal requirements for operation in dirty air regions.

    - More expensive fuels (including gasoline) and vehicles due to increased federal requirements for operation in dirty air regions.
- With more vehicles on the road and steady growth in total miles driven both in New Hampshire and nationally, strong federal emission reduction requirements for motor vehicles are essential for meeting clean air goals.
- Effective national multi-pollutant legislation for electric generating units is critical to New Hampshire if the state expects to achieve consistently healthy air quality. Meaningful legislation will also avoid unnecessary and highly expensive pollution control measures required for downwind areas (a requirement under federal law for areas with poor air quality).
- The full benefits of the proposed federal Clear Skies Act will not be realized until 2020 – too late for New Hampshire to reach clean air goals by the required attainment date of 2010 – and will only be a marginal improvement over what the existing Clean Air Act provisions require. Both the proposed congressional Clean Air Planning and Clean Power Acts achieve greater reductions sooner.
- The New Source Review overhaul as proposed by EPA will allow older, dirtier facilities to continue to make major, life-extending improvements without installing pollution control equipment. The result will be continued unhealthy air quality for states like New Hampshire due to air pollution transport and increased requirements for local controls.
- Controlling pollution is cost-effective, returning over $12 of health-related benefits for every $1 spent on controlling power plant emissions.

## - SECTION 1 -
## INTRODUCTION

Over the past 20 years, significant progress has been made in reducing emissions of air pollutants and improving air quality nationally and in New Hampshire. Programs implemented since the Clean Air Act Amendments of 1990 regulate more sources of air pollution and impose additional or more stringent regulations on previously controlled sources. Gradual air quality improvements can be attributed to mandated reductions in emissions from businesses and industries, as well as technological improvements in automobiles. Despite the progress in achieving pollution emission reductions, New Hampshire still continues to experience unhealthy air quality days and there are even a few locations where the air quality is getting worse.

While some air pollution in New Hampshire comes from obvious sources within the state, much of it comes from sources outside of New Hampshire, sometimes from thousands of miles away. Just as weather forecasters look to where the wind is coming from to forecast the weather, air pollution forecasters look in the same direction to see where air pollution is coming from. The same wind that brings us the weather often brings air pollution along with it. This movement of air pollution – called "transport" – is not a simple process. Pollutants in the air undergo complex chemical reactions, and pollution is added or removed from the air as it moves along.

In many areas of the country, such as New Hampshire, achieving healthy air quality is not limited to local air pollution reductions. In order to succeed in clearing the air, New Hampshire must work both within the state and with our neighbors to coordinate needed air pollution emission reductions. Since the wind frequently comes into New Hampshire from our west and southwest, we need to look in these upwind directions for help in cleaning the air. Clean air is needed not only for our health and environment, but for the economic well-being of our businesses and tourism industry.

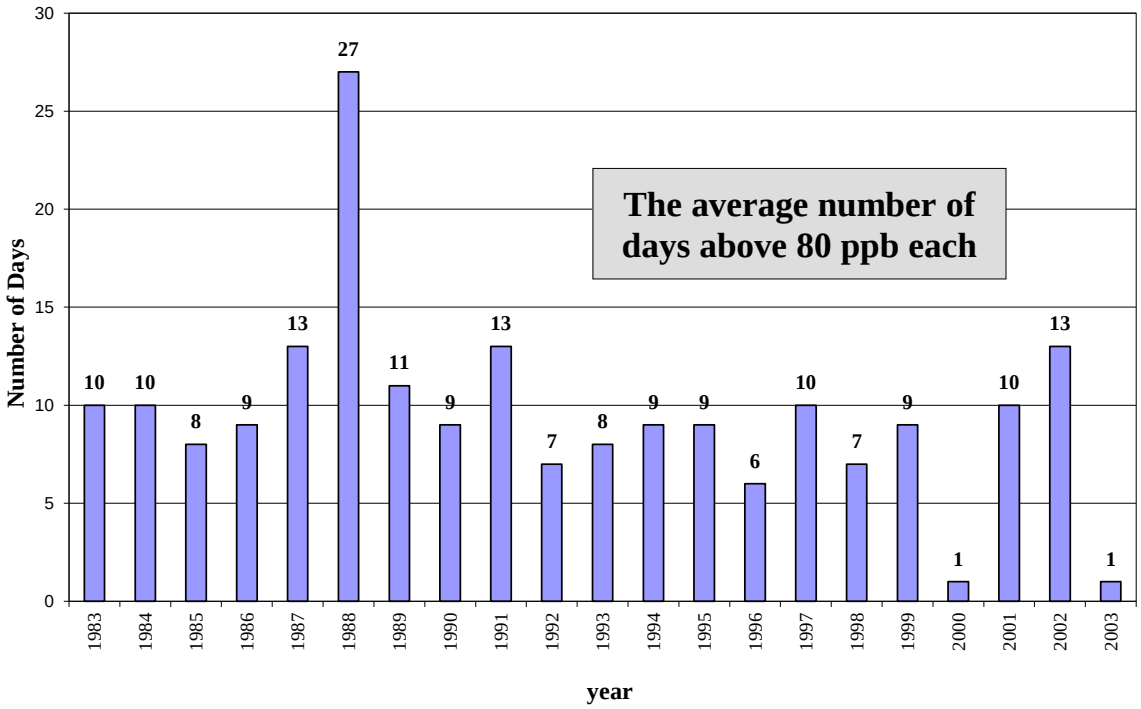
## - SECTION 2 -
## ASSESSMENT OF NEW HAMPSHIRE'S AIR QUALITY AND THE AIR POLLUTANTS THAT ARE MOST SUBJECT TO TRANSPORT

### Ozone

New Hampshire experiences an average of ten unhealthy air quality days per year when levels of ground-level ozone exceed federal health-based standards, called National Ambient Air Quality Standards or "NAAQS" (see Figure 2.1). This is sufficient enough for the U.S. Environmental Protection Agency (EPA) to classify portions of the state as "nonattainment" for ozone, in other words, these areas do not meet federal ambient ozone standards (see Figure 2.2).

> ***"Good Up High, Bad Nearby"*** *– Ozone can be good or bad, depending on where it is found. Ozone in the upper atmosphere (stratosphere) is naturally occurring and shields us from the sun's harmful ultraviolet rays. Ozone in the lower atmosphere is a manmade pollutant which can have harmful effects on living things.*

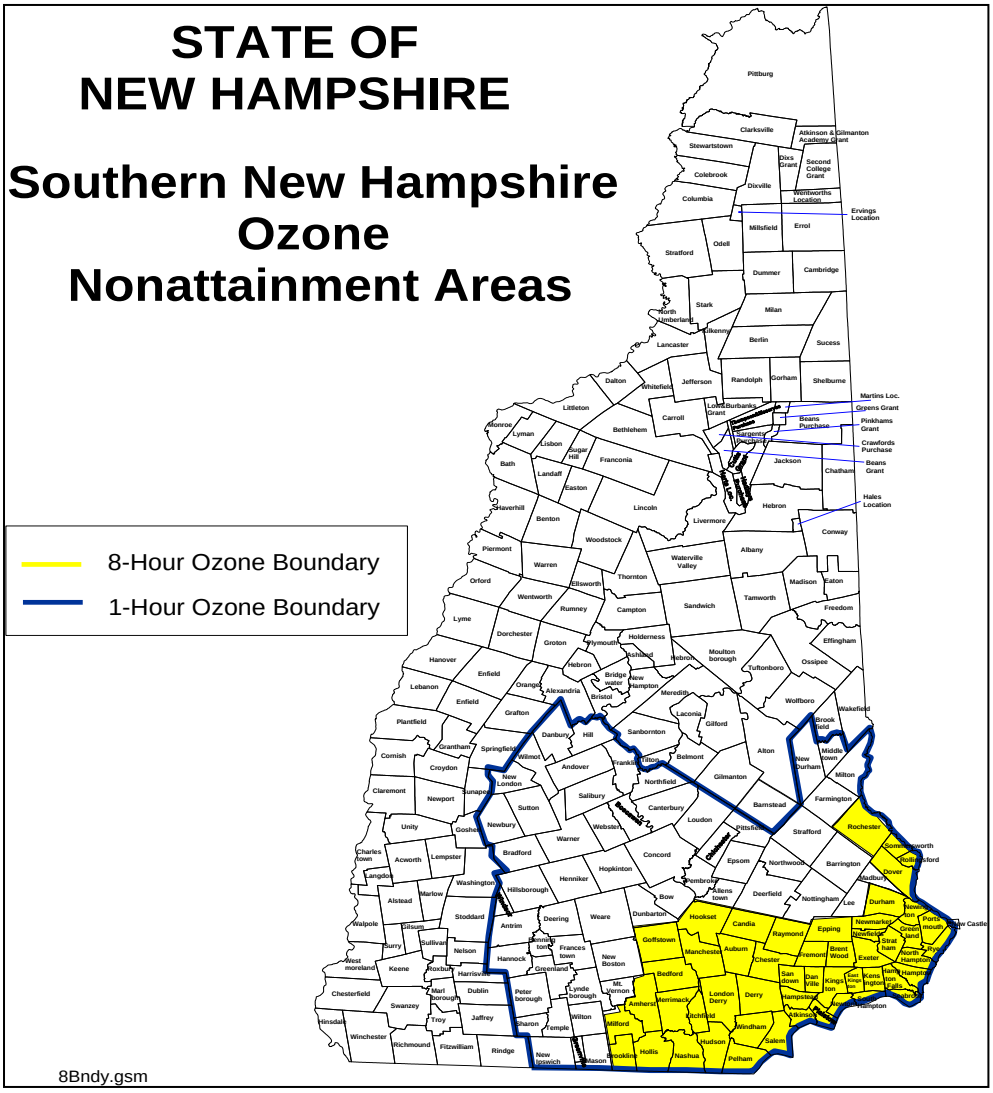
**Figure 2.1 - Number of Unhealthy Ozone Days in N.H. (Over 80 parts per billion based on the eight-hour ozone standard)**




*Total number of days per year when the eight-hour average ozone standard was exceeded in New Hampshire. Changes from year to year are largely driven by weather variations. As some years are colder or rainier than others, some years are more conducive to ozone formation than others. Source: NHDES, December 2003*

The main concern to humans relative to ground-level ozone is how it affects the respiratory system. Effects of short-term exposure include coughing, painful breathing, and temporary loss of some lung functions. Long-term exposures may cause repeated inflammation of the lungs, impairment of lung defense mechanisms and changes in lung structure, which could lead to premature aging of the lungs. Ozone can aggravate asthma, emphysema, bronchitis, and other respiratory diseases.

**Figure 2.2 - Ozone Nonattainment Areas in New Hampshire – 2004**

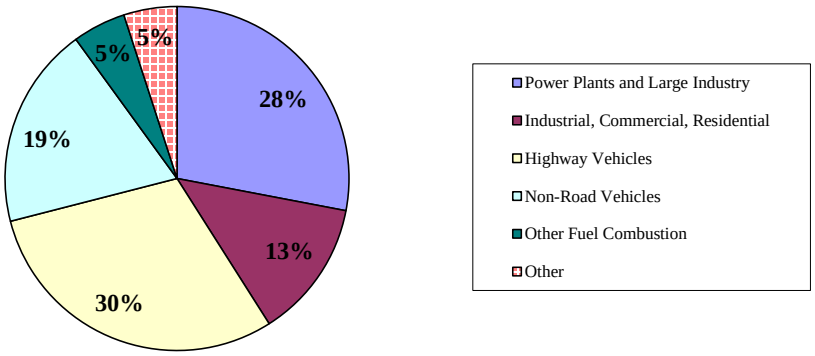



*Areas in New Hampshire where air monitoring data indicates nonattainment with the eigh ederal ozone standard (shaded yellow) and the one-hour federal ozone standard (within the dark blue line). Businesses located in nonattainment areas must adhere to more stringent requirements than businesses located in other areas. Source: NHDES, July 2003*

Ozone can also damage forests and other vegetation. Adverse effects of ozone exposure to vegetation include discoloration of leaves, light flecks, dark stipples, yellow spots, premature aging, leaf loss, and reduced growth rates and crop yields.

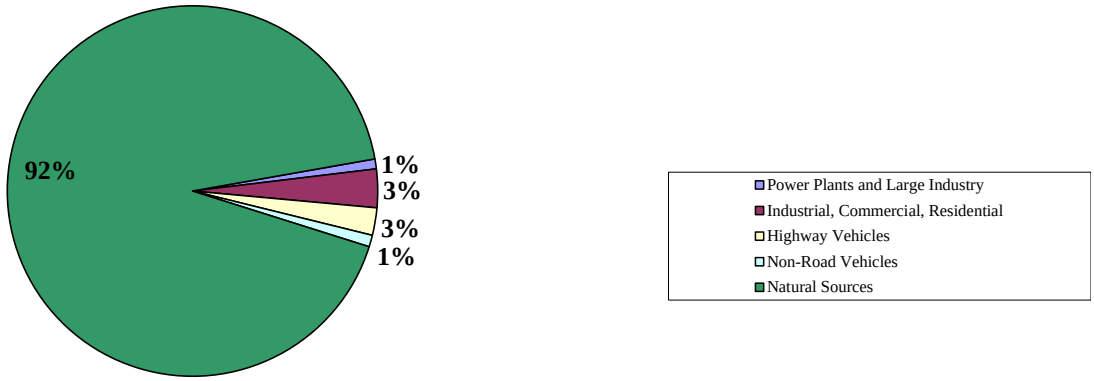
Unlike many other pollutants, ground-level ozone is not directly emitted into the atmosphere from a specific source. Instead, ground-level ozone is formed when nitrogen oxides (NOx) chemically react with volatile organic compounds (VOCs) through a series of complicated chemical reactions in the presence of strong sunshine (ultraviolet light). The sources of NOx and VOCs – called ozone precursors – are many and varied. Almost all NOx emissions originate from human activities related to fossil fuel combustion (see Figure 2.3). Conversely, over 90 percent of VOC emissions in New Hampshire result primarily from natural (biogenic) sources, mainly forests and urban vegetation (see Figure 2.4).

**Figure 2.3 - National Nitrogen Oxide (NOx) Emissions by Sector for 1996**




*Data Source: EPA 1996 National Emissions Inventory (NEI)*

**Figure 2.4 - Volatile Organic Compound (VOC) Emissions in N.H. by Sector on a Hot Summer Day (when emissions are greatest), 1996**

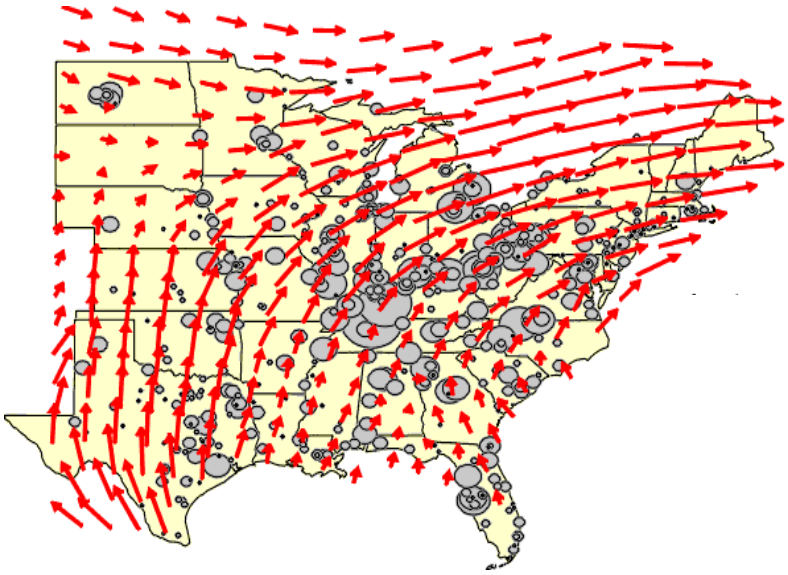



*Data Source: NHDES and EPA*

The formation of ozone is not an instantaneous process, nor is it limited in geographical scope. Numerous studies and modeling data show that in the northeastern United States, the wind often transports the pollutants responsible for ozone formation – well beyond the locality that produced the emissions. This transport phenomenon is clearly demonstrated in Figure 2.5, which shows a typical wind pattern when ozone reaches unhealthy levels in the Northeast. The location and size of the major NOx pollution stationary sources are also shown.

**Key Point:** New Hampshire's unhealthy ozone days are caused by the transport of ozone and ozone precursors into the State from upwind jurisdictions in the Northeast and industrial Midwest.

**Figure 2.5 - Wind Patterns and NOx Emissions on High Ozone Days in New Hampshire and the Northeast**



*Typical wind patterns when ozone reaches unhealthy levels in the Northeast and New Hampshire. The circles indicate the location and magnitude of NOx emissions from the major NOx pollution stationary sources – electric power plants.*
*Source: Northeast States for Coordinated Air Use Management (NESCAUM), 1997*

## Small Particle Pollution

As with ozone, portions of New Hampshire also experience elevated levels of small particles, defined as particles that are less than 2.5 micrometers (μm) in diameter, called $PM_{2.5}$. For comparison, a human hair is approximately 70 μm in diameter (see Figure 2.6).

Evidence of the dangers of small particles is growing in the published literature. These particles can be inhaled deeply into the lungs where they can induce or aggravate respiratory illnesses. Scientific studies have linked exposure to small particles with a series of significant adverse human health effects including: 1) respiratory symptoms in healthy individuals, e.g., coughing, wheezing; 2) aggravation of asthma, chronic bronchitis, or emphysema;
3) complications of cardiovascular disorders; 4) alterations in the respiratory system's defense against foreign materials; 5) damage to lung tissue; and 6) premature death.

Annual $PM_{2.5}$ concentrations have little variation across the state, averaging 10-11 micrograms per cubic meter (ug/m$^3$) (see Figure 2.7). The federal annual standard (NAAQS) for $PM_{2.5}$ is 15 μg/m$^3$. Over the past four years, annual weather fluctuations have resulted in a statewide range of 8-14 μg/m$^3$. Despite not exceeding the federal standard for small particles, the concentrations still frequently reach unhealthy levels for people who are most sensitive to the effects of particle pollution (the elderly, children, and people with lung or heart conditions).

**Figure 2.6 - Size of Small Particle Pollution**

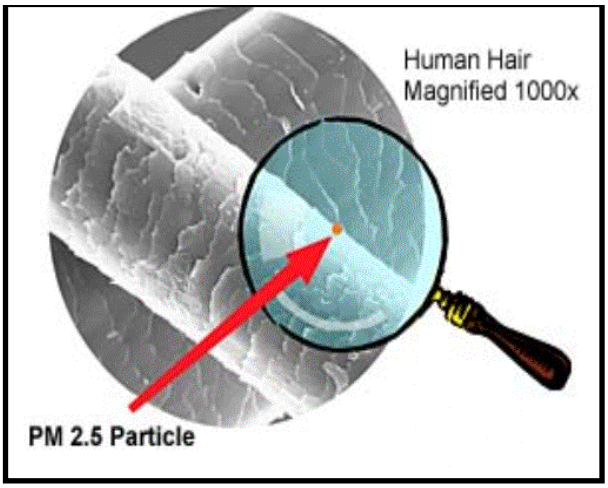
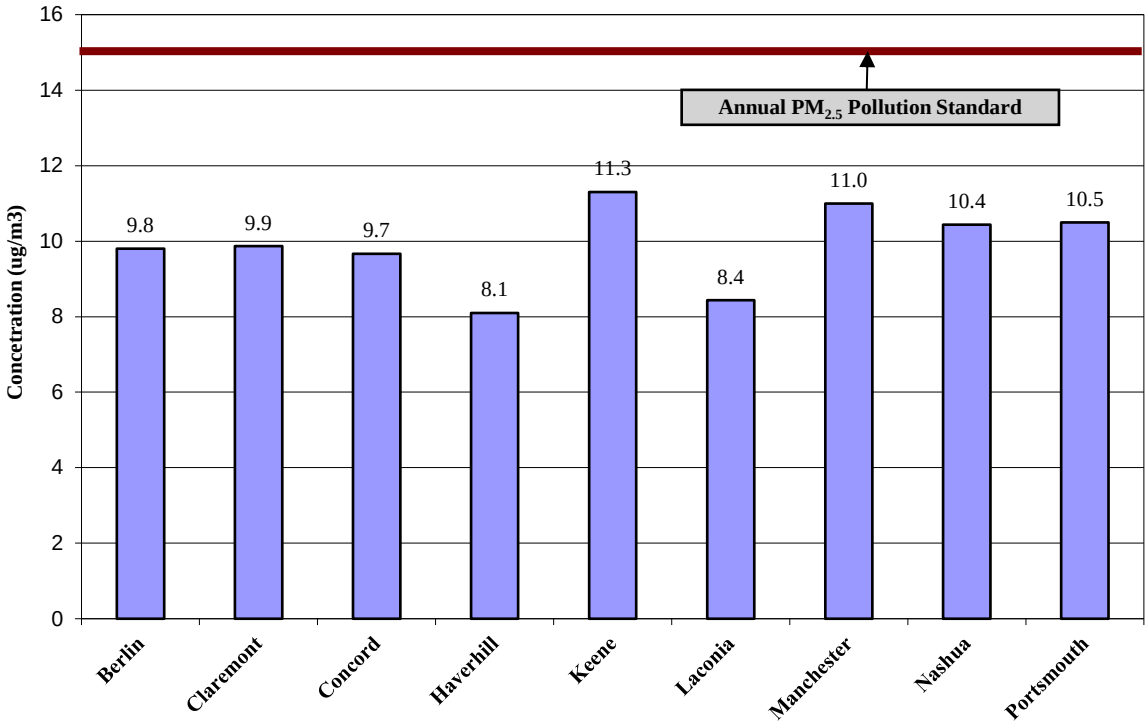


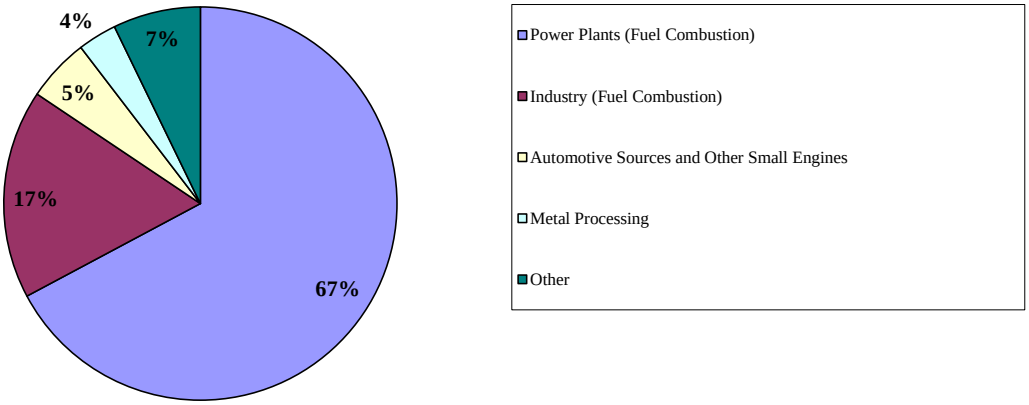
**Figure 2.7 - Annual $PM_{2.5}$ Concentrations by Location, 2001-2003 Average**




*Average annual $PM_{2.5}$ concentrations measured in New Hampshire from 2001 through 2003. Note that the typical value of around 10µg/m$^3$ is about two thirds of the standard. Data for 2003 is projected based on 9 months of complete data. Source: NHDES, 2004*

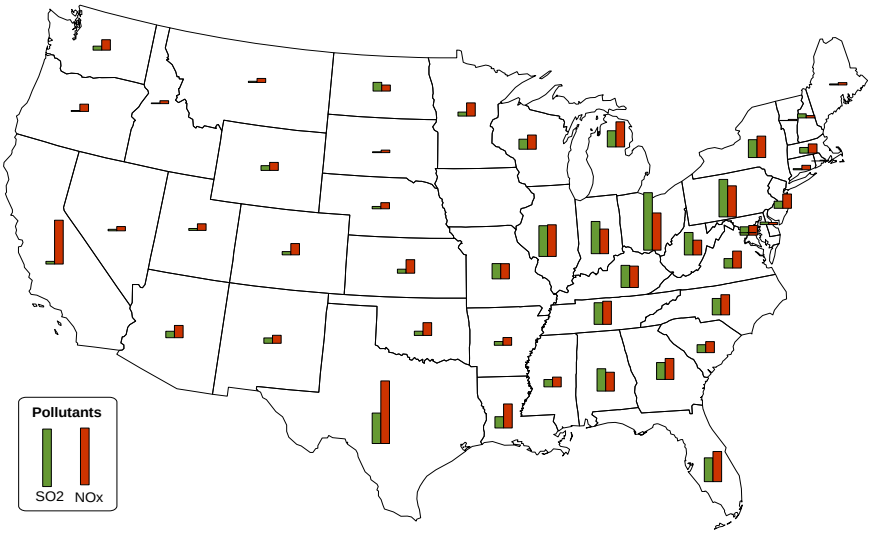
Small particles can be emitted directly from burning materials or they can be formed from other gases such as sulfur dioxide ($SO_2$), NOx, and certain VOCs, which react in the atmosphere. Most of the small particles found in the Northeast result from burning coal, diesel, gasoline, wood, and other fuels, with the large coal burning industries and power plants in upwind areas contributing the largest amounts (see Figures 2.8 and 2.9). These facilities release huge amounts of $SO_2$ that react with ammonia in the atmosphere to form ammonium sulfate [$(NH_4)_2\ SO_4$] particles. NOx also reacts with ammonia to form ammonium nitrate ($NH_4NO_3$), but it does so to a much smaller degree and mostly during the cold winter months. Small particles are also composed of elemental carbon (soot), organic compounds, biogenic organic compounds such as terpenes, and metals such as iron, lead, cadmium, nickel, copper and zinc (see Figure 2.10).

**Figure 2.8 - National Sulfur Dioxide Emissions, 1996**




*Data Source: EPA 1996 National Emissions Inventory (NEI)*

**Figure 2.9 - Total Sulfur Dioxide ($SO_2$) and Nitrogen Oxide (NOx) Emissions by State -**




**1996**

*Total $SO_2$ and NOx emissions by state. The highest emissions are not associated with population, but rather located in the states with the most electricity generated by coal combustion. The length of the bar represents the relative magnitude of emissions. Source: EPA Clear Skies Act 2003 Website Technical Appendix A*

**Figure 2.10 - Composition of $PM_{2.5}$ Concentrations at Class I Areas in the Northeast, Annual Averages 1996 - 1999**

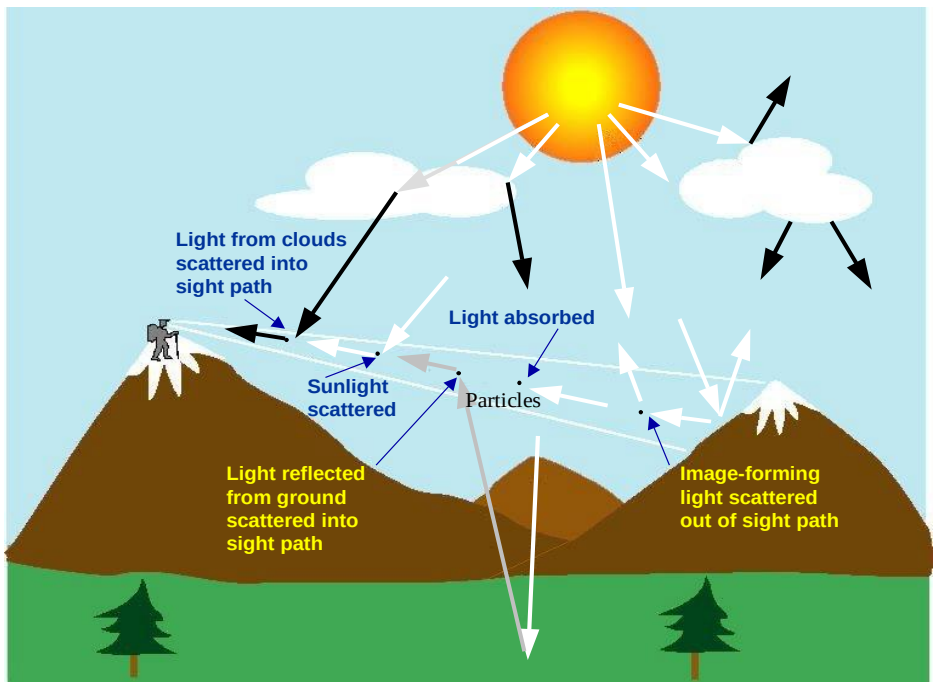
*Measured annual composition of small particles collected in New England. Sulfate-based particles dominate the annual composition of small particles in the region and are the major cause of impaired visibility throughout the Northeast. The second largest component, organic carbon, is the result of particles formed from fuels and solvents released during combustion, re-fueling, cleaning, and other industrial processes. Elemental carbon is primarily composed of particles directly released during combustion. Soot from diesel engines is the leading source of these particles. Crustal materials are soils stirred by weathering, construction, or traffic. Nitrates are formed by chemical reactions involving NOx emissions and are primarily of concern during colder weather. Source: NHDES and IMPROVE Database, 2001*

Current research is studying the extent to which particle composition contributes to health impacts. While the findings are not yet complete, what has been made clear is that the small particles found in the Northeast carry toxic and often carcinogenic materials. Small particles formed by coal burning with an especially large sulfate component, which by itself is nontoxic, often carry toxic compounds such as mercury and arsenic. Diesel and wood smoke contain particles that carry numerous carcinogenic materials as well.

**Key Point:** Small particle pollution, which often carries toxic substances, has a local impact and is also very susceptible to long-range pollution transport.

Some of the same particles linked to serious health effects are the major cause of reduced visibility, even in supposedly pristine areas like the White Mountains in New Hampshire. Reduced visibility, or "regional haze," occurs as a result of the scattering and absorption of light by particles and gases in the atmosphere (see Figures 2.11 and 2.12). The classes of small particles principally responsible for reduced visibility in New Hampshire are sulfates, organic matter, carbon (soot), soil dust, and nitrates. While all small particles and several gaseous pollutants impair visibility, ammonium sulfate (a product of $SO_2$ pollution) is usually the most light-scattering pollutant in the Northeast. Ammonium sulfate swells with increasing relative humidity, resulting in greater amounts of re-directed visible light, dimmer views, and increased whitish haze.

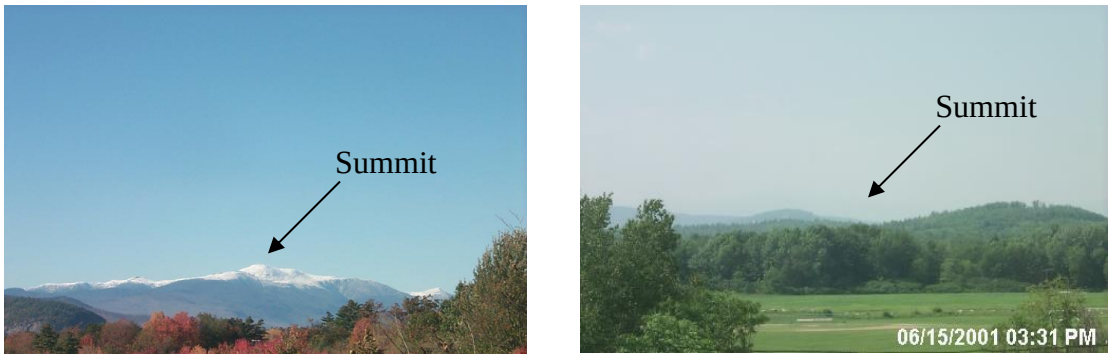
**Figure 2.11 - What Causes Haze?**




*Visibility is reduced when light is absorbed, scattered, or interfered with. Large particles are efficient at absorbing light, thus darkening a distant image. Small particles can absorb light and scatter it (obscuring the image) and they can cause interfering light to be introduced to an image (adding a whitish appearance). Gases can cause light to scatter, adding or subtracting colors to a view of an image.*
*Source: Malm, 2000*

**Key Point:** Small particle pollution transported into New Hampshire results in reduced visibility and hazy views in many regions of the White Mountains and throughout the state.

**Figure 2.12 - The Difference Haze Makes on Visibility**

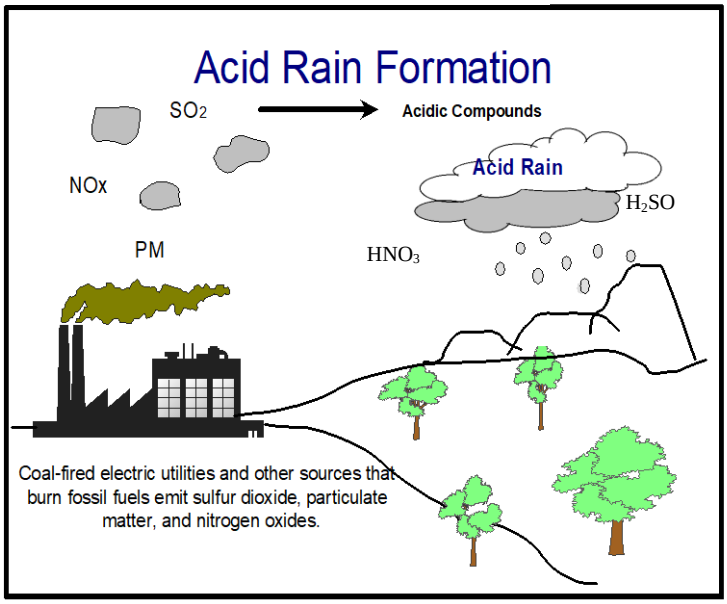



*Two photographs of Mt. Washington from the same location (camera angle slightly shifted), one on a clear day and one on a hazy day. The view of Mt. Washington on the right is completely obscured from about 17 miles away. Source: HazeCam.net, 2001*

## Acid Rain and Acid Deposition

In addition to their contribution to ozone and small particle formation, the air pollutants $SO_2$ and NOx also react to form sulfuric ($H_2SO_4$) and nitric ($HNO_3$) acid, creating acid deposition (or "acid rain") (see Figure 2.13). This acid deposition increases the acidity of New Hampshire's streams, ponds, and lakes, adversely affecting fish populations. It also strips nutrients from the soil, slowing growth of crops and trees. Trees stripped of nutrients fall susceptible to insect infestation, drought, freezing, and ozone damage. The acids also leach aluminum (Al) from soils and rocks and carry it into nearby water bodies where it can be toxic to fish. Excess deposition of nitrogen-containing compounds to coastal waters and estuaries can cause algal blooms leading to low levels of dissolved oxygen in the water, which ultimately can cause fish and shellfish kills.

**Figure 2.13 - How Acid Rain Forms**




*Acids are released directly into the atmosphere only in small amounts. The real source of most of the acids involved in acid rain and acid deposition is the acidification of $SO_2$ and NOx emissions. As these pollutants travel with the winds, they may oxidize into sulfuric acid and nitric acid within clouds where they will eventually pass to the ground and associated water resources through precipitation. Acids may also settle to the ground in the form of dry particles.*
*Source: NHDES, 1996*

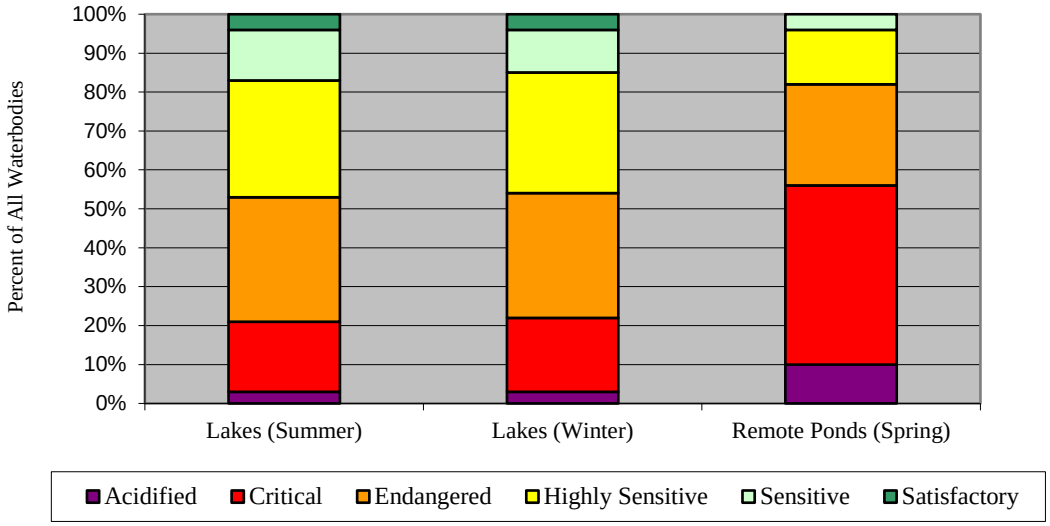
**Key Point:** Acid rain can fall up to and beyond 1,000 miles from where the acid-forming pollutants are released.

According to studies conducted by Hubbard Brook Research Station in Thornton, New Hampshire (Driscoll et al., 2001), acid deposition over the past 60 years has caused the acidity of the State's streams and lakes to reach critical levels. Under these conditions, native species of fish and plants can no longer thrive, and depletion of soil nutrients from acid leaching has threatened native species of white pine trees and forest productivity. In addition, the significant build-up of sulfates and nitrates in the soils throughout the region, much of which will continue to leach into nearby water bodies, causes substantial slowing of the recovery of the state's water ecosystems.

**Key Point:** Research at Hubbard Brook concludes that if all air pollution transport were stopped today and the acidity of precipitation was returned to normal, it would still take 20 years for the State's watersheds and forests to fully recover from the effects of acid deposition.

New Hampshire lakes are extremely vulnerable to acid deposition because their buffering capacity, which counteracts the effects of acid inputs, has been depleted due to decades of acid deposition. The buffering capacity of a water body, measured as Acid Neutralizing Capacity (ANC), is its ability to neutralize acid inputs without becoming more acidic. This capacity is determined primarily by the amount of calcium carbonate or other carbonates (e.g., limestone) in the system. New Hampshire's granite bedrock contributes few of these carbonate minerals to surface waters. A water body with either an ANC value of zero or less, or a pH below 5.0, denotes acidification. The lower the pH value is, the more acidic the water body. Acidified lakes are unlikely to support a naturally reproducing population of fish. An ANC of 10 or less is considered to be highly sensitive to acid inputs. Fully 85 percent of the State's lakes and 95 percent of the remote – mostly high-elevation – ponds are highly sensitive or worse (see Figure 2.14).

**Figure 2.14 - Acid Neutralizing Capacity Classifications of New Hampshire Lakes & Remote**

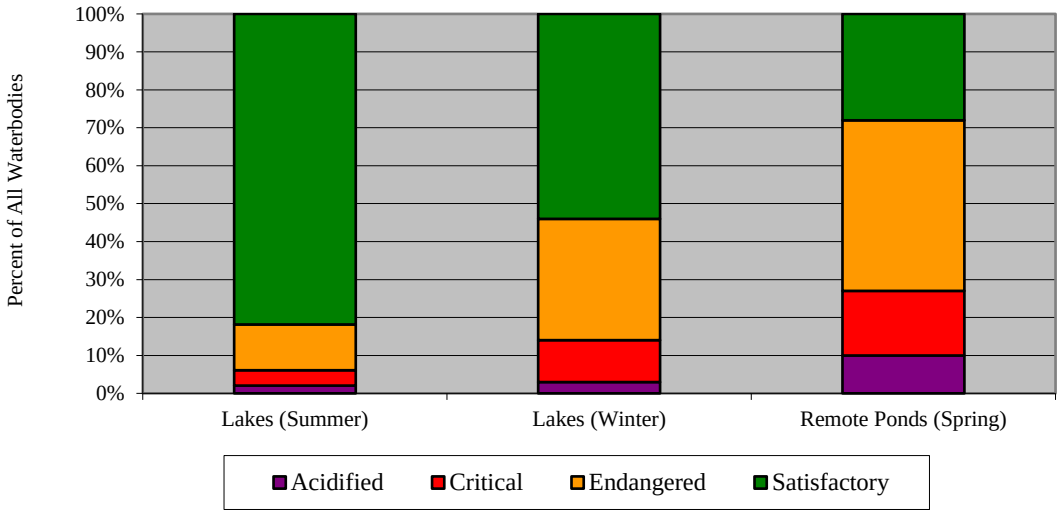



**Ponds**

*Source: NHDES, 2004*

There are some significant differences in the acidity status of lakes and ponds between summer and winter (see Figure 2.15). During the summertime, the pH of waters may be artificially elevated (less acidic) due to photosynthesis. As a result, winter pH data is a better indicator of the pH that aquatic organisms are exposed to during the year. About 20 percent of the state's lakes in the summer – but about 45 percent in the winter – have pH values of 6 or less. Remote ponds sampled in the spring after the snowmelt period indicates that over 70 percent are endangered or worse.

**Figure 2.15 - Acidity Classifications of New Hampshire Lakes and Remote Ponds (based on pH Level)**



*Source: NHDES, 2004*

The effects of acid deposition can be especially harmful in the spring when the winter snow pack melts. The ecosystem is shocked with a large volume of water carrying several months' accumulation of deposited acids and toxic metals like mercury. Further, this toxic shock occurs during the critical first phases of the annual reproductive cycles of plants, animals, and fish. The New Hampshire Fish and Game Department stocks a number of remote ponds with brook trout after the spring snowmelt. Many of these ponds would probably not support a naturally reproducing brook trout population because of the exposure of the developing embryos to the springtime acid shock. In fact, some ponds are no longer stocked by the New Hampshire Fish and Game Department because of poor fish survival or poor returns (e.g., Cone Pond in Thornton and Constance Lake in Piermont).

New Hampshire's acidified lakes and remote ponds, based on ANC and pH level, are listed by name and location in Table 2.1. As this table shows, all geographical areas of New Hampshire have acidified water bodies, indicating that all New Hampshire water bodies are vulnerable to the effects of acid deposition.

**Table 2.1 - Acidified Lakes and Remote Ponds in New Hampshire**

| Lake/Pond | Location | ANC | pH |
|---|---|---|---|
| Baker Pond | Chesterfield | 0.0 | 5.2 |
| Barrett Pond | Washington | 0.0 | 5.3 |
| Bear Hill Pond | Allenstown | -1.3 | 4.5 |
| Bowker Pond | Fitzwilliam | -0.3 | 4.8 |
| Brackett Pond | Wentworth | -0.8 | 4.7 |
| Cone Pond | Thornton | -1.0 | 4.7 |
| Constance Lake | Piermont | -0.2 | 4.9 |
| Darrah Pond | Litchfield | -1.3 | 4.5 |
| Divol Pond | Rindge | -1.2 | 4.6 |
| Four Mile Pond | Dix's Grant | -0.2 | 5.1 |
| Gordon Pond | Lincoln | -0.8 | 4.6 |
| Kilburn Pond | Winchester | -1.3 | 4.5 |
| Kinsman Pond | Lincoln | -1.9 | 4.5 |
| Lily Pond | Alstead | -0.2 | 5.0 |
| Long Pond | Lempster | -0.1 | 5.3 |
| Loon Pond | Lincoln | -1.0 | 4.8 |
| Lovewell Pond | Nashua | -3.0 | 4.3 |
| Nancy Pond | Livermore | -0.8 | 4.7 |
| Pisgah Reservoir | Winchester | 0.0 | 4.4 |
| Signal Pond | Errol | -0.6 | 4.9 |
| Solitude Lake | Newbury | -0.3 | 4.9 |
| Spruce Pond | Deerfield | -0.3 | 4.8 |
| Willey Pond, Big | Strafford | -0.7 | 4.7 |
| Willey Pond, Little | Strafford | -1.0 | 4.6 |
| Winkley Pond | Barrington | -0.2 | 5.1 |

*Source: NHDES, 2004*

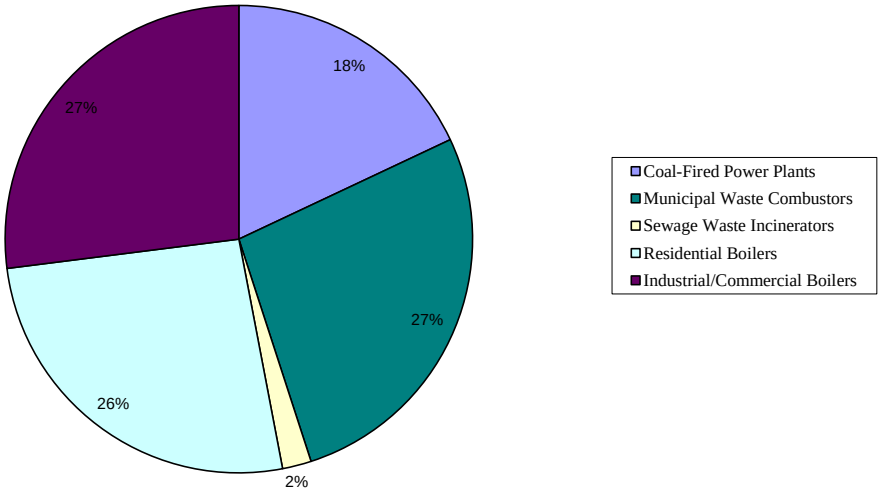
## Mercury

Mercury emissions and their fate in the environment are a major concern that has emerged over the last decade. Mercury is a highly toxic pollutant that has been linked to many health effects, including neurological and developmental problems, cancer, and endocrine disruption in fish, wildlife, and humans. Once mercury is ingested by humans, it is readily distributed throughout the body, including the brain, and is passed through the placenta to a developing fetus.

Mercury is usually emitted as a gas that is absorbed into clouds and is deposited (rained or snowed) onto nearby and distant areas, leading to mercury contamination. Coal burning sources and medical/municipal solid waste incinerators are the major sources of mercury emissions (see Figure 2.16). Nationally, mercury emissions follow similar patterns to those of $SO_2$ emissions in that coal-fired power plants are a large contributor and the industrial Midwest has a high concentration of these sources (see Figure 2.17). In recent years, laws have been passed requiring pollution controls on

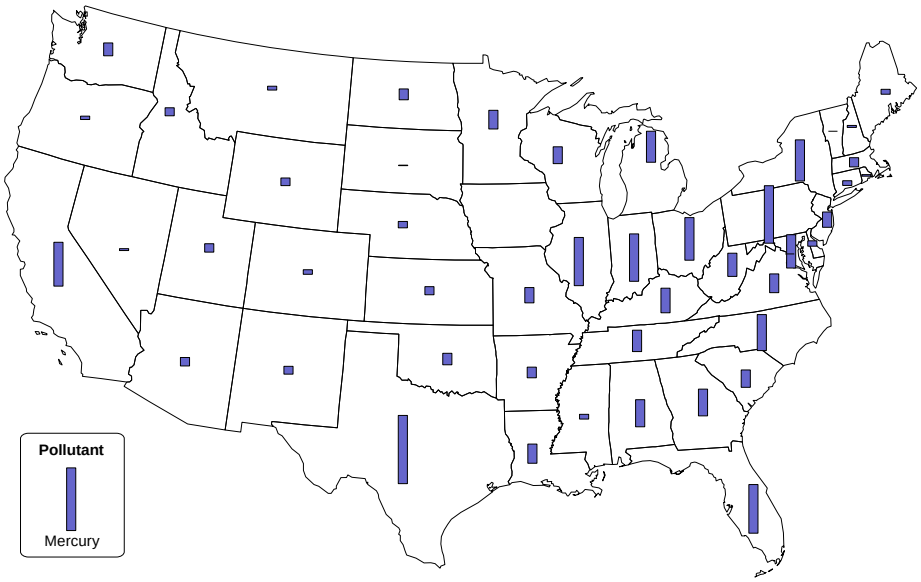
waste incinerators and most medical waste incinerators have closed, leaving fuel-burning sources as the primary source of mercury pollution in New Hampshire

**Figure 2.16 - New Hampshire Mercury Emissions by Source Sector - 2003**




*Note: Medical waste incinerator emissions are below 1%*
*Data Source: NHDES, 2003*

**Figure 2.17 - Total Mercury Emissions by State - 1996**




*The length of the bar represents the relative magnitude of emissions.*

*Data Source: EPA Clear Skies Act 2003 Website Technical Appendix A*

**Key Point:** Mercury deposition normally follows acid rain patterns, but it can also have effects on a global scale. Once mercury enters the environment, it can remain as an active toxin for over 10,000 years.

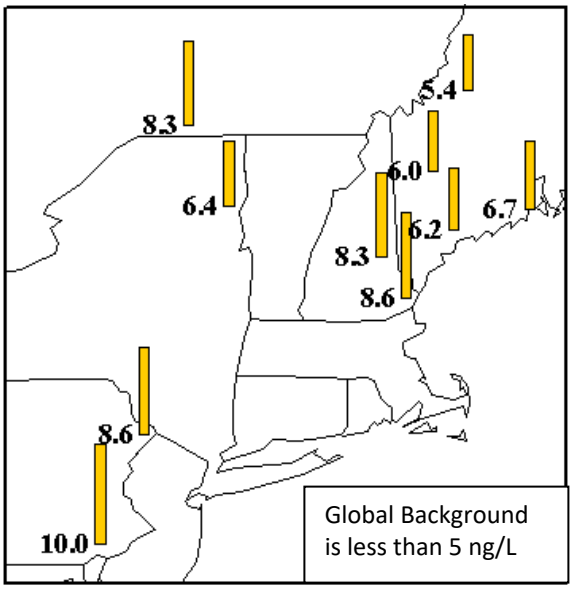
Mercury may be released into the atmosphere in (or chemically transformed into) three different forms. Elemental mercury $Hg_{(0)}$ has the longest atmospheric lifetime and transport range, and is commonly found in global mercury studies. Oxidized mercury $Hg_{(+2)}$ has an atmospheric lifetime on the order of hours, is commonly found to have local impacts near a major source, and is readily taken into the environment. Particle mercury $Hg_{(P)}$ is the third form and in the short-term is least readily absorbed into the environment. All forms of mercury are highly susceptible to being removed from the air through precipitation. Particle mercury is the most likely to deposit on the ground under dry conditions. The form of mercury produced by a given source depends on the fuel burned, the facility design, and emission controls applied.

**Key Point:** Any form of mercury deposited into a waterbody can be chemically transformed into methylmercury, a toxic form of mercury that readily enters the food chain.

Much of the health-related focus of mercury is on the contamination of certain foods, particularly fish. Fish eat the algae and plants that first take in mercury in the form of methyl mercury. Since large fish eat smaller fish, mercury consumed by the small fish accumulates in their organs and gets passed to the larger fish that consume them. Ultimately, when people, birds, or wildlife consume the fish, the mercury is passed along to them. Older fish normally contain the most mercury from a lifetime of "bioaccumulation." While the overall magnitude (or quantity) of mercury air pollution emissions is relatively small compared to other pollutants of concern, a small amount of mercury can do a large amount of damage as it accumulates in the food chain over the years.

In most of New England, regional and global mercury sources dominate mercury deposition, giving a fairly uniform distribution (see Figure 2.18). However, there are hot spots near certain sources of mercury, calling for the control of mercury at local levels as well. Figure 2.19 shows modeled mercury concentrations and clearly depicts these hot spots. In a recent study of the Florida Everglades (2003) where over 95 percent of environmental mercury originates from air pollution, sampling found localized hot spots of mercury, attributed to nearby sources. When mercury impacts locally it is usually under rainy conditions where mercury is "washed-out" of the air.

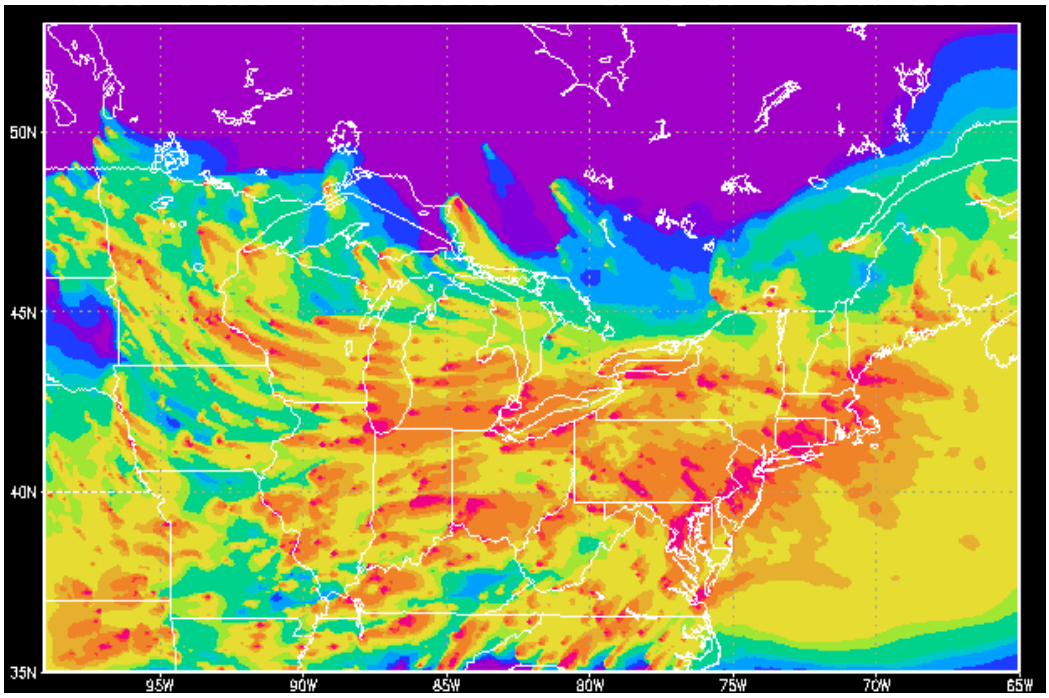
**Figure 2.18 - Annual Average Mercury Deposition (ng/L) (2000 – 2002)**




*Mercury concentrations from deposition are measured in nanograms per liter (ng/L). Concentrations can be highly variable from year to year depending on weather factors including wind direction and precipitation. Years of drought can have lower than average mercury deposition because mercury is preferentially removed from the air with precipitation. This map indicates the three most recent years of data collected in the region. The data for New Castle in Southeastern New Hampshire and Pike County in Northeastern Pennsylvania are based on two (2) years of most recent data available.*

*Data Source: National Acid Deposition Program/Mercury Deposition Network (2004)*

**Figure 2.19 - Modeled Mercury Deposition Across the Northeast United States and Canada**

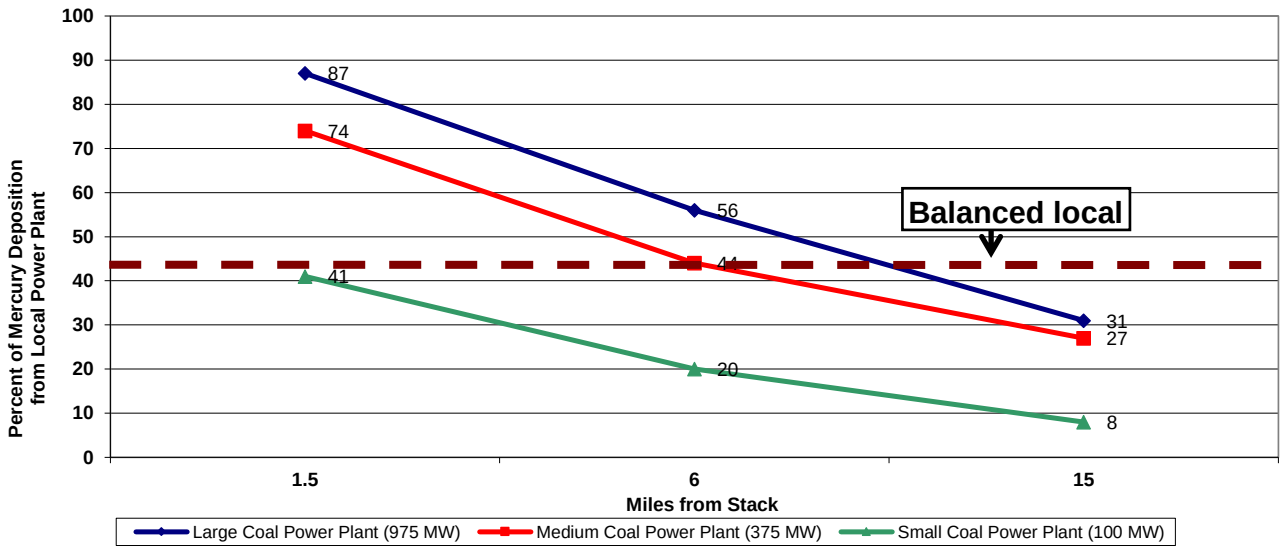



*Modeled deposition of mercury emitted from sources within the region over a 24-hour period on March 3, 2004. Dark reddish colors indicate relative hot spots of mercury deposition from nearby sources (local impact). The general yellow-orange color that*

*covers most of the region represents mercury deposition from long-range transport of mercury from many sources within the region.*
*Source: University Of Michigan Website*

An earlier study by EPA (1998) found similar results to the Florida Everglades study. The EPA study looked at mercury deposition in close proximity to coal-fired power plants in the "arid" West and "humid" East. The study found that there is a considerable hot spot of mercury deposition near coal burning power plants, with the largest sources creating the largest shadow of local effects (see Figure 2.20). Based on data collected from other studies, the majority of this local effect occurs under the most humid of conditions, especially during periods of precipitation.

**Figure 2.20 - Local and Regional Mercury Impacts from Coal-fired Power Plants**




*Local and regional mercury deposition impacts in close proximity to coal-fired power plants in the humid eastern United States. Curves show the highest mercury impacts occur near the source. Source: EPA 1998 Data/NHDES, 2004*

**Key Point:** Mercury can be deposited locally, but most of the time mercury is not immediately removed from the air pollution plume. Instead it ages and chemically transforms in the air until it enters a watershed.

## - SECTION 3 -
## HEALTH IMPLICATIONS OF OZONE AND SMALL PARTICLE POLLUTION AT LEVELS BELOW FEDERAL STANDARDS

**Key Point:** Ozone and small particles are called "zero-threshold" pollutants. This means they have proven health effects at levels below the current National Ambient Air Quality Standards (NAAQS), even at very low concentrations.

A recent study performed at Yale University (Pope et al., 2003) found that asthmatic children in Massachusetts and Connecticut suffered from asthma attacks, tightness of the chest, and shortness of breath at levels below the ozone standard. This study supports the findings of many other studies that negative health effects can be experienced when children are exposed to any level of ozone and/or small particle pollution ($PM_{2.5}$), even concentrations well below the NAAQS.

In the case of ozone, the Yale study found that for every 50 parts per billion increase in ozone levels, the likelihood of wheezing increased by 35 percent and chest tightness by 47 percent among asthmatic children on maintenance medication. A significant increase in shortness of breath and rescue medication use coincided with the highest levels of ozone recorded during the study period. These results support previous work suggesting that ozone, even at 40 percent below the level of the federal one-hour standard, is potentially hazardous to children with asthma. These levels are considered "good" by EPA's definition and it is often assumed that no adverse health effects occur at these ozone concentrations.

In response to the findings in many scientific studies, EPA promulgated new and more protective air quality standards in 1997 for both ozone and small particles ($PM_{2.5}$). In the case of ozone, a preponderance of research indicated that the health-based "one-hour" standard established in 1979 was not adequate enough to protect against prolonged exposures. A new "eight-hour" standard was established. For small particles, EPA established the $PM_{2.5}$ standard (in addition to the already existing $PM_{10}$ standard) as a result of scientific evidence which demonstrates that these smaller particles have the most adverse health effects because of their ability to settle in the deepest regions of the lungs.

***American Lung Association Report Rates N.H. Air Quality*** *– The American Lung Association releases an annual State of the Air report. As in previous years, the 2003 report gave Hillsborough and Rockingham counties failing grades for ozone air pollution. Cheshire and Merrimack Counties received a "C" for marginal air quality. Coos County includes the high elevations of the White Mountains, which receive large amounts of air pollution from out of state sources. According to the American Lung Association, over 400,000 people in New Hampshire are especially sensitive to air pollution. At least 206,000 live within the two failing counties alone, and at least another 68,000 sensitive individuals live in counties with marginal air quality.*

## - SECTION 4 -
## LOCAL AND TRANSPORTED AIR POLLUTION IMPACTS ON NEW HAMPSHIRE

Achieving clean air goals and attaining ambient air quality standards in New Hampshire requires looking at sources of air pollution, both locally and outside our borders. These sources and their impact on New Hampshire's air quality must be carefully and scientifically analyzed.

**Key Point:** In the mid-1990s, virtually all of the Northeastern states, including New Hampshire, demonstrated through modeling that they couldn't reach attainment of federal ozone standards by focusing only on local pollution controls. Even if the states turned-off all local sources of man-made air pollution within their boundaries, they would still have ozone nonattainment areas due to overwhelming air pollution transport.

NHDES has performed extensive regional modeling analyses of major air pollution episodes to assess the contribution of various sources to New Hampshire's air quality. The results of these scientific analyses used by NHDES and EPA show that transport from out-of-state pollution sources accounts for 92 percent to nearly 100 percent of New Hampshire's ozone and small particle air pollution when unhealthy air occurs in the state.

Despite this level of air pollution transport, federal laws hold New Hampshire accountable for achieving and maintaining clean air standards, even if the pollution originates outside of its boundaries. New Hampshire recognizes the need to enact these federally required local pollution reductions in order to keep the problem from getting worse for our own residents and for those living downwind. Local air pollution reductions ensure that hot spots of unhealthy air quality do not develop for our own citizens and that we don't send unhealthy air to our neighbors. By making reductions beyond federal requirements within the state, New Hampshire has demonstrated environmental leadership and has positioned itself to insist on similar reductions from upwind sources.

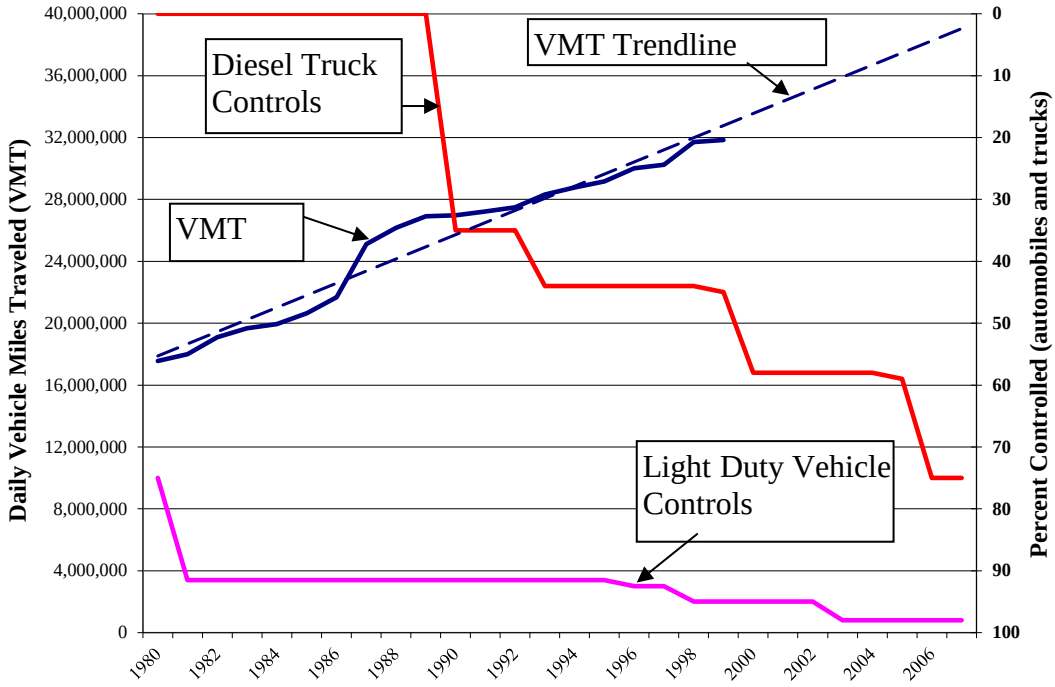
***Ozone Classification Areas*** *– Geographic regions are classified for ozone based on the federal standard according to a classification system established in the Clean Air Act Amendments of 1990. An area is designated as "nonattainment" if it is in violation of the standard. The "classification level" (severity) for the nonattainment area is based on the degree to which the standard was violated – the more severe the violation, the more severe the classification. Compliance deadlines are established in the Amendments dependent upon the classification – areas with more severe classification have later compliance deadlines. For example, the seacoast and southern areas of New Hampshire are classified as moderate nonattainment and are now required to demonstrate compliance by 2010. Unfortunately, following promulgation of the new eight-hour standard, subsequent litigation has significantly delayed implementation and compliance deadlines.*

A common argument used by upwind sources against controlling air pollution emissions to address transport is that individual sources cause only small amounts of impact beyond their local areas. But science is finding that even small contributions have negative health implications at the local level. Those implications get much worse as the small contributions are multiplied by the many, many sources making the same claim – and this pollution is transported to downwind areas.

Power plants in the Midwest, for example, have claimed that individually they are such a small part of Northeastern states' air pollution problems that they could shut down and the air quality in the Northeast would not improve. There are more than 15,000 power plants and industrial units which could make that claim. To avoid causing local air pollution problems, many of these sources have smoke stacks over 1,000 feet tall which help their pollution blow far downwind. This combined impact of over 15,000 sources causes air quality problems for states that are the furthest downwind – like New Hampshire.

Likewise, consider the impact of mobile sources. Emissions from cars, trucks, and buses (called mobile sources) contribute around 50 percent of NOx emissions and ten percent of $SO_2$ emissions nationally. Individually, new light duty vehicles are very clean compared to vehicles from 20 years ago. However, there are over 250 million vehicles on the road in the United States and Canada, and each vehicle currently averages around 16,500 miles per year. Thus, these relatively "clean" vehicles, when taken en masse, contribute a sizable share of air pollution in the Northeast and in upwind states, particularly along the heavily traveled I-95 corridor. Diesel vehicles are more of a problem because they are more polluting and many diesel trucks average over 100,000 miles per year. Overall, vehicle miles driven per year and vehicle size have been steadily increasing, counteracting much of the improvements made in vehicle emissions (see Figure 3.1).

**Figure 3.1 - Vehicle Miles Traveled (VMT) and Level of Pollution Control**




*Comparison of the growth of daily vehicle miles traveled with the increased pollution control on diesel trucks and light duty cars and trucks. Source: NHDES and EPA, 2004*

**Key Point:** The growth in vehicle miles traveled is negating a significant portion of the air pollution reductions achieved through increased emission controls.

Pollutants from mobile sources are released in the lowest levels of the atmosphere, but they typically mix upward and are carried to distant areas with only a little less efficiency than pollutants from sources with tall smoke stacks.

It is difficult to determine culpability for air pollution transport. When New Hampshire receives air pollution from long-range transport, it is not obvious which specific source or source sector – power plants, industries, mobile sources, and area sources – is responsible for it. When every source tries to individually argue its way out of its contribution to air pollution transport, it leaves no cure for the transport problem.

**Key Point:** Addressing the transport problem will require all parties, including government, industry, businesses and consumers, to recognize their contribution and accept responsibility.

## - SECTION 5 -
## DEFINING THE TRANSPORT PROBLEM

Air pollution transport is very complicated since pollutants are transported differently depending on a number of characteristics and factors. Air pollution transport typically refers to the advection of pollutants in the air over long distances, usually beyond the immediate source areas of about 10 to 20 miles (see Table 5.1). Numerous researchers are continuing to study air pollution chemistry and transport mechanisms in order to better understand this phenomenon.

***AIRMAP Project*** *– AIRMAP (Atmospheric Investigation, Regional Modeling, Analysis and Prediction) is a collaborative research project led by the University of New Hampshire and National Oceanic and Atmospheric Administration (NOAA) to obtain greater understanding of regional air quality, meteorology and climatic phenomena. AIRMAP research focuses on making scientific observations of the atmosphere, and the pollutants that travel in the atmosphere, in rural to semi-remote areas of New England.*

**Table 5.1 - Air Pollution Transport Characteristics**

| Category | Range | Pollutants Transported |
|---|---|---|
| **Local** | Less than 20-30 miles | Particles, sulfur dioxide, oxides of nitrogen, volatile organic gases (may contain toxic materials), carbon monoxide, mercury (some forms), ozone (in some cases) |
| **Regional** | 20-30 miles up to 1,000 miles | Ozone, small particles (may contain toxic materials), mercury (some forms) |
| **National** | 1,000 to 3,000 miles | Dioxin, very small particles (may contain toxic materials), mercury (some forms) |
| **Global** | Greater than 3,000 miles | CFC's (chlorofluorocarbons), mercury (some forms), carbon dioxide |

Much scientific information has been provided by the work of the Ozone Transport Assessment Group (OTAG). OTAG was created in 1995 as a temporary ad hoc group to perform modeling and scientific analyses to address the problem of air pollution transport in ozone nonattainment areas. OTAG consisted of representatives from 37 states (mostly east of the Mississippi River), several federal agencies, university researchers, and industries. OTAG and other transport research studies have developed the following general conclusions. Greater detail on air pollution transport mechanisms and confirming observations and assessments can be found in Technical Attachment A.

***Modeling Air Quality*** *- Air pollution researchers use information on air pollution chemistry and transport mechanisms to perform atmospheric modeling. Atmospheric models reproduce air pollution events and project future conditions in order to determine emission reduction strategies needed to achieve air quality standards.*

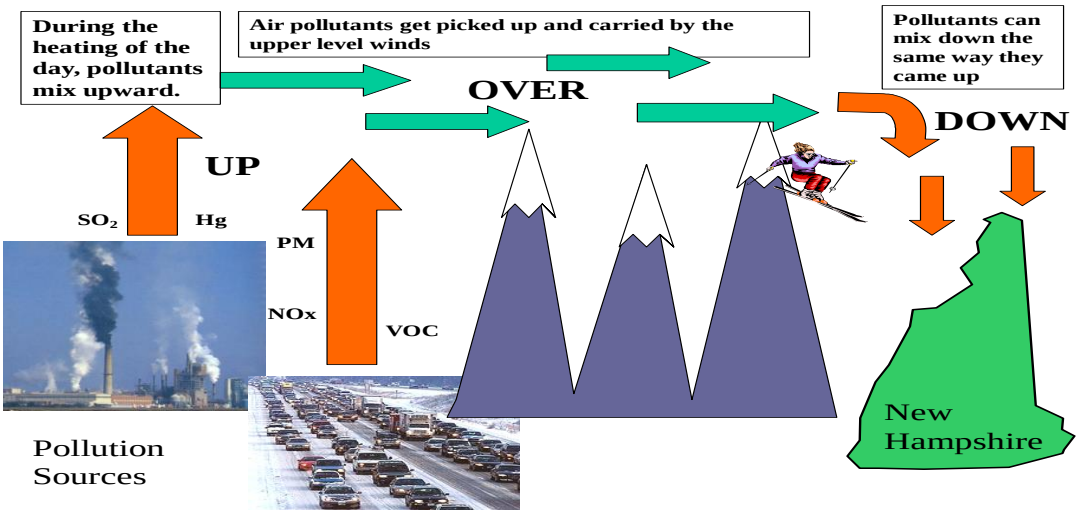
- Some pollutants such as acids, small particles, and ozone (and its precursors NOx and volatile organic gases) move with the wind and can survive in the atmosphere for several days, or even several weeks.
- Three major transport pathways (patterns) have been discovered and tracked by researchers involved with the North American Research Strategy for Tropospheric Ozone - Northeast (NARSTO/NE) analyses. These analyses involved observations taken by aircraft, tethered balloon, and mountain-top air pollution monitors. These pathways include:

  Low-Level (also called Near-Surface Flow): Most emissions are released near the ground in the lowest 600 feet of the atmosphere and move horizontally with surface-level winds. These winds swirl around objects such as buildings and trees. There are also vertical motions to these winds that can lift pollution to higher levels and can bring pollution down from higher levels.

  Mid-Level (also called Channeled Flow): Mid-elevation winds from about 600 to 2,500 feet above the ground usually follow terrain features such as mountain ridges and can move pollution fairly quickly across a region of several hundred miles. Power plants often release pollutants directly into this layer. Pollution in this layer mixes up and down. Researchers have recently discovered a mid- to low-level wind phenomenon called the "low-level jet" that often forms at night that can move pollution at high speeds northeastward along the eastern front range of the Appalachian Mountains.

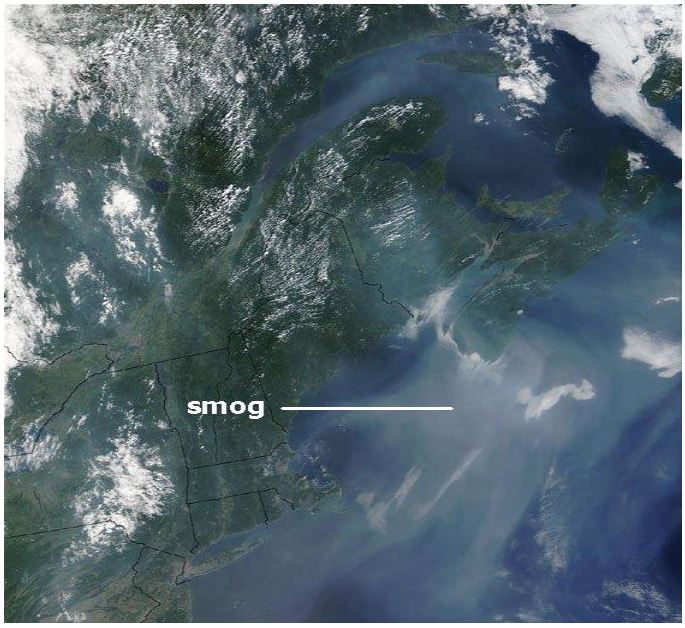
  High-Level (also called Synoptic Flow): Higher-elevation winds from around 2,500 to 7,000 feet above the ground follow large-scale weather features such as high and low pressure systems and cold and warm fronts. Pollution in this layer moves horizontally and mixes upward and downward to and from mid-levels during the heating of the day, often in great quantities. These systems can move pollutants at speeds of up to 100 miles per hour (see Figure 5.1).
- Ozone pollution transport may travel with the wind through all three different transport pathways for over 600 miles (see Figure 5.2).
- Pollution generally decreases in concentration as it moves away from its source. However, when there are many sources of similar pollutants and when conditions permit, there is a cumulative effect where the concentrations can actually build downwind.
- The most pervasive and persistent air pollutants are also the same pollutants that survive in the atmosphere long enough to transport across jurisdictional boundaries.
- Carbon monoxide (CO), sulfur dioxide ($SO_2$), large particles, and certain air toxics are typically highest in concentration in near proximity to their sources.

**Figure 5.1 - How Upper-Level Transport Works**




*Pollution transport should not be thought of only as a horizontal phenomenon. Pollutants can move upwards in the air and then travel downward in sinking air currents after being transported over great distances at elevations above 2,500 feet.*
*Source: NHDES, 2004*

**Figure 5.2 - Typical Widespread "Smog" Event in the Northeast**




*Satellite photograph shows a typical widespread "smog" (high concentrations of small particles and ozone) event throughout the Northeastern states and Canadian Maritime Provinces. Green indicates land, blue is water, bright white is clouds, and milky-white is from the sulfate particles within the smog.*
*Source: Sea WiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE, 2002*

From its research, OTAG made a range of emission reduction recommendations, based on a modeling strategy that approximated attainment in most areas with the one-hour version of the ozone standard. EPA used these recommendations in forming a "22-State NOx State Implementation Plan (SIP) Call" to help downwind states achieve the one-hour ozone air pollution standard. Attaining the new standards for ozone (eight-hour version) and $PM_{2.5}$, which are more protective than the previous standards, will require an even greater degree of emission reductions beyond what is already required under the older standards and recommended in the NOx SIP call.

Since OTAG's studies have clearly shown that air pollution can travel great distances across several state boundaries, it will take a program that also does not recognize such boundaries to successfully provide healthy air for all. Ignoring what crosses into and out of individual jurisdictions guarantees prolonged debate, uncertainty, and continued health and environmental degradation. New Hampshire and other Northeastern states have come to the conclusion that strong regional and national rules and/or legislation is the only fair way to rectify the transport problem and get upwind areas to take responsibility for the pollution that they create and send beyond their borders with the wind. The Northeastern states cannot succeed on their own in meeting certain air pollution standards with piecemeal efforts.

**Key Point:** Ozone, mercury, small particles, and the pollutants that cause acid rain and regional haze may and be transported very efficiently at higher levels of the atmosphere for hundreds to thousands of miles to downwind areas, like New Hampshire. Since these pollutants do not recognize state or other political boundaries, strong regional and national actions are necessary to get upwind areas to take responsibility for the pollution that they create and send beyond their borders with the wind.

## - SECTION 6 -
## THE ECONOMIC IMPACTS OF
## AIR POLLUTION TRANSPORT ON NEW HAMPSHIRE

The price of not acting regionally and nationally to address the transport of air pollution into New Hampshire comes in the form of negative direct and indirect economic impacts to the residents and businesses of the state. These economic impacts include increased costs for healthcare, reduced economic development due to increased costs of permitting and operating businesses in New Hampshire, and lost revenue from the travel and tourism industry.

Public health and economic well-being are influenced by many factors. Human health, for example, is influenced by genetics, environment, and social choices. These factors do not act individually, but collectively, resulting in compounded and often synergistic effects. Putting a price tag on any one of these factors is a complex process. Fortunately, recent research and scientific studies provide sufficient evidence to calculate the health-related costs associated with certain air pollutants.

Similarly, economic well-being is influenced by many factors, including air quality and the environment. Most economists agree that the United States cannot have a healthy economy without a healthy environment (Whitelaw, 2003). Protecting the natural resources of New Hampshire, including air quality, ensures that the state will remain a place for citizens and visitors alike to fully enjoy.

**Key Point:** Failing to have a healthy environment will ultimately reduce business opportunities, which in turn will reduce jobs, lower income and jeopardize the economic outlook of affected communities.

The following lists of potential impacts on healthcare, business and economic development, and travel and tourism are detailed in the sections below. Currently, research and data (as discussed below) are available to assign monetary values to the direct and indirect healthcare impacts. The economic impacts to businesses and tourism are discussed in qualitative terms, with no dollar amounts assigned, but the costs are expected to be considerable and are worthy of further research.

<u>Potential impacts of air pollution transport on health-related costs:</u>

- Increased mortality
- Increased emergency room asthma visits and asthma attacks
- Increased chronic and acute bronchitis
- Increased hospital admissions
- Increased upper and lower respiratory symptoms
- Increased cardiovascular symptoms and illnesses

- Increased health claims and health risks for all New Hampshire residents
- Possible decrease in resistance to disease, viruses, and bacterial infection

Potential impacts of air pollution transport on business costs, including tourism:

- Increased employee work days lost
- Increased employee minor restricted activity days
- Higher insurance costs due to higher claims
- Higher cost of electricity and fuels
- Added environmental remediation requirements for locations in poor air quality area
- Lost ability to attract new businesses and jobs due to environmental remediation requirement for locating in poor air quality area
- Reduced crop yields and loss of agricultural business
- Lost tourism and associated business loss

## Impacts on Health-Related Costs

NHDES has estimated direct health-related costs to air pollution transport of small particles and ozone based on analyses conducted by Abt Associates (October, 2000) and the Harvard School of Public Health (Levy et al., December, 2001). These analyses show that annual health-related value losses to New Hampshire approximating $790 million in 2007 would be attributable to adverse respiratory health effects due to small particle pollution ($PM_{2.5}$) transported into the state. Though the Abt Associates report projects cost estimates for only 2007, current cost estimates are expected to be similar. An additional $235 million per year are currently attributable to ozone air pollution transport for a total of over $1 billion annually. Accounting for the direct health-related values associated with all pollutants subject to transport (including mercury and other pollutants) would increase this total significantly, as would modeling indirect health-related costs. A breakdown of the various health-related costs and methodologies used for each of the pollutants is located in Technical Attachments B and C.

**Key Point:** Health-related cost impacts to New Hampshire from transported particle and ozone air pollution are expected to exceed $1 billion annually in the year 2007.

## Particle Pollution ($PM_{2.5}$)

NHDES used the Abt Associates (October, 2000) report to estimate health-related costs associated with air pollution transport of small particles ($PM_{2.5}$). Abt Associates conducted extensive modeling and analyses to quantify the health impacts

attributed to small particle air pollution relative to premature deaths, hospitalizations, emergency room visits, asthma attacks, and a variety of other respiratory symptoms.

Abt Associates developed a population-based exposure computer program called the Criteria Pollutant Air Modeling System to assess changes in human exposure due to modeled changes in air pollution concentrations. This model used inputs produced by an EPA accepted model for predicting airborne particle concentrations and apportioned the results according to county-level populations. Abt Associates developed health impact estimates for every state and major metropolitan area, including the New Hampshire/Boston Consolidated Metropolitan Statistical Area (CMSA). The model adjusts the results to avoid any double-counting of an individual case to multiple and redundant costs.

The valuation assessment (monetary value of each health impact in 1999 dollars) used by Abt Associates is based on a statistical evaluation to establish the mean of the population's willingness to pay (WTP) to avoid a given health result. The WTP is established based on reviews of associated published research. The methodology employed by Abt Associates was consistent with current and previous damage valuation work for EPA, and has been extensively reviewed by the EPA Science Advisory Board. NHDES does not attempt to debate the validity of the Abt and EPA methodology and data. Instead, NHDES uses this published work as-is as the means for estimating financial impacts to the state of New Hampshire.

The number of health effect incidences (i.e., number of deaths, hospital visits, number of cases, etc.) estimated by NHDES for New Hampshire for 2007 is based on extrapolations of the Abt Associates data to account for:

- New Hampshire's entire state population (New Hampshire's portion of the CMSA, which is 13.5% of the total New Hampshire/Boston CMSA, multiplied by a factor to account for the entire of the state).
- All sources of manmade $PM_{2.5}$ pollution (Abt Associates numbers are for power plant pollution only).
- The portion of New Hampshire's air pollution attributed to transport, 92 percent conservatively selected as the low end of the transport range for the entire state during modeled air pollution episodes.

The monetary value of each health incidence from Abt Associates valuation assessment expressed in 1999 dollars was then applied to New Hampshire's estimated incidence numbers to estimate the total value for each impact category. Table 6.1 presents the direct health-related costs due to air pollution transport of $PM_{2.5.}$ A detailed summary of this table and discussion of the calculations can be found in Technical Attachment B. In total, respiratory related healthcare costs resulting from transport of $PM_{2.5}$ air pollution amount to over $790 million per year. This cost estimate is largely driven by the cost of premature mortality.

The Abt Associates report reviewed the available literature on health valuations and arrived at values consistent with others who have attempted to calculate health impact costs. The estimates presented in Table 6.1 are substantiated by approximating New Hampshire's portion of EPA's $43 billion (2010) and $93 billion (2020) estimated benefits from reductions of $PM_{2.5}$ on a national basis under the federal Clear Skies Act of 2003 (see discussion in Section 7). Extrapolated $PM_{2.5}$ values for New Hampshire from the EPA analyses range from $1.07 to $1.17 billion in 2010 and from $1.16 to $1.26 billion in 2020. These values were estimated based on the ratio of predicted health outcomes for New Hampshire for mortality, chronic bronchitis, and emergency room/hospital admissions (123, 82, and 118 respectively) with those predicted on a national level (6,400, 3,900, 5,600 for 2010 and 11,900, 7,400, 10,400 for 2020).

**Table 6.1 - Health-Related Costs from Transport of Small Particle Pollution into New Hampshire**

| Health Impact Category | Estimated N.H. Incidences (Projected for 2007) | Monetary Value per Incidence (Abt Associates, 1999$) | N.H. Estimated Annual Health Valuations for 2007 (1999$) |
|---|---|---|---|
| **Premature deaths (Mortality)** | 123 | $6,120,000 | $753,470,000 |
| **Chronic bronchitis cases** | 82 | $331,000 | $27,110,000 |
| **Acute bronchitis** | 228 | $57 | $13,000 |
| **Hospital admissions** | 87 | $14,811 | $1,290,000 |
| **Emergency room asthma visits** | 31 | $298 | $9,000 |
| **Asthma attacks** | 1,947 | $40 | $106,000 |
| **Upper Respiratory Symptoms - URS** | 1,923 | $23 | $61,000 |
| **Lower Respiratory Symptoms – LRS** | 1,800 | $15 | $36,000 |
| **Work days lost** | 17,146 | $105 | $2,410,000 |
| **Minor restricted activity days** | 117,150 | $48 | $5,670,000 |
| **State Total** | | | **$790,170,000** |

The estimates presented above take into account measured $PM_{2.5}$ concentrations for a typical year. Another estimate of $664 million is arrived at using the modeling results as directly presented in the Abt Associates report, which were not

based on a typical year. This valuation is lower because it uses data and modeling for 1996, a year with lower than normal $PM_{2.5}$ concentrations across the northern portion of New Hampshire.

It should be noted that more recent research has demonstrated an increase in cardiovascular symptoms such as heart attacks due to small particle pollution. Extrapolating from EPA estimates in the Clear Skies Act analyses, NHDES estimates that 107 non-fatal heart attacks could be avoided per year in New Hampshire by significantly reducing small particle pollution. These costs were not included in the Abt Associates analysis and valuation factors were not readily available, thus are not included in this report.

**Key Point:** In determining the impacts associated with small particle pollution on health-related costs in New Hampshire, a picture begins to emerge from existing data as to their magnitude. One can see that the economic impacts from only small particle pollution transported into the state are significant.

**Ozone**

The link between ozone and its health effects is clear and well established in literature, and generally accepted by the scientific community. The costs associated with the health effects of ozone pollution are only now being realized. In a study conducted by the Harvard School of Public Health (Levy et al., December, 2001), health-related impacts due to ozone were isolated and estimated as being approximately $19.80 per person per part per billion (ppb) of ozone in the ambient air on an annual basis. The study valuation per incidence is done similarly for ozone as it is for small particles. The main difference is that research data are not as conclusive for some health conditions and thus those conditions were not included in the cost factor used in the Harvard study. Mortality, asthma, hospitalizations, and minor restricted activity day costs are included in the calculations. Hospitalizations for ozone-related conditions in the Harvard study were typically associated with acute bronchitis and cardiovascular outcomes, including ischemic heart disease, dysrhythmias, and heart failure. As with small particles, valuations are based on willingness to pay (WTP) estimates for each condition.

Building from the Harvard School of Public Health Study cost factor and estimating annual ozone levels throughout New Hampshire, NHDES conservatively estimates that transported ozone air pollution has a health-related value impact to the State of approximately $235 million per year. As shown in Table 6.2, this calculation is based on estimated annual manmade transport of ozone, county populations, and a value of $19.80 per person per part per billion. A more detailed summary of the calculations and a full explanation on the methodology used to determine the ozone concentrations is located in Technical Attachment C.

**Table 6.2 - Health-Related Costs from Transport of Ozone Pollution into New Hampshire**

| County/Monitor Location | Estimated Annual Ozone (ppb)[1] | Estimated Annual Manmade Transport (ppb)[2] | County Population (2000 census) | N.H. Estimated Annual Health Valuations for 2007 for Ozone[3] (1999$) |
|---|---|---|---|---|
| **Belknap / Laconia[4]** | 33.9 | 14.9 | 56,325 | $16,590,000 |
| **Carroll / Conway** | 27.5 | 8.4 | 43,666 | $7,240,000 |
| **Cheshire / Keene** | 25.6 | 7.1 | 73,825 | $10,360,000 |
| **Coos / Pittsburg** | 23.4 | 4.9 | 33,111 | $3,200,000 |
| **Grafton / Haverhill** | 27.8 | 9.3 | 81,743 | $15,040,000 |
| **Hillsborough / Nashua** | 27.3 | 10.4 | 380,841 | $78,630,000 |
| **Merrimack / Concord** | 22.0 | 5.3 | 136,225 | $14,240,000 |
| **Rockingham / Portsmouth[5]** | 27.8 | 10.6 | 277,359 | $58,070,000 |
| **Strafford / Rochester** | 28.3 | 11.2 | 112,233 | $24,810,000 |
| **Sullivan / Claremont[6]** | 27.0 | 8.5 | 40,458 | $6,780,000 |
| **State Totals** | | | **1,235,786** | **$234,970,000** |

[1] Estimated annual ozone averages including both manmade and naturally occurring ozone, based on monitoring data.

[2] Manmade portion of the annual ozone averages attributed to transport, based on location specific factors derived from photochemical modeling.

[3] Estimated health valuations based on $19.80 (Levy et al., December 2001) per person per part per billion of annual transported manmade ozone.

While indoor ozone levels (where people spend the majority of their day) are normally about one-half of the outdoor levels (range of 30 to 70 percent), the valuation process used in the Harvard report considers this actual exposure. Individuals spending more time outdoors would have greater risk, while those spending more time indoors with air conditioning or air filtration would have a lower risk of ozone related complications.

Since care was taken in the published studies to isolate the effects of $PM_{2.5}$ and ozone, it is highly likely that when taken together, ozone and $PM_{2.5}$ health-related impacts will exceed the sum of the individual components. In other words, exposure to both pollutants in the air at the same time will likely have greater synergistic health impacts and costs than exposure to the pollutants individually.

It is interesting to note that one of the studies used in the derivation of the ozone cost estimates considered annual ozone levels in six eastern cities which were lower than the levels measured and estimated for New Hampshire. In fact, those cities had annual ozone concentrations of 20 to 22 ppb (two cities had 28 ppb) during a relatively high ozone period from the late 1970s to the early 1990s. The New Hampshire measurements and estimates ranged from 22 to 34 ppb and were based on the recent and relatively low ozone period of 2000-2002. Impacts would be higher than the $235

million estimate if more applicable data were available to refine the cost factor for the range of ozone concentration found in New Hampshire.

In addition, observations made over the past few winters in the Northeast have shown ozone levels well above what were previously assumed for the colder weather. Wintertime health impacts of ozone could be compounded for certain sensitive populations, such as people with asthma, bronchitis, or other respiratory diseases. New Hampshire has measured higher than expected ozone levels during the cold weather, especially in the rural parts of the state. With higher than expected ozone and respiratory ailments that are common to cold weather could also increase the ozone health impact costs beyond the cost factor used in this report.

Likewise, indirect health-related costs such as lost workdays and increased health insurance claims are not included. If these costs were included, the Harvard study cost factor would increase and therefore the overall cost to New Hampshire would be higher.

**Key Point:** The $235 million cost for ozone related healthcare impacts is likely underestimated because the valuation factor is based on lower levels than occur exclusively in New Hampshire and on ozone levels monitored only during warm weather months. Recent observations demonstrate that exposure to ozone occurs year-round, compounding the health implications for sensitive populations and suggesting that overall healthcare impacts may be significantly more costly.

**Impacts on New Hampshire's Businesses and Tourism Industry**

Beyond increased employee work days lost and increased insurance claims that could increase insurance premiums paid by employers, there are added costs of doing business in areas that have unhealthy air quality. Higher operating costs result for certain businesses due to increased federal requirements and air pollution controls required for operation in dirty air regions (nonattainment areas). Obtaining national and regional pollution reductions makes a big difference in what local businesses must face in terms of emission controls and permit restrictions. If the air blowing into the state is already dirty, there is less room for local sources to release air emissions before the local air becomes unhealthy. In fact, there are already many instances when there is no room at all for local emissions because the incoming air is already unhealthy. This places a serious barrier on new businesses trying to locate in New Hampshire.

Many businesses in New Hampshire must work through strict environmental permitting rules and regulations and have to buy air pollution credits as a condition for obtaining an air operating permit. In addition, because of strict air pollution controls required of most power plants in the New England area, the cost of electricity is relatively higher in New Hampshire in relation to states with better air quality, increasing the electricity rates paid by businesses in the State.

State agricultural businesses have seen stunted growth and reduced crop yield as a result of ozone pollution and acid rain. Ozone has been shown to suppress the immunity of crops and other foliage to freeze and insect damage. Loggers supplying the state's paper mills have noted a decline in forest health and growth rate of timber supplies in the Northeast. Acid rain further extends the problem by leaching nutrients from soils, thus slowing forest growth, and in some cases, killing vegetation. If crop growth and forest health decline due to transport of air pollution, so too does revenue from related industries, such as farming, the maple sugar industry, and the timber industry (NHDES Clean Power Strategy, 2001).

Tourism is the second largest industry in New Hampshire, bringing in more than $8.6 billion annually to the economy and employing over 65,000 residents (N.H. Division of Travel and Tourism). The tourism industry includes hotels, restaurants, attractions, museums, art galleries, theaters, parks, and sports facilities.

People that support the tourism industry often come to New Hampshire for the "clean air" and beautiful mountains and lakes. Visitors may be less satisfied with their stay in New Hampshire if they encounter unhealthy air in the state's supposedly pristine areas. People may be less likely to return to New Hampshire for vacation or business purposes and they may stay for shorter periods of time. The end result is lost revenue and a decline in New Hampshire's tourism industry.

***Air Pollution in the White Mountains*** *- How does one account for the loss of not being able to see the other side of a lake or a nearby mountain because of haze? What are the costs associated with suffering from an ozone-induced burning sensation in the lungs from hiking in our White Mountains? Hikers in the high country don't expect reduced visibility and unhealthy air quality while hiking in the remote backcountry, but air pollution transport affects all areas of the northeastern United States and southeastern Canada, including New Hampshire's White Mountains. For example, the summit of Mt. Washington often records ozone levels comparable to the more populated areas in south central New Hampshire and the Boston Metropolitan area.*

## - SECTION 7 -
## ADDRESSING AIR POLLUTION TRANSPORT WITH MULTI-POLLUTANT CONTROL STRATEGIES

New Hampshire and the Northeast states have already worked together to implement a number of emission reduction programs within their boundaries in order to attain National Ambient Air Quality Standards (NAAQS) and provide healthy air quality. Even with these efforts, as described earlier, the only way the Northeast states will achieve their clean air goals is through aggressive national or near-national actions aimed at all major sectors of air pollution – power plants, industry, cars, trucks, distributed generators and various small engines such as boats, lawnmowers, and snowmobiles.

Relative to mobile sources, states must depend on EPA's regulatory programs to reduce mobile source pollution since the Clean Air Act prohibits all states, except for California, from establishing separate emission standards. EPA has passed or proposed regulations to address the mobile source sector. More stringent motor vehicle emissions and fuel standards went into effect beginning in 2004, which over time will reduce emissions from all light-duty vehicles, including minivans and sport utility vehicles, and require fuel with lower sulfur content. Additionally, there are pending and proposed regulations to reduce air pollution from heavy-duty diesel vehicles beginning in 2004 and 2007 and from non-road heavy-duty diesel sources such as construction equipment beginning in 2008. Unfortunately, EPA's regulatory programs for heavy-duty vehicles will not realize their full benefits for many years due to the durability of these types of engines and a slower fleet turnover rate. There also remains considerable uncertainty as to whether these plans will ever be fully implemented due to threats of legal action. With over 1.1 million registered vehicles in New Hampshire and steady growth in vehicle miles traveled, these federal emission control requirements for mobile sources are critical for meeting clean air goals.

***States are Limited*** *- States like New Hampshire have few options for significantly reducing mobile source emissions at a local level. States are already prevented from seeking cleaner vehicles and fuels than what is accepted on a national level unless they go as far as adopting "California level" emission control equipment (California is the only state allowed to set its own vehicle and engine emission levels and fuel needs). Further, state and local control options are being reduced due to a provision of a Fiscal Year 2004 VA-HUD appropriations bill which prohibits states from regulating non-road engines smaller than 50-horsepower. While seemingly small compared to power plants and other large industries, the small engines targeted for prohibition of state regulation include millions of lawnmowers, leaf blowers, and boat engines that produce a disproportionately large amount of air pollution.*

**Key Point:** With more vehicles on the road and steady growth in total miles driven both in New Hampshire and nationally, strong federal emission reduction requirements for motor vehicles are essential for meeting clean air goals.

Given the limitations on further controlling mobile sources beyond federal actions, much of the focus of current emission reduction regulations is on large industry, especially power plants. Several states are examining and adopting air pollution control strategies designed to simultaneously control electric generating units (EGUs) (i.e., power plants) for more than one pollutant. This concept is growing in popularity since emission reductions for several pollutants are required to achieve compliance with the new air quality standards for ozone and small particle pollution.

In early 2002, New Hampshire was the first state in the nation to pass legislation requiring fossil fuel-fired power plants to reduce emissions of four pollutants – sulfur dioxide ($SO_2$), nitrogen oxides (NOx), mercury (Hg), and carbon dioxide ($CO_2$). Connecticut, Massachusetts, and North Carolina have also developed legislation that requires large utilities to reduce their emissions of $SO_2$, NOx, mercury, and in some cases, $CO_2$. Congress and EPA are also reviewing multi-pollutant options which would be applied on a national scale.

Industry prefers regulations that control several pollutants simultaneously because they provide a more comprehensive, cost effective approach to planning for long-term facility layout and equipment requirements. In the past, regulations required industry to address one pollutant at a time. This, unfortunately, resulted in industry having to occasionally relocate or replace equipment that had been installed to control one pollutant with new equipment to control other pollutants, thus increasing compliance costs. In many cases, the industry would have chosen a different type of pollution control technology capable of controlling more than one pollutant if it had known that reductions of another pollutant were soon to be required. From the industry's perspective, the "one pollutant at a time" procedure lacks regulatory certainty and is ultimately more expensive than controlling multiple pollutants simultaneously.

**Key Point:** Effective national multi-pollutant legislation for electric generating units is critical to New Hampshire if the state expects to achieve consistently healthy air quality and avoid unnecessary and expensive pollution control measures required under federal law for areas with poor air quality.

The following three EGU multi-pollutant legislative proposals are currently under consideration in Congress. A fourth proposal, known as the Clean Air Interstate Rule (CAIR), formerly known as the Interstate Air Quality Rule (IAQR), was first introduced by EPA in late 2003. This rulemaking proposal is described later in this section.

- Clear Skies Act of 2003 (S. 485 & H.R. 999) – Proposed by President Bush and EPA, first introduced as legislation in 2002.
- Clean Air Planning Act of 2003 (S.843 & H.R. 3093) – Proposed by Senators Carper, Chafee, and Gregg, and Congressman Bass, first introduced in 2002.
- Clean Power Act of 2003 (S. 366 & H.R. 2042) – Proposed by Senators Jeffords and Reed in 2003.

Each of these legislative proposals is undergoing review and if successful, may be revised prior to implementation. The 2003 version of each proposal is the most recent available and is the version assessed in this report. A 2004 version of the Clear Skies Act has been proposed, providing some minor adjustments from the 2003 edition. All of the plans include reductions of $NO_x$, $SO_2$, and mercury while the Clean Air Planning Act and Clean Power Act also include reductions in carbon dioxide ($CO_2$), a greenhouse gas. Each of these multi-pollutant plans contains market-based legislation that allows trading of air pollution credits through a cap and trade program, which speeds the process of implementing reductions and reduces overall costs.

Each of the legislative proposals (including comparisons to earlier versions) has been evaluated by NHDES relative to the following criteria (see Table 7.1):

(1) Its impact on New Hampshire's air quality and ability to meet clean air goals, i.e., which pollutants will be reduced, by how much, and by when.

(2) The cost to implement control technologies and strategies to achieve emissions reductions called for in the proposal.

(3) The benefits in terms of healthcare costs savings and business benefits.

(4) Its impact on New Hampshire's ability to protect itself under the law from upwind polluters (referred to as "States' Rights").

Relative to the control costs associated with implementing the proposals, according to early estimates, the Clean Air Planning Act and Clean Power Act are only marginally more expensive to implement than the Clear Skies Act. Based on EPA's calculations for the costs and benefits of the Clear Skies Act, the additional control costs for any of these legislative proposals range between five to ten percent of the overall air pollution control costs already required under the existing federal Clean Air Act. More recent cost estimates conflict with earlier data and project a higher range of costs for the proposals. Unfortunately, this data has yet to be verified and accepted by researchers.

***What is a Cap and Trade Program?*** *Under a cap and trade program, a limit, or cap, is set for the emissions of a specific pollutant for all sources affected. The cap generally reflects a certain reduction of the pollutant from baseline conditions. Sources are given allowances – each allowance represents a measured amount of a specific pollutant – based on a limited number of allowances to meet the cap. At the end of each year, every source must have enough allowances to cover its emissions for that year. Unused allowances may be sold or saved for future use. This market-based approach allows sources to optimize their emission reduction strategies while ensuring achievement of the overall reduction goal. Even though not every source makes actual air pollution reductions, the end result of cap and trade is that it 1) speeds up overall air pollution emission reductions, 2) reduces the overall costs of compliance, and 3) can even reduce emissions beyond required levels.*

More important than the cost of control is the cost-benefit ratio between the costs of control and the resulting health benefits. Based on EPA cost-benefit calculations for the Clear Skies Act, the healthcare benefits and associated cost savings are worth in the range of $12 to $18 for every $1 spent on emission controls for the reduction levels proposed by the three multi-pollutant control acts, making pollution controls a good investment and any delay expensive (see Table B.3 in Technical Attachment B). Adding other qualitative economic benefits such as reduced mercury, acid rain, improved visibility, and improved business costs to downwind areas could as much as double this cost/benefit ratio.

**Key Point:** The healthcare benefits and associated costs savings realized by installing the pollution control technologies proposed in the multi-pollutant programs far outweigh the costs of the pollution control technology itself.

Of the three multi-pollutant EGU program proposals, the Clear Skies Act is the least beneficial to New Hampshire, providing virtually no ozone benefit by the federally required attainment date of 2010. The benefits to New Hampshire will be from reduced $PM_{2.5}$ transport, but the full benefits from the Clear Skies Act won't occur until 2020 and those benefits will only be a marginal improvement over what the existing Clean Air Act provisions already require. A more expeditious implementation timeline is needed for New Hampshire to meet its federally mandated clean air attainment dates, thus reducing impacts to the state's economy and public health sooner rather than later.

**Key Point:** The full benefits of the proposed Clear Skies Act will not be realized until 2020. This will be too late for New Hampshire to reach clean air goals by the required attainment date of 2010 and will only be a marginal improvement over what the existing Clean Air Act provisions require. Both the Clean Air Planning Act and Clean Power Act achieve greater reductions sooner.

Additionally, according to a recent modeling analysis study performed for the Ozone Transport Commission (OTC), the air pollution reductions and the associated health benefits of the Clear Skies Act may have been somewhat overstated. OTC is a multi-state organization created by Congress to address the ozone problem in the Mid-Atlantic and Northeast region of the United States. Its study found that a much larger percentage of the nation's population will live in areas that are expected to fail to achieve clean air goals for ozone by their federally mandated attainment dates than claimed after implementation of the Clear Skies Act. Since most of the areas failing to meet the clean air standards are downwind states, these areas will have to then focus on local control measures, which may be very costly and ineffective at producing any additional meaningful reduction benefits.

With the goal of building an emission reduction strategy that will help the states meet their federally mandated clean air goals by their scheduled attainment dates, the OTC calls for aggressive national measures on all major sectors of air pollution sources, not just power plants, but also industry, cars, trucks and other motor vehicles. Similarly, an analysis done by the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officers (STAPPA/ALAPCO), a national association of air pollution officials, resulted in a multi-pollutant resolution designed to reach clean air goals by the required dates.

**States' Rights**

Another concern about the Clear Skies Act for New Hampshire is related to the concept of "States' Rights." Ensuring the authority of the state to protect itself from the actions of the federal government or other state governments (or "States' Rights" as provided under the federal Clean Air Act) is of critical importance in order for New Hampshire to shield itself from harm done to it by polluters in other states. The Clear Skies Act substantially weakens the state's ability to prevent degradation of air quality within the state due to pollution transport from other states. In one Clear Skies Act provision, New Hampshire will be prevented from asserting its right to address upwind pollution by seeking legal assistance in obtaining needed pollution emission reductions from facilities in upwind states, even if those sources significantly contribute to New Hampshire's inability to meet federal air quality standards. As a result, the Clear Skies Act will actually increase the burden on New Hampshire by shifting the burden of air pollution control away from polluting regions to the regions suffering from its effects. Both the Clean Air Planning Act and the Clean Power Act provide better protection of States' Rights.

The philosophy in the Clear Skies Act behind limiting states legal recourse is to provide protection to businesses during the process of phasing-in their emission reductions required by the Act. However, areas downwind of these sources may already know that the planned pollution reductions are not enough. By restricting States' Rights, the Clear Skies Act prevents downwind areas from acting in any legal way to protect their own residents and businesses for a number of years. After the restricted time period expires, the downwind states would then face modified rules for filing legal action that include cost calculations that are so burdensome that few states, if any, would have the resources to effectively complete them. EPA would be equally strained in finding the resources to review them.

**Key Point:** Limitation of States' Rights effectively shifts the burden of air pollution regulation back to increasing local controls. As has been demonstrated, this is not effective in reaching overall clean air goals in areas dominated by air pollution transport, like New Hampshire.

In New Hampshire, local controls for highly transported air pollutants (such as ozone and $PM_{2.5}$) are somewhat effective in keeping local and downwind air quality from getting worse, but are ineffective as a sole strategy for reaching local clean air goals. Local controls within New Hampshire are most effective for air pollutants that are not dependent on chemical, thermal, or phase-change to become harmful (including carbon monoxide, $SO_2$, large particles, mercury and other numerous toxic air pollutants). Since the most cost effective local control measures have already been implemented in the Northeastern states for certain pollutants, any additional requirements would mean less cost effective and less desirable local controls.

Table 7.1 summarizes the three federally proposed Acts for controlling multiple pollutants. Included in the table are EPA's estimates of annual health-related benefits on a national basis in 1999 dollars for the reduction of ozone and small particles. The methodologies used by EPA for calculating benefits associated with each proposal are similar to those used in this report. Greater detail can be found in Technical Attachment D.

**Table 7.1 - Comparison of Federally Proposed EGU Multi-Pollutant Legislation**

| Proposal | Pollutants Final National Emission Caps (millions of tons per year) | Year for Implementing Final Cap | Impact on State's Rights | Estimated Annual National Benefit (1999$) |
|---|---|---|---|---|
| **Clear Skies Act of 2003 (S. 1844 & H.R. 999)** | NOx 1.7<br>$SO_2$ 3.0<br>Mercury 15<br>$CO_2$ None | 2018<br>2018<br>2018 | Major | $4.3 billion – 2010<br>$4.4 billion – 2015<br>$6.3 billion – 2020 |
| **Clean Air Planning Act of 2003 (Carper/Chafee/Gregg/Bass) (S. 843 & H.R. 3093)** | NOx 1.7<br>$SO_2$ 2.25<br>Mercury 10<br>*(plus 70% reduction at each facility)*<br>$CO_2$ 2001 levels | 2013<br>2016<br>2013<br><br>2013 | Minor | $5.6 billion – 2010<br>$8.7 billion – 2020<br>*Estimated based on CAPA 2002* |
| **Clean Power Act of 2003 (Jeffords/Reed) (S. 366 & H.R. 2042)** | NOx 1.51<br>$SO_2$ 2.25<br>Mercury 5<br>*(with unit-by-unit controls)*<br>$CO_2$ 2.05 billion tons | 2009<br>2009<br>2008<br><br>2009 | None | Not available |

*Source: NHDES, 2003*

## Cap and Trade Program and Mercury Considerations

Certain issues need to be considered when evaluating and implementing a cap and trade program. For example, as noted earlier, mercury can have local impacts, but it is also transported and deposited many miles from its source. The vast majority of the mercury pollution in New Hampshire comes in the form of rainfall contaminated with mercury from coal- burning sources. Therefore, the more stringent the control requirements for power plants on a nationwide and even global basis and the sooner they are implemented, the better off the residents of the state will be. Under a cap and trade program, NHDES estimates that a national cap of at most ten tons of mercury emitted by electric power plants per year and additional reductions from other source types are necessary to protect the health of the public from this very toxic pollutant. According to recent studies (e.g., Ozone Transport Commission), the control technology to reach this level is currently available, with additional options for control undergoing

field-testing. While cost effectiveness varies, some types of control equipment have the added benefit of simultaneously reducing the emissions of several pollutants.

**Key Point:** Applying a cap and trade system to implement mercury reduction requirements must be done with caution since mercury has both local impacts and is subject to long-range transport. In order to adequately protect public health and the environment from this toxic pollutant, each facility must reduce mercury levels to some degree and these reductions can be used for complying with a national mercury emissions cap.

Since there is a mercury hazard to areas near the source of mercury emissions, providing economic relief to sources controlling their pollution emissions through the application of a traditional market-based cap and trade system must be done with caution. Such an application would have to differ from how cap and trade is traditionally used for $SO_2$ and NOx. These pollutants do not have the same localized hazards because they are less likely to be "washed-out" in the nearby area like mercury. In time, these pollutants convert into acids or particles, a process that might cause the pollutants to travel hundreds to thousands of miles before they are removed from the air. $SO_2$ and NOx are normally in gaseous form near the source and are regulated as criteria pollutants through the National Ambient Air Quality Standards (NAAQS). While mercury is also regulated in New Hampshire in gaseous form under New Hampshire's Ambient Air Limits (AALs) for most sources, the AALs do not address local "washed out" deposition which is very hazardous to the environment. A cap and trade application for mercury should be focused on expediting facility-specific controls. In addition, most credits or allowances would have to expire upon full implementation of the final cap in order to ensure that every community benefits from local controls.

**EPA's Clean Air Interstate Rule and Mercury MACT Rule**

A fourth multi-pollutant proposal to regulate NOx and $SO_2$ was published by EPA in January of 2004, called the Clean Air Interstate Rule (CAIR), formerly known as the Interstate Air Quality Rule (IAQR). This rule replicates the proposed Clear Skies Act in many ways, including the approximate pollution reduction levels and general timelines for 29 states and the District of Columbia. It should be noted that the Clean Air Interstate Rule is an outgrowth of a formerly proposed air pollution transport rule that originally included non-power plant, industrial type pollution sources, along with the EGUs included in the current proposal. Because the rule works within the Clean Air Act and there are no new provisions to the contrary, it does not limit or replace any other provisions such as States' Rights.

The Clean Air Interstate Rule proposed by EPA cannot address mercury due to certain restrictions contained in the Clean Air Act. As a result, in January 2004, EPA simultaneously issued two proposed regulations that would limit mercury emissions

from coal-fired electric utility steam generating units: a proposed Maximum Achievable Control Technology (MACT) regulation and an alternative regulation that would establish a national mercury emissions cap and trade system.

EPA's simultaneous release of these two conflicting proposed mercury regulations has created considerable regulatory uncertainty and legal controversy, especially regarding EPA's preferred regulatory approach. Despite issuing the proposed MACT rule, EPA has stated its preference to withdraw its original regulatory finding that mercury is a hazardous air pollutant (HAP) and that MACT-based mercury emission controls for coal-fired electric utility steam generating units are appropriate and necessary. EPA would then not issue a final MACT standard for utility boilers. EPA would prefer to only issue the alternative regulation which allows for a national cap and trade program for mercury emissions from coal-fired electric utility steam generating units to achieve an overall 29 percent reduction of mercury emissions from coal-fired electric utility steam generating units by 2008 and a potential 70 percent reduction by 2018.

The proposed mercury MACT regulation requires electric utility steam generating units burning bituminous coal to meet a mercury emission limit (2.0 lbs/Trillion Btu) resulting in a 29 percent reduction by the end of 2007. The proposed MACT rule applies a phase-in of mercury controls through a market-based cap-and-trade program.

**Key Point:** In order to ensure that mercury reductions are effective both locally and nationally in reducing impacts, a mercury MACT program together with a national mercury emissions cap and trade system are necessary.

## - SECTION 8 -
## NEW SOURCE REVIEW AND ITS IMPACT ON AIR POLLUTION TRANSPORT

In the late 1980s, industry representatives reached an agreement with EPA and Congress that allowed the oldest power plants to avoid the installation and operation of expensive pollution controls as long as no major changes were made to improve them or extend their lifespan. Only basic maintenance was to be allowed under the agreement. When major repairs or upgrades were necessary, the owner could choose between making the improvements and adding the same pollution controls required of any large new facility, or retiring the plant from service. The goal was to let these old facilities operate under a "grandfathered" provision and avoid expensive controls while they complete their normal lifespan, at which time cleaner facilities would be constructed to replace their capacity. On the basis of this agreement, the New Source Review (NSR) requirements of the federal 1977 Clean Air Act Amendments were extended to apply to power plants under certain conditions when the Clean Air Act was amended in 1990.

Because NSR requirements affect power plants and other industrial sources, their implementation has a significant effect on air pollution transport. EPA is in the final phases of overhauling the NSR rule. While it is generally agreed that streamlining the rule would improve compliance, determining how to improve the rule has been a point of contention. After a detailed review of the changes being made by EPA, NHDES finds that some of the proposed changes create too many loopholes that defeat the Congressional intent of the program. In addition, many of the revisions increase, rather than reduce, the complexity of the rules. New Hampshire has challenged EPA's NSR revisions in court. A "stay" was recently granted on the most harmful of the revisions, the "routine maintenance" exemption, which is described below.

***What is "New Source Review?"***

*The New Source Review program, a provision in the federal Clean Air Act, covers the construction of new major power plants and industrial facilities and existing large facilities that make major modifications which result in a significant increase in air pollution. The program requires that new large facilities, including power plants, and major modifications to existing large facilities, obtain a permit before construction, which will be issued only if the new facility or major modification includes pollution control measures that reflect best available control technology or lowest achievable emission rate technology.*

Revisions to NSR are further complicated by the fact that several years ago, EPA and several states, including New Hampshire, filed a lawsuit against dozens of power plants to enforce the NSR provisions of the Clean Air Act. These facilities allegedly made major improvements to their equipment without first obtaining NSR permits and without installing the required pollution controls. Litigation by EPA and several states sought immediate review of these facilities and the prompt installation of pollution controls required under NSR. A number of settlements have resulted in large decreases

in emissions. EPA is now in the awkward position of creating a new rule that conflicts with its previous position and at least one court's view of the Clean Air Act. In a sense, EPA has prosecuted past NSR violations while simultaneously amending the rules to allow for future violations of those same rules.

EPA's proposed revision to the "routine maintenance" exemption would allow facilities to perform maintenance and upgrade projects worth up to 20 percent of the unit's monetary value without installing pollution controls. The changes could also allow an incremental overhaul of a facility with multiple projects, each accounting for 20 percent of the plant's value, so that the full facility could be replaced without reducing its emissions. EPA's earlier rule changes, which are currently in effect, would also allow facilities to make modifications based on the facility's highest levels emitted over the past ten years. If a facility has made emissions reductions in recent years, it would be allowed to return to higher emission levels.

A number of states, including New Hampshire, feel that these rule changes are extremely unfair to businesses that added the required pollution control equipment when they upgraded their facilities. New Hampshire and several other states filed appeals in a federal appeals court to halt the new NSR rules from going into effect. Fortunately, the court ruled that the routine maintenance NSR rule would cause irreparable harm to downwind states and stayed that rule before it went into effect. Older and dirtier power plants would be allowed to extend and increase operations instead of being required to upgrade with cleaner and more efficient technology or retire in favor of newer clean technology.

What does this mean for New Hampshire if the revision of the rules is ultimately successful? Very few New Hampshire facilities will benefit from the revised NSR. Those that do will likely lose any advantage gained under the revisions by incurring additional expenses required of businesses located in areas not meeting clean air standards. As discussed previously, when air pollution transport isn't addressed expeditiously, federal laws require that additional local pollution controls be implemented in any state with poor air quality. Because New Hampshire is overwhelmed by pollution transport, additional local pollution controls will be expensive and largely ineffective. New Hampshire counts on the reductions in upwind areas from the retirement of older, more polluting sources, or the addition of pollution controls on those sources, to lessen the transport of pollution over time.

**Key Point:** The New Source Review overhaul as proposed by EPA will allow older, dirtier facilities to continue to make major, life-extending improvements without installing pollution control equipment. The result will be continued unhealthy air quality for states like New Hampshire due to air pollution transport and increased requirements for local controls.

The NSR overhaul allows older and dirtier facilities to continue operating without additional controls. This defeats the program's goal of improving air quality and the economic business environment in downwind states like New Hampshire. The end result is continued higher costs for electricity, fuels, and cars, an economic disadvantage for new businesses locating in New Hampshire, and higher health impacts and associated costs. In short, the NSR changes will decrease the likelihood of better air quality in states like New Hampshire.

## - SECTION 9 -
## CONCLUSION

As the case for air pollution transport becomes more clearly defined and confirmed by scientific research, so do the effects on downwind states such as New Hampshire. Increasing scientific evidence shows that the health of the state's citizens and its environment are adversely impacted by long-range transport of air pollution from upwind sources. The economy of the State is significantly affected in terms of direct and indirect economic impacts to businesses and industry, including travel and tourism. Many businesses operating within the state will have to pay the costs of increased health care, decreased worker productivity resulting from air pollution-induced respiratory problems, and increased compliance with more stringent regulations as a result of unhealthy air.

While New Hampshire has made great strides in reducing air pollution from sources within the state, real progress toward cleaning the air cannot be made without the commitment of the federal government, governments of upwind states, and companies located in these states whose emissions directly impact New Hampshire. Though there has been resistance by both government and industry in regions upwind of the state to reduce emissions, the evidence is becoming clear that these emissions have a substantial health and economic impact on areas far downwind due to the phenomenon of air pollution transport.

At the same time that downwind states like New Hampshire are facing increasingly serious health and economic impacts from pollution transport, many federal regulations that are critical for achieving clean air goals are in jeopardy of being weakened. Revisions to the federal New Source Review program and proposals such as the Clean Air Interstate Rule and the Clear Skies Act do not adequately deal with transported air pollution and will leave downwind states such as New Hampshire with much of the burden of achieving clean air. Compared to states with similar populations, New Hampshire has already made more than its share of stationary source emission

reductions. Relative to mobile sources, further local pollution controls are limited by the Clean Air Act, which prevents states from requiring cleaner vehicles, fuels and small engines. The only truly effective option to ensure clean air in downwind areas is to limit pollution produced in the industrial states to our south and west. Meaningful federal legislation is the tool by which the goal of clean air for all people can be accomplished.

The failure of the federal government to adopt meaningful rules and the resistance of upwind polluters has resulted in several rounds of litigation. With new federal proposals such as the Clear Skies Act severely limiting legal recourse to address pollution transport, the ability of states to force upwind emissions reductions is greatly diminished. Without effective federal statutes and regulations, there would no longer be a means to limit upwind pollution and states such as New Hampshire would have to seek alternative means to address unhealthy air.

Rolling back State's Rights and delaying the installation of pollution controls, which will inevitably result from some of the proposed legislation, would only add to the costs which downwind states must bear. Analysis has shown that the current regulatory system results in costs to New Hampshire exceeding $1 billion annually solely from the health-related impacts of transported air pollution. This number does not account for non-health-related costs to the state and its residents as a result of increased cost of doing business and lost revenue from tourism. It also does not address lost opportunities for attracting new companies to the state because of comparatively strict pollution control regulations federally required for areas of poor air quality.

Quality of life in New Hampshire is clearly being impacted by air pollution transported into the region from urban areas to the south of New Hampshire and large industrial sources in the Midwest. Unless meaningful legislation and regulations are adopted and effective emission controls are applied nationally, health impacts will increase, the costs borne by the people and businesses of the state will continue to rise, and overall quality of life will suffer.

# TECHNICAL ATTACHMENTS

# TECHNICAL ATTACHMENT A

## DETAILED TRANSPORT MECHANISMS

### 1.0 Introduction

***Definition:*** **Air Pollution Transport can be defined as the advection of pollutants in air over long distances, typically beyond the immediate source area of about 10 to 20 miles.**

The term "Transport" is most commonly applied to ozone, small particles ($PM_{2.5}$), mercury, and airborne acids and is used when these air pollutants cross jurisdictional boundaries such as state or international borders. Here are two key questions which are central to the issue of air pollution transport: How do we know that air pollution transport is real? How much of a problem is it?

Scientists have been studying air pollution transport for decades - initially in an attempt to address acid deposition problems in the northeastern United States. While preparing their ozone state implementation plans in the mid-1990s, most of the northeastern states found that they could not reach ozone attainment, even if they "turned off" all manmade pollution sources in their own states. Local controls were not getting the improvements needed. This drew the attention of the U.S. Environmental Protection Agency (USEPA), which called for further study that eventually lead to the creation of the Ozone Transport Assessment Group (OTAG).

### 2.0 OTAG Assessments

OTAG was created to "identify and recommend a strategy to reduce transported ozone and its precursors which, in combination with other measures, will enable attainment and maintenance of the national ambient ozone standard in the OTAG region." (OTAG Final Recommendations, 1997). OTAG consisted of 37 states and hundreds of stakeholders, and it conducted the most comprehensive modeling and analysis of ozone transport performed to date.

The OTAG Air Quality Analysis Workgroup concluded that ozone transport may range from zero to over 500 miles, based on direct observations and statistical analyses correlating regional patterns with meteorological factors. The lower end of this range is more likely to be observed in the southern portion of the OTAG modeling domain (the Southern Atlantic and Gulf Coast states), and the higher end of the range is much more common between the Midwest and the northeastern states where the west to east winds are stronger. OTAG modeling results, particularly subregional modeling, supported this scale of transport and showed that emissions in some subregions of the domain, particularly in the Midwest, affect ozone concentrations far downwind in many other areas of the domain.

The Urban Airshed Model (UAM-V) used for the OTAG analyses has been shown to under-predict ozone transport, thus the actual upper end of the range of transport is likely to be somewhat greater than 500 miles and the concentrations of transported ozone are likely to be somewhat higher than the modeling shows.

The OTAG assessments clearly confirmed the existence and significance of ozone transport within the OTAG domain, especially within the Northeast. The OTAG Policy Group (OTAG Final Recommendations, 1997) concluded: "Air quality data documents the widespread and pervasive nature of ozone and indicates transport of ozone. Air quality analyses also indicate that ozone aloft is carried over and transported from one day to the next. Generally, the range of transport is longer in the North than in the South."

The OTAG Policy Group reached these conclusions only after a thorough analysis of monitoring station data, weather patterns, and extensive modeling using "state-of-the-science" models. OTAG also used quality assured databases for simulating the physical and chemical processes involved in the formation and transport of ozone and precursor species over multi-day episodes on regional scales. In short, "the OTAG modeling system provides the most complete, scientifically-credible tools and data available for the assessment of interstate transport." (USEPA Staff Report, 1997).

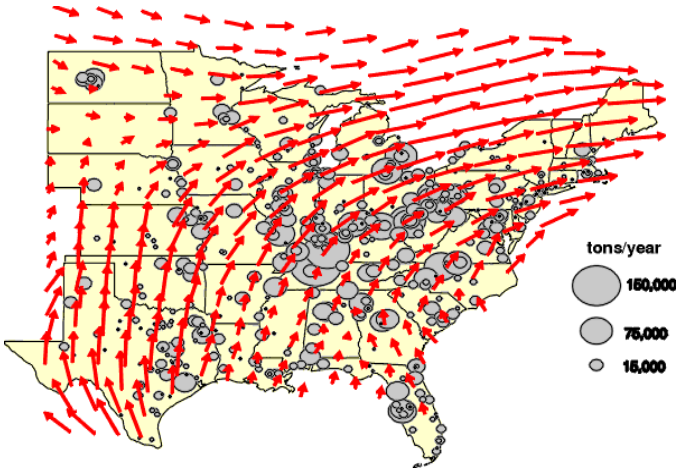
A NESCAUM report on OTAG and air pollution transport (NESCAUM, 1997) concluded the following:

i. Long range transport exists and has been clearly documented in the eastern United States.
ii. Aircraft flights have measured elevated transported ozone readings at night.
iii. Transported ozone from aloft mixes downward to ground level during the morning hours. Downward mixing may occur far downwind of the source regions.
iv. During high ozone events, wind flow (i.e., pollutant transport) patterns over the northern United States are highly aligned from the Midwest to the Northeast.
v. Ozone production on a regional basis is limited by NOx emissions.
vi. NOx emissions from the industrial Midwest are vastly greater than those from the Northeast, a disparity that will increase as the Northeast continues to reduce emissions under the OTC NOx Memorandum of Understanding (MOU).
(OTAG 1990 inventory data for generating facilities in OTAG Subregions 1-7 shows that New Hampshire emissions comprise less than 1% of the total emissions, and that emissions in the entire OTR comprise only about 29% of the total emissions).
vii. Back trajectory analyses of airmass movements for the most severe ozone days in the eastern United States indicate that pollution was transported to the Northeast from the industrial Midwest. Similar trajectory analyses done for clean air days in the Northeast show airmasses originating in Canada.

viii. Computer modeling performed by OTAG is consistent with measured ozone levels and back trajectory analyses in showing significant impact from transported ozone from the industrial Midwest into the Northeast.

ix. Cost effective NOx reductions can be readily made in the industrial Midwest and these reductions would be especially beneficial to the Northeast.

**Figure A.1 - Wind Patterns on High Ozone Days in the Northeast**




*Arrows show air flow when high ozone levels are present in the Northeast. Also shown are locations and NOx emissions of electric generating plants.*

*Source: NESCAUM*

## 3.0 Transport Mechanisms

Ozone transport may range from 150 to more than 600 miles in the Northeast, based on direct observations and statistical analyses of regional patterns. For example, multiple analyses of weather patterns, wind speeds and directions, and ozone concentrations suggest statistically significant correlations between upwind and receptor areas 1000 or more kilometers apart; back trajectories calculated from receptor sites in the Northeast during high ozone episodes frequently show aloft airmass travel of 800 to 1000 km in a 24 hour period (Poirot and Wishinski, 1996; Husar and Renard, 1996; and Porter, et al., 1996).

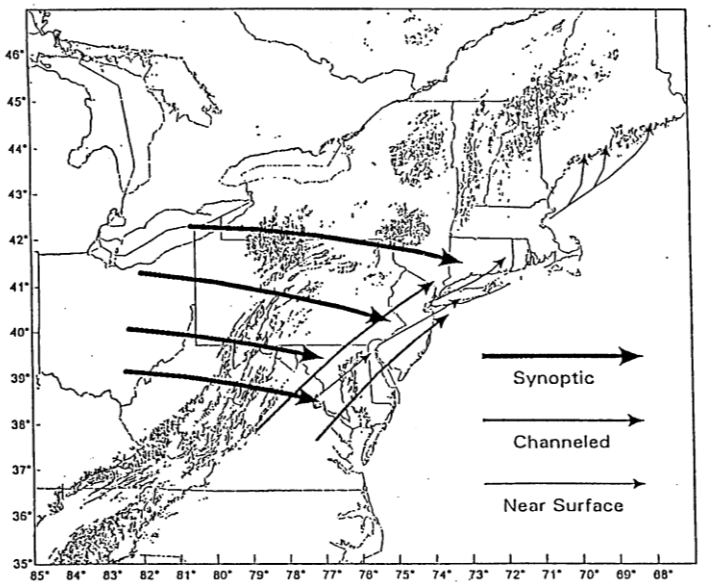
The predominant transport patterns in the Northeast were observed and documented in a study conducted by the North American Research Strategy for Tropospheric Ozone - Northeast (NARSTO/NE) entitled "Initial Results on Transport and Mixing Based on NARSTO-Northeast Data," and dated January 28, 1997. This study identified three basic flow regimes: synoptic, channeled, and near surface.

- The S*ynoptic flow* is the pattern of airflow at higher elevations (above 2600 feet). Synoptic flows are unaffected by large-scale frictional ground level objects such as mountains, valleys, and lakes.
- *Channeled flows* occur at lower elevations (650 to 2600 feet) where synoptic flow patterns are interrupted by large objects such as mountains, hills, and valleys but are not affected by lower, smaller objects such as trees and buildings.

- *Near-surface flows* (below 650 feet) are affected by nearly all surface frictional objects including trees and buildings.

Synoptic flows are generally from west to east, transporting pollution from the Midwest to the Northeast, while channeled flows generally follow the Appalachian Mountains from southwest to northeast, transporting pollution from the Northeast urban corridor toward northern New England.

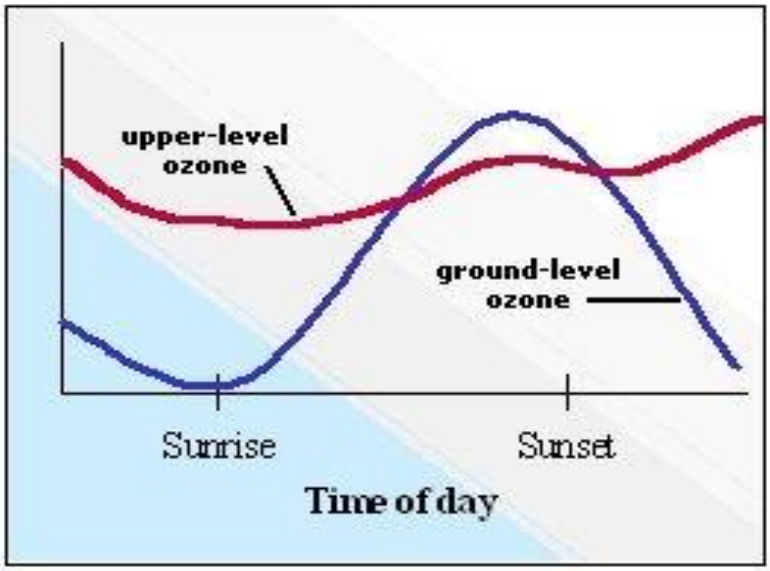
**Figure A.2 - Major Transport Regimes in the Northeast**




*Different types of wind flows common during ozone events.* *Source: NARSTO-Northeast*

Absent transport, ground-level ozone concentrations increase during sunlight hours as a result of photochemical production and decrease substantially at night when ozone removal exceeds production (also known as diurnal variation or fluctuations within the daily cycle). However, in areas such as New Hampshire which are downwind of large urban regions, ozone concentrations often rise through the evening and/or early morning hours and peak between 6:00 p.m. and 6:00 a.m. due to transport from upwind sources. At higher elevations, concentrations of ozone and ozone precursors may remain high at night, since there is minimal downward mixing of the atmospheric transport layers at night. During daylight hours when solar energy heats the ground, the resulting warm air near the ground begins to rise. Rising air creates an unstable atmospheric situation resulting in the upward and downward mixing of air masses (including ozone transport layers). Thus ground level ozone concentrations typically rise for several hours immediately after sunrise.

**Figure A.3 - Typical Day/Night Ozone Cycle at Ground Level and Aloft**




*Solar ultraviolet energy helps to create ozone which is present in high quantities late in the day. At night, there is no ultraviolet sunlight to create ozone and ground level objects and gases act to remove ozone, resulting in the curve in blue, which represents ozone at ground level. Ozone at higher elevations, conversely, is often not depleted at night and may remain at elevated concentrations throughout the day (red curve).*

**3.1 Confirming Observations and Measurements**

Episodes of elevated ozone in the New England region generally occur between June and August, during periods of persistent, generally southwesterly surface winds, widespread sunshine, and high temperatures. Typically, the associated meteorological patterns feature an area of high pressure to the south, often centered to the east of the Carolinas, which results in anticyclonic (clockwise) circulation over New England. A typical episode begins with elevated ozone levels in southwestern New England. By the second day, ozone levels rise in northern and eastern areas. Ozone levels on any given day tend to peak earliest in southwestern New England, and a pattern of sequentially ordered peaks often appears in northeastern New England where, the farther downwind a site is located, the later in the day peak ozone concentrations are reached. New Hampshire and Maine generally record their highest ozone levels in the late afternoon and evening, with high measured ozone levels occurring sequentially along a monitoring network from Massachusetts through northeastern Maine. In contrast, the monitors furthest to the northeast (Acadia National Park, for example) often record their highest ozone levels during the overnight hours.

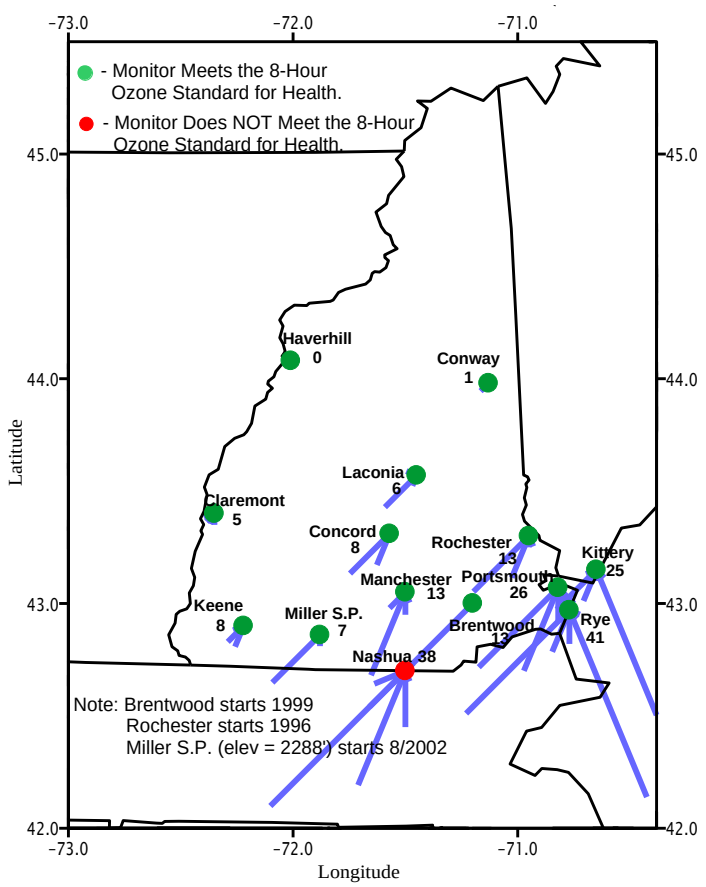
Observations collected by NARSTO-NE on July 14, 1995 confirmed elevated levels of ozone extending the length of the Northeast Corridor from Virginia to Maine during the early morning hours (Blumenthal et al., Feb. 1997). Ozone concentrations in excess of 70 ppb were found at an altitude of 1600 feet, and since these observations were made before the production of ozone had begun on that day, and given the relatively

high wind speeds demonstrated by back trajectories, it is apparent that this ozone had been transported into Maine and the Northeast corridor from a considerable distance overnight. This transport mechanism and distance is consistent with that observed by Clark and Ching (1983) in their observations of an ozone plume extending from northern Ohio to the western boundary of the Northeast Corridor over a 26-hour period.

Field measurements during ozone episodes in the late 1980s and early 1990s provide additional evidence of overnight transport via the Midwest to Northeast flow demonstrated by the OTAG analyses described in the previous section. During an episode of elevated ozone concentrations in July 1988, for example, early morning ozone concentrations ranging from 80 to 120 ppb were recorded at rural mountain top locations and at low elevation sites along the western and southern boundaries of the Ozone Transport Region (OTR), which covers most of the eastern United States. Because ozone does not begin to be produced until later in the morning, these measurements represented ozone that had survived from the previous day. Moreover, in light of the prevailing winds during this episode, these measurements demonstrate that high levels of ozone were transported into the OTR overnight from the West. Relatively small additional amounts of locally produced ozone would have been enough to push these areas over the standard during the day.

NHDES performed studies on what weather conditions have led-up to poor air days in the state. This study can be accessed on the State's website. Generally, the majority of the ozone transported into the state comes from the Northeast corridor (Washington, DC, Baltimore, Philadelphia, New York, and Boston regions). On certain days, the Boston area provides the greatest amount of ozone along the immediate New Hampshire seacoast. The non-New England portion of the corridor provides the majority of the ozone for the remainder of New Hampshire. Air pollution contributions from the Midwest are significant and on some days provide the vast majority of pollution reaching New Hampshire. New Hampshire has its worst air pollution days when low-elevation winds come from the cities to our southwest (Northeast Corridor) and mid-elevation winds come from the Midwest. The haziest days occur when there is a slow airflow from the Midwest. Based on NHDES forecasting expertise and experience, these hazy days correspond to days with high $PM_{2.5}$ concentrations.

**Figure A.4 - Number of 8-Hour Ozone Events Exceeding 85 ppb and Corresponding Wind Direction (1995 – 2002)**



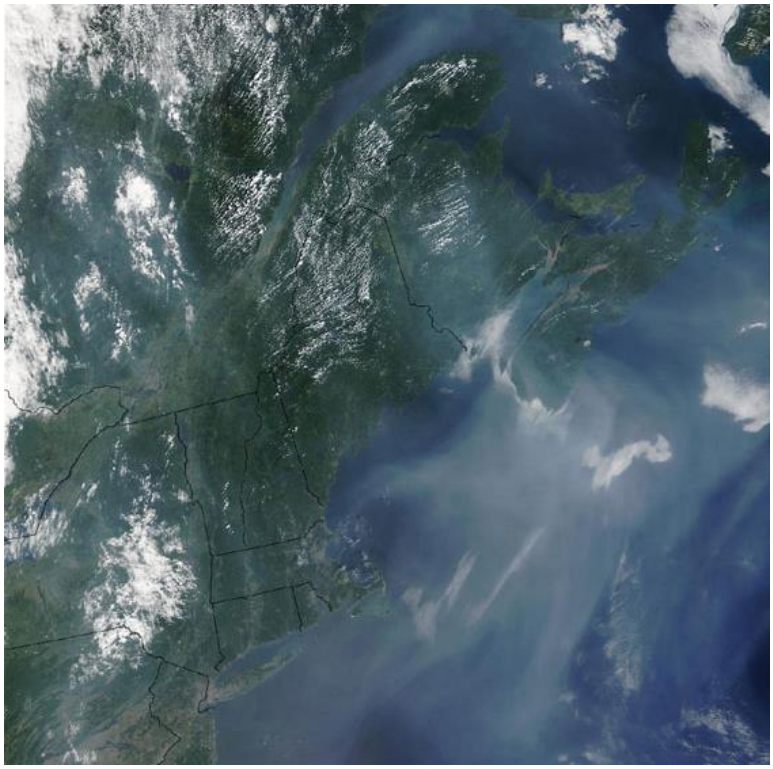

*Wind directions at the time unhealthy ozone levels were measured in New Hampshire between 1995 and 2002. There is an overwhelming trend of winds coming into the state from the southwest, with the exception of the seacoast area which also suffers from a seabreeze that brings pollution from the Boston metro area to coastline communities. (Numbers indicate the number of unhealthy days.)*

*Source: NHDES*

On a November 4, 2003 flight over the Ohio River Valley, an NHDES official observed a visible smoke stack plume extending over 60 miles without any signs of breaking up. While a visible plume of over 60 miles is somewhat unusual, it does demonstrate how easily the invisible components of air pollution can travel with the wind. Normally a visible plume is bright white and largely caused by condensed water vapor. The water vapor normally evaporates and becomes invisible after traveling a handful of miles downwind. The visible plume seen over the Ohio River Valley started bright white, but quickly became a milky and bluish white, normally caused by very high levels of sulfur dioxide ($SO_2$) and particles.

The following satellite photos capture the widespread nature of some air pollution events. Such events are not caused by a single smoke stack, instead they are more dependent on many sources acting together to create the effect. Satellites commonly capture the smoke plumes caused by forest fires and volcanoes, and occasionally can detect broad areas of elevated pollution concentrations.

**Figures A.5 and A.6 - Satellite Views of Widespread Smog Events in the Northeast**



*Satellite photograph of widespread smog event throughout the Northeastern states and Canadian Maritime Provinces. Green indicates land, blue is water, bright white is clouds, and milky-white is smog.*

*Source: Sea WiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE*

*Satellite photograph for June 24, 2003 of another widespread smog event throughout the Midwest, Northeast and Canadian Maritime Provinces. Green indicates land, blue is water, bright white is clouds, and milky-white is smog*.

*Source: Sea WiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE*

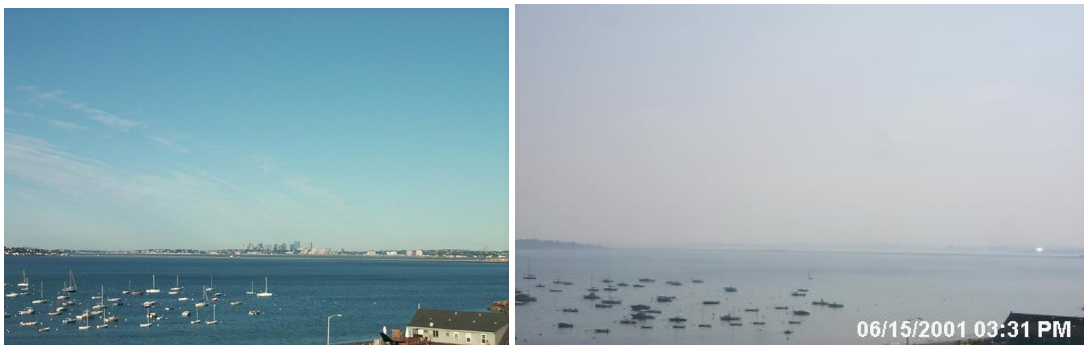
**Figure A.7 - Satellite View of the Mt. Etna Volcano Eruption**

*Satellite photograph of July 23, 2001 eruption of Mt. Etna (Italy), showing the ash plume extending for hundreds of miles.*

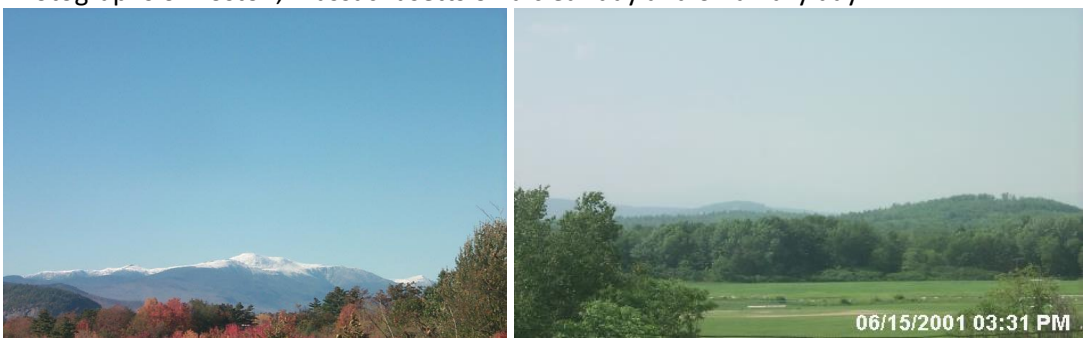
*Source: NOAA*

Transport is not restricted to ozone and its precursors. Another class of pollutants, called small particles ($PM_{2.5}$), are hazardous to human health and are often the main cause of reduced visibility in the Northeast, including in many natural areas where there are few local sources. Small particles can scatter or absorb light to create a haze that hovers in the air and obstructs the view. The haziest days occur when there is a slow airflow from the Midwest. Based on NHDES forecasting expertise and experience, these hazy days correspond to days with high $PM_{2.5}$ concentrations. The following photographs taken by NESCAUM's CAMNET program show the dramatic difference between clean air days and those days plagued, in this case, by high levels of sulfate particles (sulfate particle pollution is very efficient at reducing visibility in the Northeast).

**Figure A.8 - Comparison Views of Clear and Hazy Days in the Northeast**

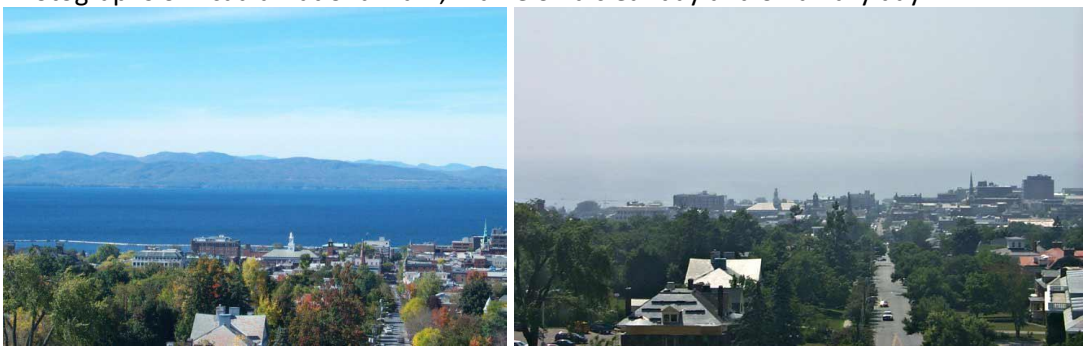



Photographs of Boston, Massachusetts on a clear day and on a hazy day.




Photographs of Mt. Washington, New Hampshire on a clear day and on a hazy day. Note: view of Mt. Washington on right is completely obscured from only about 10 miles away.

Photographs of Acadia National Park, Maine on a clear day and on a hazy day.



Photographs of Burlington, Vermont on a clear day and on a hazy day.

*Source: [www.hazecam.net](http://www.hazecam.net)*

### 3.1.1 High-Elevation Transport

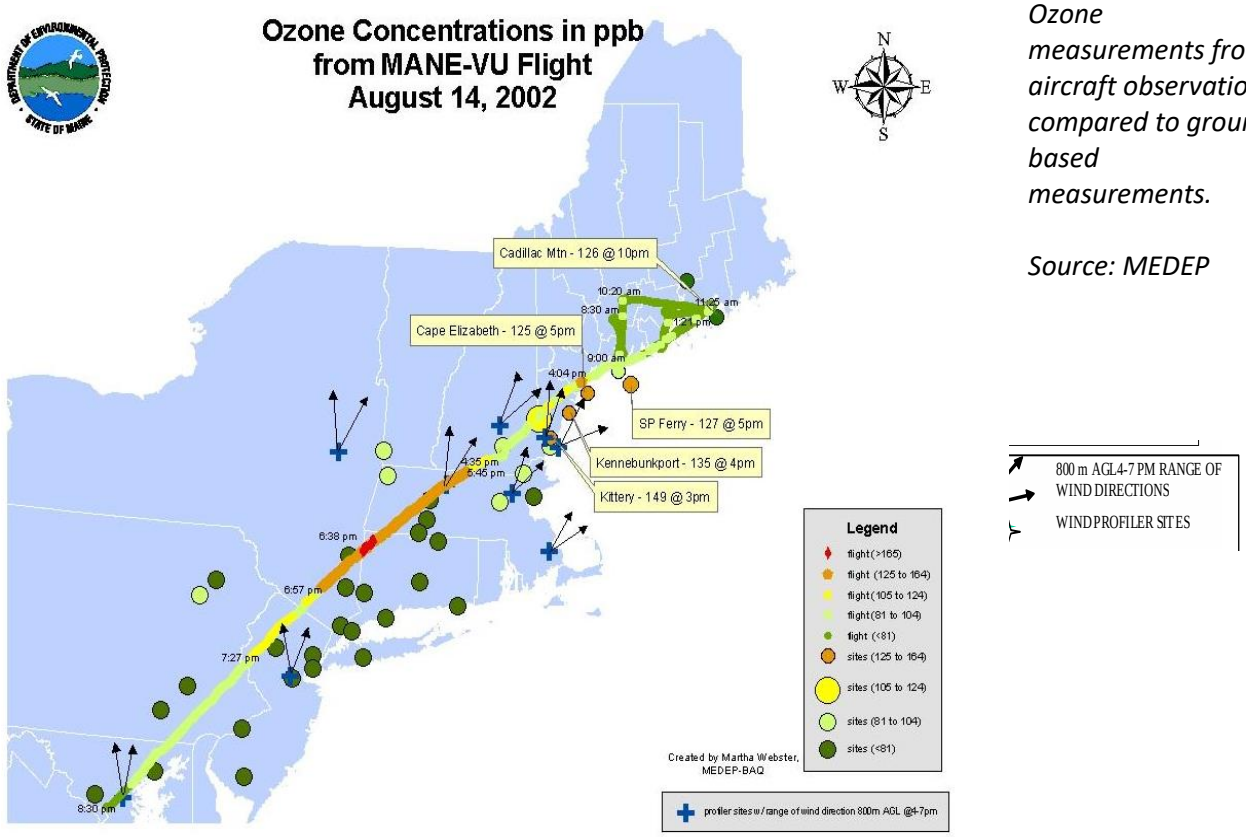
*Aircraft Measurements*

Aircraft measurements by the North American Research Strategy for Tropospheric Ozone-Northeast (NARSTO-NE) during the July 1995 ozone episode also demonstrate the existence of significant transport into and within the region, contributing to exceedances of the ozone standard in Maine (Blumenthal et al., 1997). Several "spiral" flights a few thousand feet above Poughkeepsie, NY, Gettysburg, PA, and Shenandoah, VA, recorded ozone levels of 100 ppb or greater in the early morning (4 AM) on two days. One aircraft actually recorded an ozone concentration well above 120 ppb at an elevation of approximately 2600 feet above Poughkeepsie on July 14, 1995, when ground level ozone measured about 30 ppb. Another flight during the early morning of July 14, 1995, from Virginia to Maine recorded ozone levels in the range of 70 to 100 ppb at an elevation of 1600 feet throughout the Northeast corridor.

These elevated ozone concentrations measured in the early morning at high elevations suggest that the ozone and its precursors originated during the active times of the previous day or days and traveled up and away from the source locations. Spiral flights in the afternoon over the same three cities, measured uniform ozone levels from ground level to 2600 feet, showing that the air had become well mixed during the day and had thus brought transported ozone aloft down to the surface. A second flight along the length of the entire corridor showed that ozone levels at 1600 feet had risen well above 120 ppb in the Baltimore-Washington and New York metropolitan areas. Being well above the ground, this ozone was presumably destined to be transported further downwind overnight.

On behalf of the Mid-Atlantic Northeast Visibility Union (MANE-VU), additional aircraft measurements were taken to track a regional haze event in the Northeast in August of 2002. The aircraft measured light scattering from particles as well as ozone. Like the earlier NARSTO-Northeast measurements, the MANE-VU study found high levels of ozone aloft which were blowing toward the northeastern states. In most cases, the ozone measured aloft exceeded measurements collected at ground level, indicating that the ground-level ozone was not all created locally. It is also noteworthy that the preliminary measurements collected above Baltimore, MD were already rich in ozone, suggesting that a large amount of the pollutant was blowing into the region from upwind areas. It should be noted that ozone aloft is depleted much more slowly than ozone at ground level, which comes into contact with various surfaces and obstructions. This means that, once ozone is present at high elevations, it becomes more likely to travel long distances downwind without breaking down.

**Figure A.9 - Aircraft Ozone Observations in the Northeast**




*Ozone measurements from aircraft observations compared to ground based measurements.*

*Source: MEDEP*

*<u>Mountaintop Monitoring - Mt. Washington, New Hampshire</u>*

Mt. Washington in Pinkham Notch, New Hampshire, is tall enough (6288 feet) to reach well up into the upper ozone transport layers with minimal obstruction by other terrain features. Ozone levels recorded at the summit mirror NARSTO findings, showing consistently elevated levels of ozone with little diurnal variation during most episodes – clear evidence of long range transport. As further evidence of long range transport, Camp Dodge (2400 feet), located at the base of Mt. Washington, usually records lower ozone concentrations than those seen contemporaneously at the summit.

Both monitors have no major NOx sources within 75 miles and no major sources upwind in the direction of prevailing winds for approximately 150 miles. Transport from more distant upwind sources is the primary source of ozone monitored at these sites. Since the summit of Mt. Washington is high enough to be exposed to high elevation transport (synoptic flows), downward mixing is not a factor in creating the peak ozone values it experiences. In fact, transport time from upwind source areas appears to be the single largest factor in determining the time at which the maximum ozone level occurs at the summit. Daily maximum ozone levels at Camp Dodge are dependent on inversion breakup caused by downward mixing from upper transport elevations, and thus are typically recorded during the afternoon hours. On the contrary, maximum ozone levels at the summit occur most often during the overnight hours,

when no ozone is produced locally. The percent share of daily one-hour ozone maxima which occur during daylight heating hours and outside of daylight heating hours on the summit of Mt. Washington, and at Camp Dodge are listed in the table below.

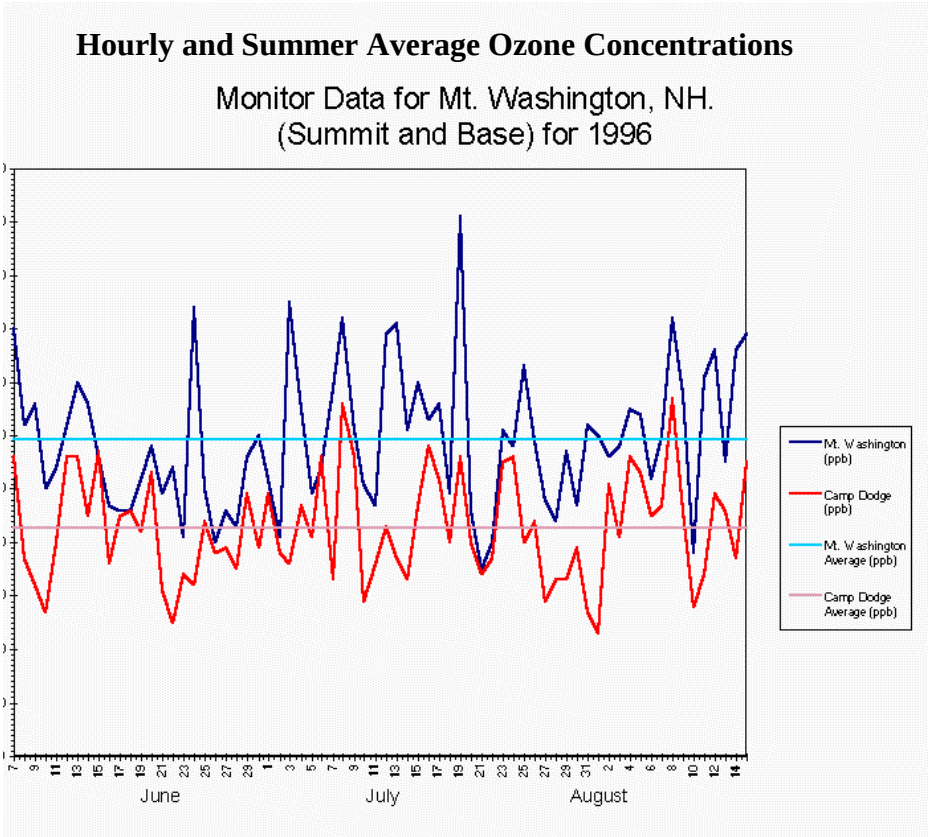
**Table A.1 - Night and Daytime Patterns of Ozone at the Base and Summit of Mt. Washington**

| Mt. Washington Monitor Location | Percent of Hourly Maxima During Daylight Hours (9 a.m. to 5 p.m.) | Percent of Hourly Maxima During Overnight Hours (6 p.m. to 8 a.m.) |
|---|---|---|
| Summit | 18% | 82% |
| Base (Camp Dodge) | 80% | 20% |

*Note: Daylight heating hours are hours of the day when solar energy drives vertical mixing of transport layers*

The difference in ozone concentrations at the summit and base can also be seen when looking at plots of maximum ozone levels at each site. The following graph is typical of summertime ozone at Mount Washington.

**Figure A.10 - Comparison of Ozone Concentrations at the Base & Summit of Mt. Washington**




*Relative comparison of mountaintop (elev. 6288 feet) ozone with mountain base (elev. around 2000 feet) hourly ozone. Often the ozone is higher in concentration at the summit due to pollution transport from distant sources. Many times the ozone at the base is driven by downward mixing from the upper transport layers during the day.*

*Source: NHDES (Data: AMC)*

*Pack Monadnock Mountain - Miller State Park, New Hampshire*

A similar mountaintop air pollution monitor was established in 2002 in Miller State Park at the summit of Pack Monadnock Mountain in Peterborough, NH (elevation 2288 feet). The mountain is located in the south-central portion of New Hampshire in an ideal location to track air pollution transport into the state. The monitor is only a short distance from the heavily visited and hiked Mt. Monadnock. The early findings from this monitor are similar to those of Mt. Washington in that when an ozone or $PM_{2.5}$ episode begins to build into the region, it is detected at higher elevations first where the stronger transport currents are located. The new Miller State Park monitor has been useful in tracking air pollution events entering the populated Merrimack Valley area (Nashua, Manchester, and Concord).

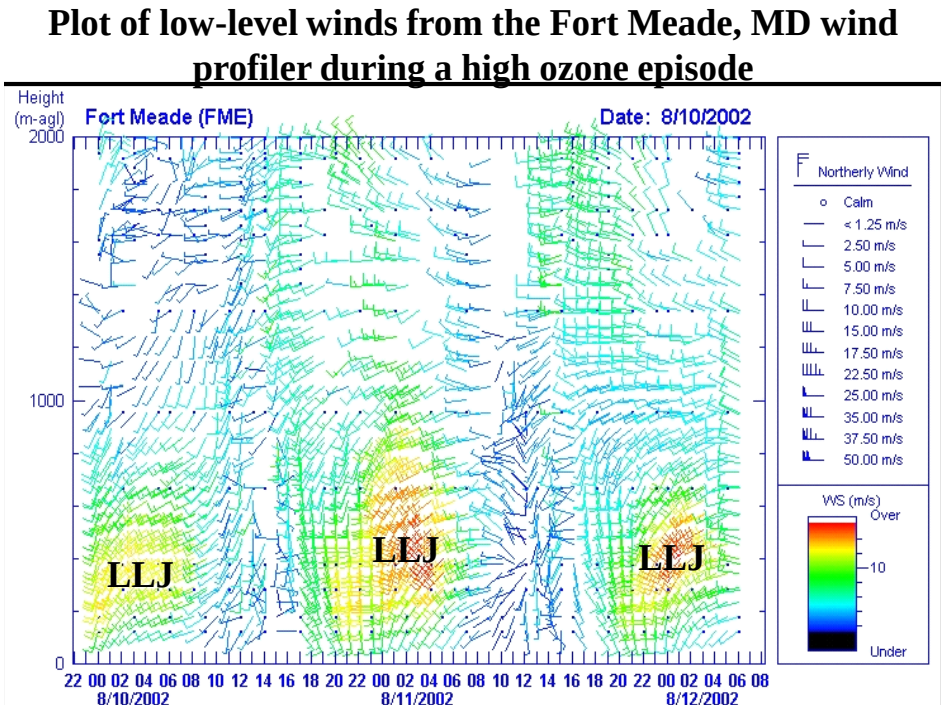
### 3.1.2 Mid-Elevation Transport

Mid-elevation transport is usually dominated by the effects of large topographical features, such as mountains, which redirect airflows and cause a channeling of the wind. In the Northeast, channeled airflows may occur on either side (east or west) of the Appalachian Mountain range and also between the subranges that comprise the Appalachian chain. Unhealthy air quality can be present on one side of a mountain while just a few miles away on the other side, the air quality is substantially cleaner. This mid-layer is generally heavily

influenced by the airshed layers above and below that mix polluted, or clean air into it. Pollutants can also be injected directly into this layer by some of the very tall smoke stacks (around 1000 feet tall) commonly found in the Midwest.

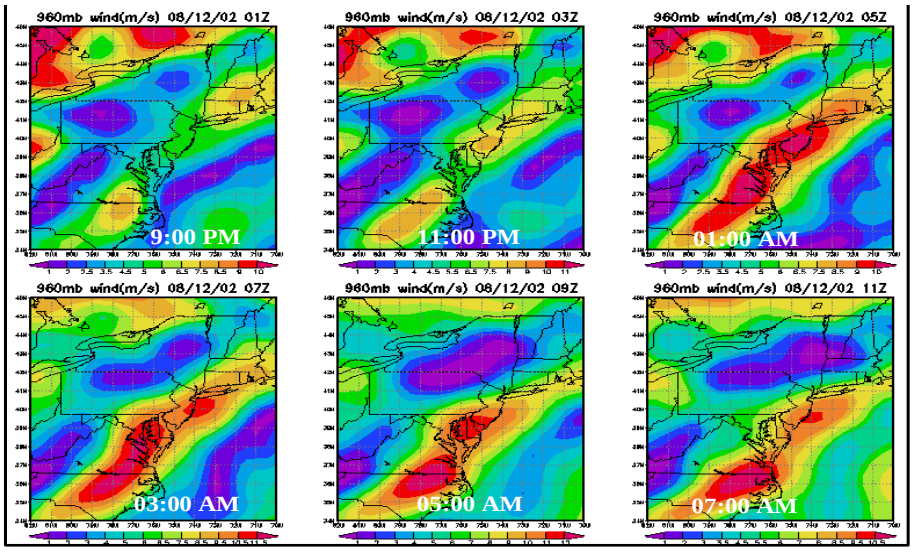
Mid-level transport is often affected by a phenomenon known as the low-level jet (LLJ). It is called "low-level" because it is lower relative to the well know Jet Stream, a high elevation airflow that drives the movement of weather systems around the world. Recent advances in remote sensing instruments (i.e., radar profilers) have allowed the LLJ phenomena to be observed. During the overnight and early morning hours, a LLJ frequently forms just east of the Appalachian Mountains. Once formed, the LLJ is a strong west to southwest wind flow that develops at low altitudes just above the nocturnal boundary layer. These winds typically reach speeds of 40-50 mph and are located at approximately 1,000 – 2,000 feet above the ground. The figures below depict the LLJ observed during an August, 2002 ozone event.

**Figure A.11 - Wind Profiler Observations of the Low-Level Jet**




*Wind profiler observations for Fort Meade, Maryland. The low-level jet phenomenon developed for these 3 consecutive days where ozone levels were high in the area. These areas of high wind speeds develop overnight and are associated with wind direction shifts (identified in yellow, orange and red). Source: University of Maryland*

**Figure A.12 - Computer Model Illustration of the Low-Level Jet in the Northeast**




*The low level jet (shown by red, orange, and yellow) normally set up along the eastern side of the Appalachian Mountains and blow from southwest to northeast.*

*Source: University of Maryland*

### 3.1.3 Low-Elevation Transport

A number of one-day and multi-day transport mechanisms have been observed along the northeastern coastal plain. Blumenthal et al., (1997) described several transport mechanisms, including near-surface flows that act within a thousand feet of the ground and are capable of transporting ozone and its precursors along the urban corridor as far as 160 miles during the daylight hours. Near surface flows are especially useful in explaining the transport and presence of the elevated ozone concentrations monitored aboard the *MS Scotia Prince* in the Gulf of Maine (Portland, Maine ferry to Yarmouth, Nova Scotia, Canada).

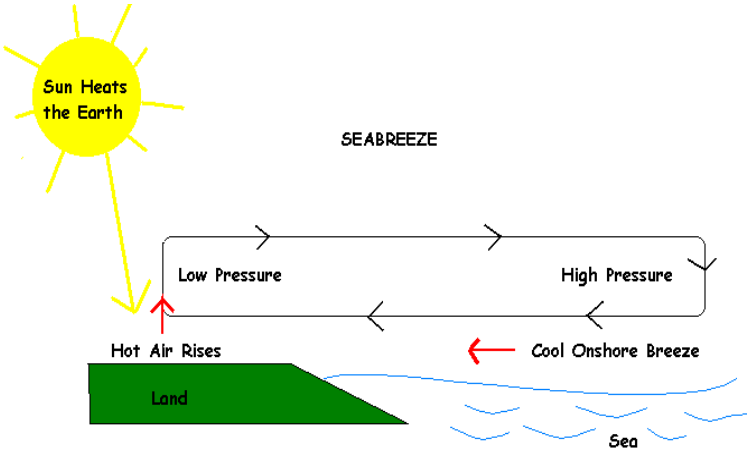
Other transport mechanisms, including boundary layer synoptic (upper level) flows and channeled (mid-level) nighttime flows are capable of transporting ozone and precursors as far as 600 km in a 24-hour period and are responsible for longer range transport from the south and west (Blumenthal et al., 1997).

Residence time (or the time a pollutant stays in the air) analysis (Wishinski and Poirot, 1996) is a technique whereby the spatial characteristics of long-term trajectory climatology can be analyzed by keeping track of the residence time (in hours) for selected back trajectories. This was done for several New England sites during the summers from 1989 through 1995. Back trajectories from Port Clyde, Maine show that for days on which Maine exceeds the ozone national ambient air quality standard (NAAQS), the wind is invariably from the south and west. These trajectories also show that the Northeastern Corridor is principally responsible for nonattainment in New Hampshire and Maine, with areas to the south and west of the Corridor having lesser, but still significant impacts.

*Sea Breeze*

The Atlantic Ocean produces changes in wind directions and wind speeds along the shoreline, especially in New England. While most inland areas experience regional wind patterns with only small variations due to terrain features and other frictional effects, coastal locations are far more variable. Sea breezes develop during the heating of the day when the ground heats up, warming the onshore air mass. This air mass then rises, causing cooler air near the surface to flow in from over the ocean. Sea breezes are actually a subset of the NARSTO/NE near-surface flows that are driven by temperature differences between land and water, which also affects changes in mixing heights. Daytime sea breezes flow from the relatively cool waters of the ocean towards the coast, and diminish over a short distance due to mixing with regional wind patterns persisting further inland and with diurnal mixing. Such sea breezes are the primary reason why high ozone concentrations occur along the New Hampshire coast, while substantially lower concentrations are recorded just a few miles further inland.

**Figure A.13 - How the Sea Breeze Works**




*The sea breeze is developed through the temperature differences between the ground and the water. As the sun warms the ground, it begins a cycle by causing the air to rise. This air cools as it moves over the water, sinks and then blows back towards the shore.*

The afternoon sea breeze shifts the wind direction to the south and east, bringing ozone from over the ocean onshore. As documented by the New Hampshire Department of Environmental Services and the Maine Department of Environmental Protection, sea breezes develop suddenly, shifting the wind from the northwest to the south or southeast, and driving ozone concentrations sharply upward. The offshore ozone blown in by sea breezes appears to originate from precursors emitted in the metropolitan Boston area.

*Offshore Transport*

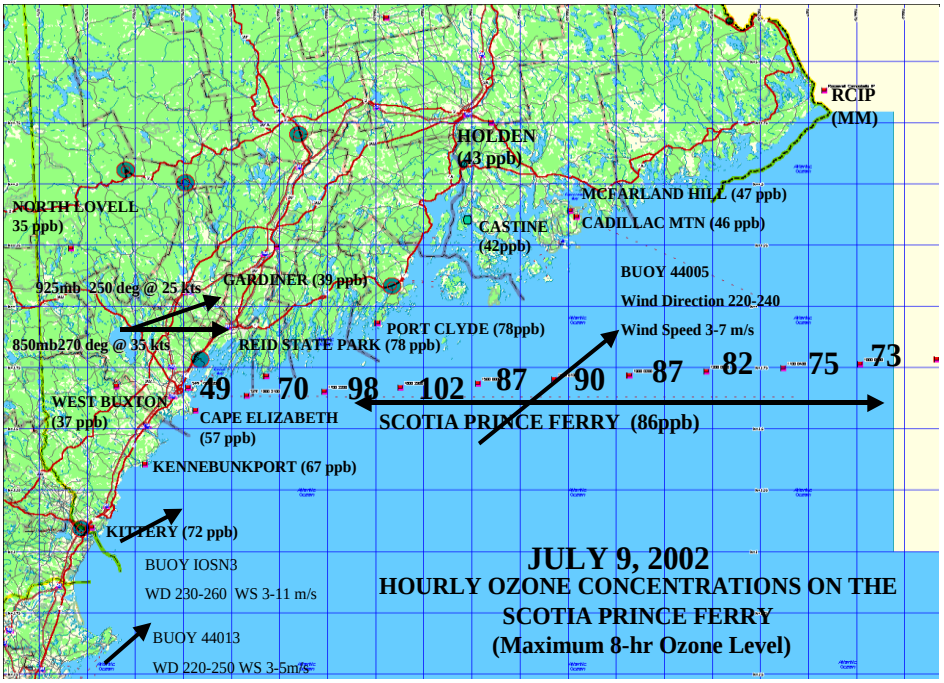
Offshore, just beyond the strongest coastal sea breezes, larger scale wind fields develop that may differ in direction from the inland regional wind pattern. Lower mixing heights, differing temperature gradients, and lower frictional effects cause this differential. Off the New Hampshire and Maine coasts, it is not uncommon for the over-water wind field to come from the south, while the inland regional wind field is more from the southwest. This pattern allows transport of the ozone plume from the metropolitan Boston area to travel over the Gulf of Maine to the New Hampshire coast, even when inland wind observations suggest this should not be happening.

The North Atlantic Regional Experiment (NARE) measured surface level ozone and precursor concentrations at both coastal and offshore locations in the Gulf of Maine during August and September of 1993 (Ray et al., 1996). The researchers observed ozone plumes in the Gulf of Maine ranging in width from 55 to 93 km, and extending the entire length of the New Hampshire and Maine coastlines. The timing of the observed peak ozone concentrations, the presence of elevated ozone levels only along the coast, and low $NO_y$ concentrations all suggest that urban plumes transported over the Gulf of Maine are brought inland by sea breezes to the coastal regions, and that regional control strategies will be needed to reduce ozone concentrations along the coast.

Recent photochemical modeling utilizing the CALGRID model (Earth Tech, 1997) serves to confirm the presence of an urban plume moving northeastward over the Gulf of Maine, where it is then carried by afternoon sea breezes to the coast.

Along the New Hampshire and Maine coastlines, ozone levels have not been observed to exceed the NAAQS unless there is at least a moderate westerly to southwesterly wind at the surface. Typical ozone episodes are characterized by the concentration of transported ozone and precursors in the Gulf of Maine during the morning and mid-day hours, with afternoon sea breezes bringing high concentrations of ozone ashore in the afternoon and evening. Monitored ozone concentration data and measured wind vectors show ozone exceedences in Maine to be the direct result of a large mass of both ozone and unreacted precursors being transported into the Gulf of Maine from areas to the south and west. Here, precursors react and are then transported ashore, a conclusion supported by data collected by monitors on both the MS Scotia Prince (see figure below) in the Gulf of Maine and on land-based monitors that show significantly decreased levels of ozone at inland sites (AIRS).

**Figure A.14 - Offshore Ozone Measurements from the Scotia Prince Ferry**




*The Scotia Prince ferry is a scheduled passenger and vehicle ferry that runs between Portland, Maine and Yarmouth, Nova Scotia, Canada. This ferry has an ozone monitor that tracks air pollution levels during its journey between ports. The ferry often identifies distinct air pollution areas or plumes offshore over the Gulf of Maine. Source: MEDEP*

Ozone air quality monitors within the State of Maine also confirm the presence and significance of transported ozone and its precursors. The ozone monitoring network in Maine extends along the coast from the photochemical assessment monitoring station (PAMS) located in Kittery, Maine (operated by the State of New Hampshire Department of Environmental Services) to as far north as Bar Harbor. Maximum ozone concentrations along the Maine coast almost always follow a sequential pattern, with the most southerly sites monitoring daily ozone maximums in the mid to late afternoon, and downwind sites experiencing maximum readings later in the day and into the evening hours. Data from the Kittery site is especially illustrative in that it represents ozone concentrations at the Maine/New Hampshire border and is an objective measure of transport from areas immediately to the south; elevated ozone concentrations at this site can only be the result of inter-state transport**.**

## 3.2 Confirming Modeling and Assessments

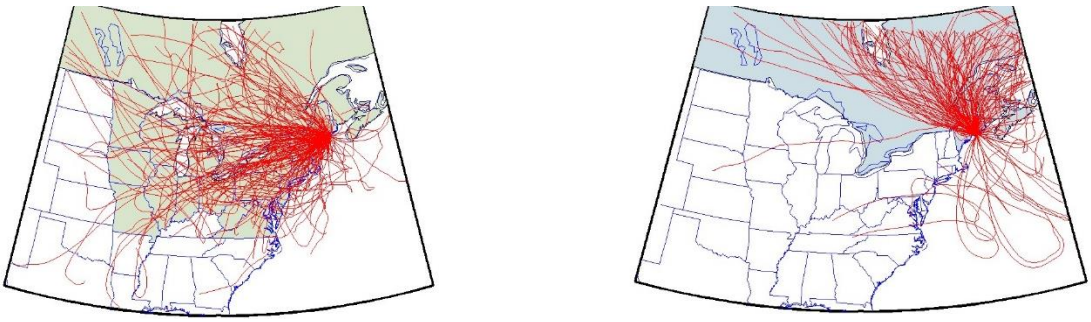
### 3.2.1 Back-Tracking Air Pollution to the Source Area

Back trajectory frequency analyses presented by Poirot and others to OTAG concluded that the cleanest air masses originate in Canada and northern New England (Maine, New Hampshire, Vermont, and northeastern New York). The most polluted air masses originate in a region that is approximately outlined by Chicago, St. Louis, Memphis, Washington, DC, and Boston. This region includes the industrial Midwest and most of the Ozone Transport Region. Figure A.15 shows these back trajectories for a site in northern Maine on both clean and hazy days.

**Figure A.15 - Wind Trajectories on Clean and Hazy Days at Acadia National Park in Maine**

HY-SPLIT Back Trajectories for Acadia National Park 1997 - 1999

*Source: NESCAUM*



20% Worst Visibility 20% Best Visibility

*Red lines indicate where the wind came from during days of bad and good visibility at Acadia National Park from 1997 to 1999.*

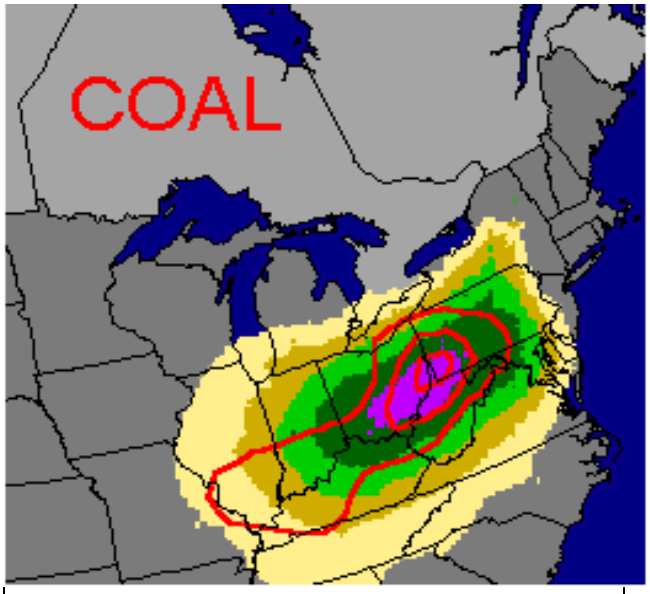
Studies by Poirot et al., (2002) determine probable emission source areas during periods of high levels of air pollution in Lye Brook, Vermont and Brigantine, New Jersey. These studies considered back trajectories during periods when certain species of pollutants were measured to be at elevated levels. Some of the results of these studies are shown in Figure A.16. This figure shows emissions distributions as well as probable source regions based on trajectory analysis.

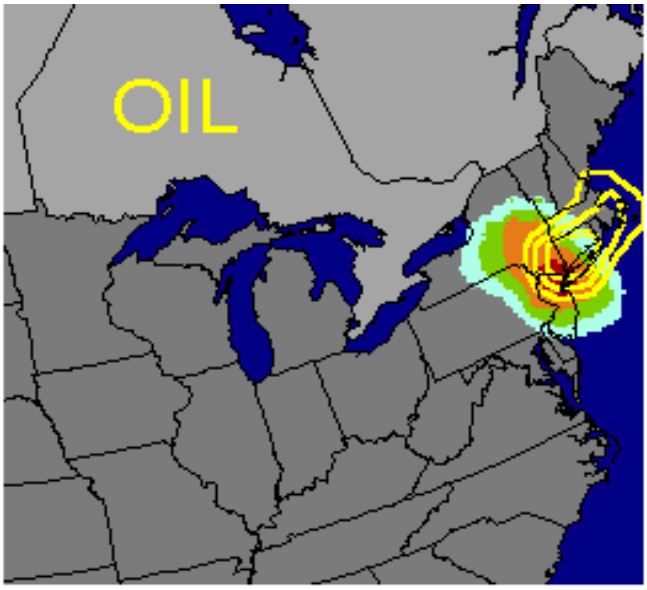
A report presented to OTAG by Husar and Renard, "Ozone as a Function of Local Wind Direction and Wind Speed: Evidence of Local and Regional Transport (1997)," which supports the OTAG Air Quality Analysis (AQA) group recommendations, states:

> *"The Boston, MA metropolitan area shows virtually no dependence of ozone concentration on wind speed, except during northeasterly winds. The lack of wind speed dependence clearly indicates that the average concentration in Boston is dominated by transport and that the local contributions to the average are virtually undetectable. Directionally, southwesterly winds are the highest at 70 ppb, and northeasterly transport brings lowest ozone concentrations at about 45 ppb."*

If ozone concentrations in the metropolitan Boston area are dominated by transport, then it follows that the impact of transport is even more dominant in areas that are proximate to, downwind of, and have lower emissions than metropolitan Boston itself, such as New Hampshire.

**Figure A.16 - Trajectory and Probability Analysis Results Poirot, et al. 2002**



Wood smoke in the Northeast is largely a product of New England wood stoves, fireplaces, and open burning as well as Canadian forest fires.

*Source: Poirot 2002, VTDEC*

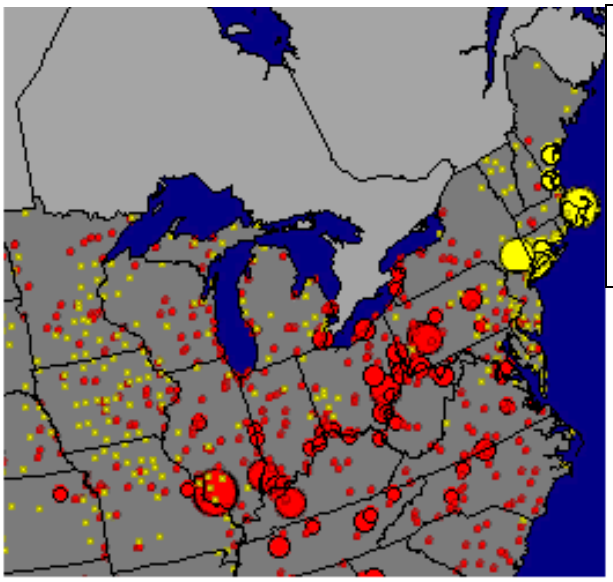


**Figure A.17 - Trajectory and Probability Analysis Results Poirot, et al. 2002**

SO2 emissions from coal (red) and from oil (yellow). Relative emission magnitude indicated by size of circle. Oil emissions are indicated 10 times larger than actual. Source: EPA EGRID database

### 3.2.2 Ozone Contribution Analyses Based on OTAG Data (Culpability Analysis)

New Hampshire conducted a thorough analysis of grid cell-by-grid cell, hour-by-hour data for the approximate 35,000 grid cells used for OTAG's modeling of the 1995 ozone episode ("Apportioning Relative Ozone Culpability" and "Assessment and Apportionment of Ozone Culpability"). Through this analysis, an "ozone response curve" was developed which correlates ozone impacts directly with NOx emission control levels in the various OTAG subregions.

"Culpability analysis" uses this ozone response curve to assign relative responsibility to upwind source regions for downwind transported concentrations. New Hampshire believes that culpability analysis provides the best available evidence that non-New Hampshire sources, including electric generating facilities in the Midwest, contribute significantly to the transport of ozone and ozone precursors to New Hampshire.

Culpability analysis using OTAG subregional zero-out run data was performed for the July 10-18, 1995 ozone episode, which was a period of several ozone exceedances of the NAAQS in New Hampshire. It is clear from this analysis that ozone and its precursors can contribute to downwind ozone levels over distances as far as 1000 miles from emission sources. In addition, the analysis shows that the entire OTAG domain is subject to regional ozone transport to a significant extent, ranging from 20% to over 70% in some areas. It is noteworthy that at least 20% of the ozone in each OTAG subregion appears to be produced outside of the subregion. In other words, to a greater or lesser extent, all OTAG subregions both contribute to and are recipients of significant regional ozone transport.

The results of New Hampshire's culpability analysis for the fine grid OTAG Subregions which contribute more than 5% to New Hampshire's ozone concentrations are as follows:

**Table A.2 - Culpability for Ozone in New Hampshire According to the New Hampshire Culpability Study During the OTAG Assessments**

| General Description of OTAG Subregion | Culpability from OTAG Subregion to New Hampshire |
|---|---|
| Southern half of Wisconsin, Northern half of Illinois, Parts of Indiana, Iowa, Michigan. | 5 to 10% |
| Southern half of Michigan, Northern half of Ohio, Part of Indiana. | 5 to 20% |
| Most of Pennsylvania, Western half of New York. | 30 to 50% |
| All of New Jersey, Delaware, Connecticut, Part of eastern Pennsylvania, Metropolitan New York City. | 10 to 30% |
| Southern half of Illinois, Eastern Missouri, Western Kentucky, Southern Indiana. | Up to 10% |
| Southern half of Ohio, Eastern half of Kentucky, Western half of West Virginia, Parts of Indiana and Virginia. | Up to 10% |
| All of Maryland, Most of Virginia, Eastern half of West Virginia. | Up to 10% |
| Massachusetts, Vermont, New Hampshire, and Maine | 5 to 50% |

OTAG data suggests that over distances of approximately 100 to 150 miles, concentrations of ozone in the Northeast are reduced by half (i.e., a "half-distance" applies which is similar to the concept of "half-life" in radioactivity). Using this approach, NHDES has determined that ozone and NOx can be transported more than 600 miles while retaining more than 6% of their ozone forming capability. Such contributions from distant sources could easily move New Hampshire from attainment to nonattainment. For example, generating facilities located 750 miles upwind and emitting 320 tons of NOx per day can provide equivalent pollutant impact to facilities emitting 10 ton of NOx per day located less than 150 miles upwind of New Hampshire.

Applying the "half-distance" concept to generating facility emissions focuses primarily on a large number of nearby sources or groups of sources, adding more distant ones as they exceed greater "half-distance" emission thresholds. For each concentric "half-distance" one moves upwind, sources or groups of sources of twice the size have the same downwind ozone impact. This dynamic is illustrated in Table A.3 below. While this approach is based on generating facilities which emit 10 tons or more of NOx per day, the collective transport impact of facilities with lesser emissions should not be ignored.

**Table A.3 - Ozone Half-Distance Range Estimates Based on the OTAG Modeling Assessments**

| Half-Distance Range (miles) | Facility NOx Emissions (tons/day) |
|---|---|
| 0-150 | 10 |
| 150-300 | 20 |
| 300-450 | 40 |
| 450-600 | 80 |
| 600-750 | 160 |
| 750-900 | 320 |

### 3.2.3 New Hampshire Photochemical Modeling

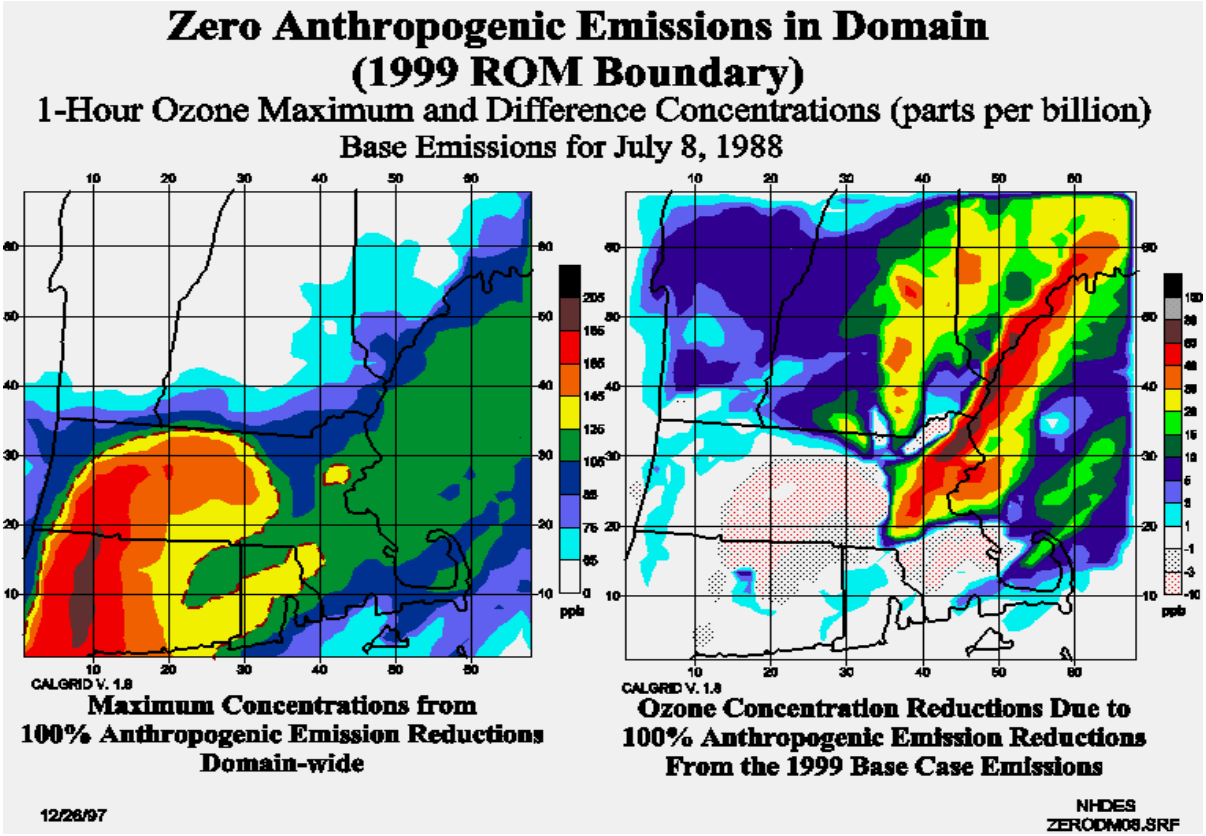
The state of New Hampshire performed 1-hour ozone photochemical modeling with the Commonwealth of Massachusetts and filed the most recent Progress Report for the New England Domain Ozone Attainment Demonstration (Progress Report) in February of 1997. As recommended by EPA, the Progress Report employs the Urban Airshed Model (UAM) to assess the effect of various control strategies on attainment. The Progress Report modeled two 1988 episode days, July 8 and July 11, for the purposes of evaluating model performance, preliminary testing strategies, and determining the impact of transport into the domain. During the July 8 episode, exceedences were recorded in two ozone plumes, one large plume stretching from the southwest corner of the domain north through Connecticut and along the Connecticut River Valley in Massachusetts, and one plume running from Boston, Massachusetts north along the coast of New Hampshire and Maine. In the July 11 episode, a large plume stretched from the southwest corner of the domain east through Connecticut, Rhode Island, and southeastern Massachusetts, with a second plume again extending from Boston north along the coast.

With respect to transport, the model predicted that elimination of all anthropogenic emissions in the domain would eliminate the smaller coastal plume from Boston north. Less drastic strategies were less effective; rate of progress controls through 1999 reduced, but did not eliminate the exceedences for July 8 in either the main plume or the north coastal plume. Recent photochemical modeling utilizing the CALGRID model (Earth Tech, 1997) serves to confirm the presence of an urban plume moving northeastward over the Gulf of Maine, where it is then carried by afternoon sea breezes to the New Hampshire and Maine coast.

Modeling for the New Hampshire 1-Hour Ozone Attainment demonstration found that the major pollution sources in the region are located in the Boston area. When these emissions were theoretically eliminated, there was still a large amount of ozone transport into the New England region. Many areas in southern New Hampshire were already between 80 and 90 percent of the 1-hour ozone health standard, without any pollution emissions anywhere in New England, thus the air was so dirty when it came into the area that it would take very little additional emissions to exceed the standard. The modeling further showed that 94% to 100% of

the ozone measured in New Hampshire comes from out-of-state sources. The exact sources vary from day-to-day depending on wind patterns. The analysis also showed that eliminating all manmade sources within New Hampshire would result in only minimal air quality improvement.

**Figure A.17 - Photochemical Modeling Case Where All Manmade Pollution Emissions Were Theoretically Eliminated Within New England**

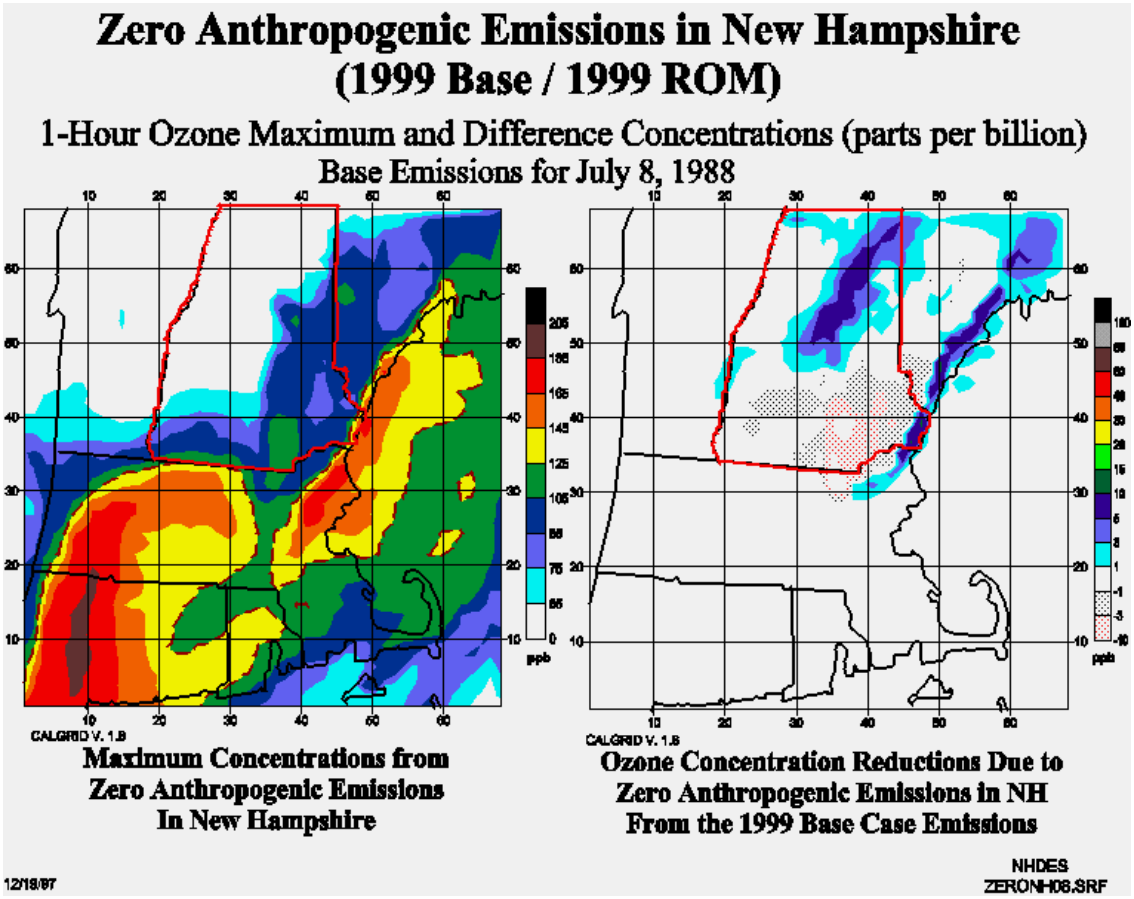



*Source: NHDES*

***Left side**: Modeled ozone levels in a hypothetical case where all manmade air pollution emissions are eliminated in the area shown in the map. High levels still exist in the area (shown by green, yellow, orange, red and brown).*

***Right side**: Modeled ozone reductions under the same case. Large reductions (green, yellow, orange, red, and brown) are made in areas downwind of metropolitan Boston where emission density is the highest within the area shown by the map.*

**Figure A.18 - Photochemical Modeling Case Where All Manmade Pollution Emissions Were Theoretically Eliminated Within New Hampshire**




*Source: NHDES*

***Left side****: Modeled ozone levels in a hypothetical case where all manmade air pollution emissions are eliminated New Hampshire. High levels still exist in the area (shown by green, yellow, orange, red and brown).*

***Right side****: Modeled ozone reductions under the same case. Only modest reductions (shades of blue) are made in areas downwind the Merrimack River valley and the seacoast areas where emission density within the state is the highest (also I-93 and I-95 areas).*

# TECHNICAL ATTACHMENT B

## $PM_{2.5}$ HEALTH VALUATION CALCULATIONS

Two methods were used to develop estimates for health impact valuations from transport of fine particle ($PM_{2.5}$) pollution into New Hampshire. Both methodologies are based on the Abt Associates report, October 2000. Initial estimates were conducted based on modeling analyses results for New Hampshire during 1996 as reported directly in the report. A revised "best estimate" accounts for updated population information and adjusts for decreased $PM_{2.5}$ concentrations in northern areas. Table B-1 below presents the valuations from the best estimate metholodogy, chosen by NHDES as the most accurate of the two. Description and calculations for both methodologies follow this table.

**TABLE B-1: Projected Risk Values Due to $PM_{2.5}$ Transport Into New Hampshire (1999$)**

| | Power Plant Only | | Total New Hampshire Estimated Incidents[1] | Mean 1999$ Valuation per Incident[2] (Abt range) | Total New Hampshire Valuation[2] (1999$) |
|---|---|---|---|---|---|
| **Adverse Effect** | **Abt Boston CMSA Incidents[3]** | **New Hampshire CMSA Incidents[4]** | | | |
| **Premature Mortality** | 454 | 60 | 123 | $6,120,000 (3.8-8.9 million) | $753,472,724 |
| **Chronic Bronchitis** | 302 | 40 | 82 | $331,000 (57,000-1,275,000) | $27,107,858 |
| **Acute Bronchitis** | 839 | 111 | 228 | $57 (17-98) | $13,055 |
| **Hospital Admissions** | 320 | 42 | 87 | $14,811 (6,634-18,387) | $1,285,271 |
| **ER Asthma Visits** | 113 | 15 | 31 | $299 (222-414) | $9,151 |
| **Asthma Attacks** | 9,540 | 1,266 | 2,587 | $41 (15-69) | $105,527 |
| **Upper Respiratory Symptoms** | 9,420 | 1,250 | 2,555 | $24 (9-42) | $60,874 |
| **Lower Respiratory Symptoms** | 8,820 | 1,170 | 2,392 | $15 (6-24) | $36,045 |
| **Work Days Lost** | 84,000 | 11,143 | 22,779 | $106 (N/A) | $2,410,045 |
| **Minor Restricted Activity Days** | 432,000 | 57,308 | 117,150 | $48 (20-78) | $5,673,597 |
| **Total** | | | | | **$790,174,146** |

Note: Valuations are estimated only for $PM_{2.5}$ health effects and do not include valuations associated with ozone, mercury, and other materials that may or may not be toxic in nature. Estimated valuations do not account for damages done to the environment including contaminated water resources, vegetation and animal species shifting, reduced forest and agricultural productivity. Increased cost of living and doing business including higher costs for fuels and vehicles in a designated nonattainment area (area of poor air quality) are also not included.

---

[1] Does not include incidents that may be attributed to locally generated emissions especially diesel emissions and emissions from certain industries. Values in northern New Hampshire were adjusted 12.7 percent further to account for the concentration gradient.

[2] Does not include heart attacks. Research has demonstrated that elevated levels of $PM_{2.5}$ can trigger heart attacks (Pope, et al. 2003).

[3] Source: Abt Associates, October, 2000.

[4] New Hampshire portion of the Boston CMSA is based on the ratio of the New Hampshire Counties to the total CMSA 2007 projected population (944,546 to 6,911,998 or 13.51%). New Hampshire values were then discounted by 1.8% based on measured concentration gradient to account for improving air quality toward the northern portion of the CMSA.

## Calculation Methodology

Estimates of health impact valuations were initially conducted based on model results directly as reported in the Abt, 2000 report. The Abt study reported results on a state-by-state basis, as well as based on entire Consolidated Metropolitan Statistical Areas (CMSAs). The modeling analyses in each case were based on the weather patterns that existed during 1996.

The Abt "all power plant" scenario modeling results for New Hampshire are listed in the first column of table B-2. These results were then extrapolated from being focused only on power plants to including all man-made pollutants by multiplying by 1.67 (a factor based on speciated small particle concentrations measured in the region (see Figure 2.10 in the main text). This factor assumes that all of the 57.1% of sulfate is from power plants and that all of the 4.5% of soil particles are not manmade and transported). After this, the total number of New Hampshire health incidents caused by transported small particles was estimated by multiplying by a 92% transport factor. The resulting values are located in the second column in Table B-2. Transport factors were calculated for locations throughout New Hampshire using long-term ozone exposure photochemical modeling results from multiple ozone episodes. The 92% factor was the lowest factor calculated within the state and was conservatively applied throughout the state. The application of the factor to small particles is reasonable based on the known similarities in their transportability, which has been supported by small particle modeling performed by EPA in support of the Clear Skies Act. The mean value of numerous health valuations compiled in the Abt report was then multiplied by the number of small particle related health incidents within the state to provide state-wide valuations.

### TABLE B-2: Calculated 2007 Health Impact Valuations Based on Unadjusted modeling results from the Abt Report

| | (Abt) Power Plants New Hampshire | New Hampshire Total Transport Caused | Mean Valuation Factor | (Abt) Total Transport Valuation |
|---|---|---|---|---|
| Premature Mortality | 67 | 103 | $ 6,120,000.00 | $ 630,930,200 |
| Chronic Bronchitis | 48 | 74 | $ 331,000.00 | $ 24,446,930 |
| Acute Bronchitis | 152 | 234 | $ 57.38 | $ 13,420 |
| Hospital Admissions | 46 | 71 | $ 14,811.00 | $ 1,048,328 |
| ER Asthma Visits | 18 | 28 | $ 298.62 | $ 8,271 |
| Asthma Attacks | 1,540 | 2,370 | $ 40.79 | $ 96,656 |
| Upper Respiratory Symptoms | 1,700 | 2,616 | $ 23.83 | $ 62,334 |
| Lower Respiratory Symptoms | 1,600 | 2,462 | $ 15.07 | $ 37,101 |
| Work Days Lost | 13,500 | 20,773 | $ 105.80 | $ 2,197,731 |
| Minor Restricted Activity Days | 69,800 | 107,402 | $ 48.43 | $ 5,201,457 |
| | | | **Total** | **$ 664,042,428** |

| | | |
|---|---|---|
| Sulfate Component | 0.571 | (regional avg.) |
| Soil Component (non-transport) | 0.045 | (regional avg.) |
| Total Transportable Components | 0.955 | |
| Ratio of total to sulfate | 1.67 | |
| Transportable Pollutants from out of state | 0.92 | (Lowest NH rate) |
| Adjusted Ratio of power plants to all transported | 1.54 | |

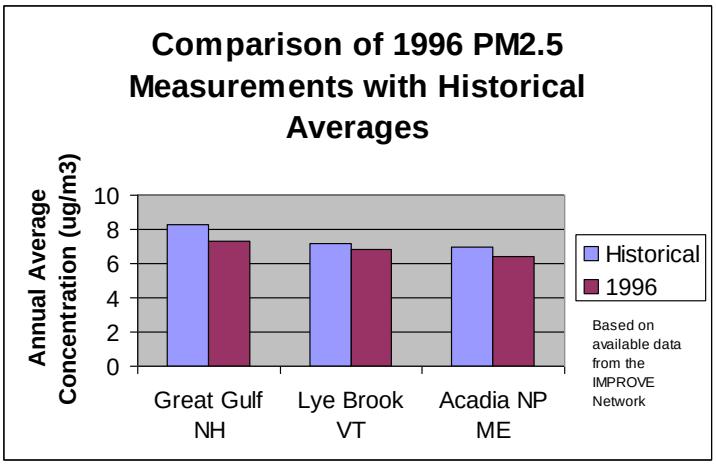
| | PM2.5 Mass | |
|---|---|---|
| | % SO4-based | % Soil |
| Lye Brook, VT | 57.4 | 4.5 |
| Acadia NP, ME | 56.8 | 4.5 |
| Average | 57.1 | 4.5 |
| IMPROVE Annual Average (1996-99) | | |

Note: The 92% transport factor applied to New Hampshire was derived from NHDES photochemical modeling for ozone. Its applicability to $PM_{2.5}$ appears reasonable and was cross-checked with EPA's Interstate Air Quality Rule modeling for $PM_{2.5}$. The EPA modeling found that New Haven, Connecticut receives about 95% of its power plant pollution from out of state sources. Accounting for non power plant sources, Connecticut's emissions of $PM_{2.5}$ and VOCs (direct precursors to local $PM_{2.5}$) are 3 to 5 times greater than the emissions in New Hampshire and New Hampshire is nearly twice the geographic size of Connecticut. This combined with the fact that New Hampshire has a higher ozone precursor to $PM_{2.5}$ emission and precursor ratio than Connecticut

suggests that New Hampshire would actually receive a greater percentage of overall $PM_{2.5}$ transport than Connecticut, but the 92% factor is applied as a conservative estimate of $PM_{2.5}$ transport. NHDES will seek to refine this estimate with future modeling.

As noted above, the Abt report studied the weather for the year 1996 in order to calculate health impact valuations. NHDES reviewed how normal small particle concentrations were in the state during 1996 and found that while small particle concentrations in the southern portion of the state were near normal, the concentrations in the northern portion of the state were below normal (See Figure B-1). As a result, the health valuations in Table B-2 are believed to be an underestimation of more typical values for the state. Therefore, an alternative method was developed to adjust Abt modeled results to what is believed to be more normal values.

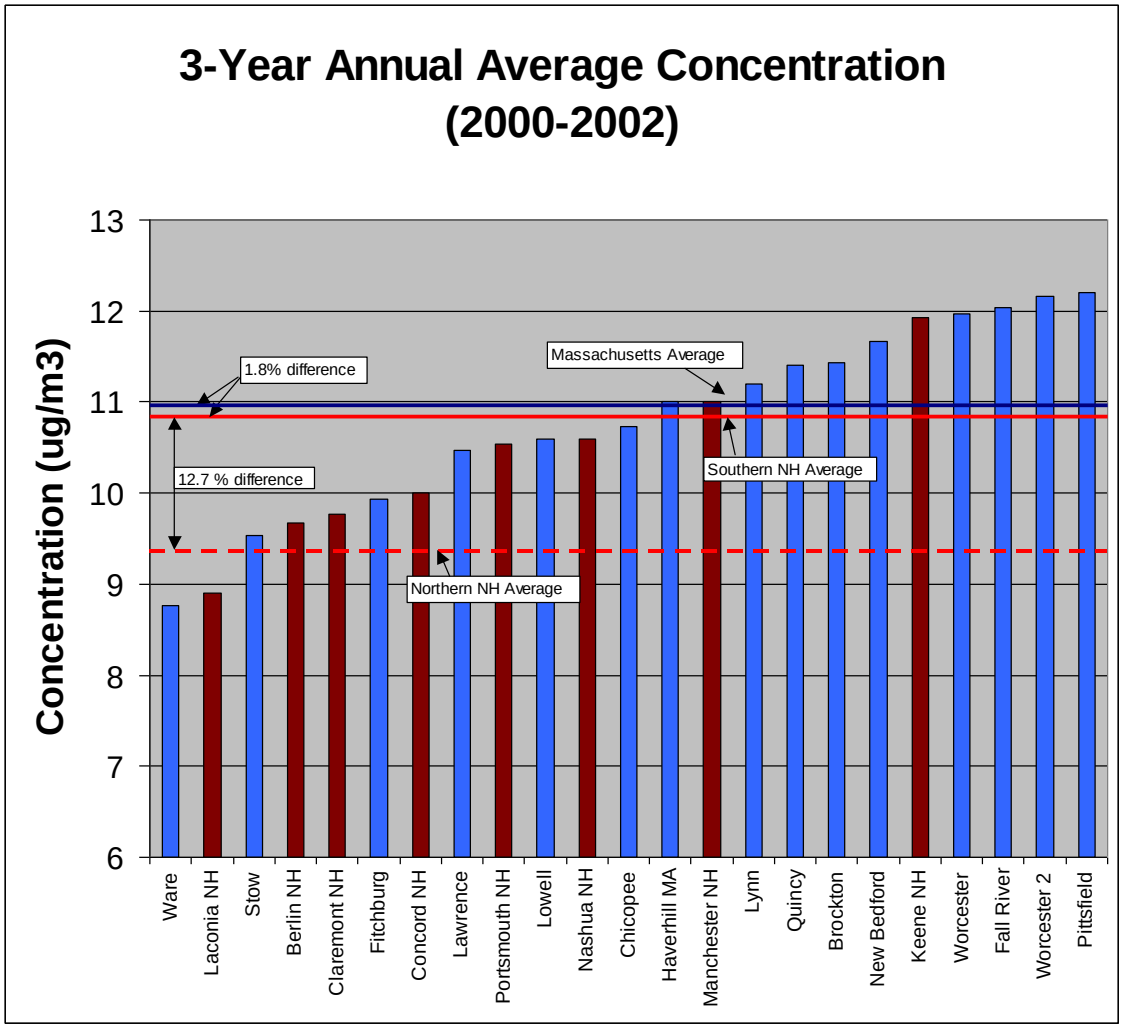
**FIGURE B-1: Comparison of 1996 to Historical Small Particle Concentrations Measured in and Near New Hampshire**




In order to make the needed adjustments to the Abt modeled values, estimates of typical small particle concentrations across the region were reviewed. Figure B-2 summarizes the 3 most recent years of small particle concentrations available across New Hampshire and the Boston CMSA (excluding downtown Boston where high levels of vehicle exhaust substantially effect localized small particle concentrations. Remember, the Abt report focuses on power plants.)

According to measurements of small particles from 2000 to 2002, the concentrations in the southern portion of New Hampshire (i.e., New Hampshire portion of the Boston CMSA), are about a 1.8% lower than those in the Massachusetts portion of the CMSA. The small particle concentrations in northern New Hampshire are another 12.7% lower than those measured in the southern part of the state.

**FIGURE B-2: Recently Measured Small Particle Concentrations in New Hampshire and the Boston Consolidated Metropolitan Statistical Area (CMSA)**




The revised, or "Best Estimate" calculations of typical New Hampshire small particle health impact valuations are detailed in Table B-3. The first column reports the Abt, 2000 all power plant health incidents for the full Boston CMSA. The second column isolates the southern New Hampshire portion of the Boston CMSA (based on 13.51% of the total CMSA population) and adjusts the rate of incidents downward by 1.8% from the rates used for Massachusetts to account for the lower small particle concentrations measured in southern New Hampshire. The third column adjusts from a power plant only scenario to a scenario of all manmade small particles using a factor based on speciated small particle concentrations measured in the region (see Figure 2.10 in the main text). This factor assumes that all of the 57.1% of sulfate is from power plants and that all of the 4.5% of soil particles are not manmade and transported. Then the northern portion of New Hampshire was added into the state estimates on a population basis (total state population versus New Hampshire areas of the Boston CMSA). The rate of incidents in the northern areas of New Hampshire were reduced 12.7% below the rates used for the southern part of New Hampshire based on measured concentrations. A 92% transport

factor was then applied to the estimated the number of health incidents due to transport of small particles into the state. Finally, the New Hampshire estimated small particle health incidents were then multiplied by the Abt health valuations.

### TABLE B-3: Adjusted (Best Estimate) of New Hampshire Small Particle Health Valuations

| | (Abt) Power Plants Boston | Power Plants New Hampshire portion of CMSA adjusted by 1.8% | New Hampshire Portion of CMSA Total Transport Caused | New Hampshire Total Transport Caused northern counties adjusted by 12.7% | (Abt) Mean Valuation Factor | Total Transport Valuation |
|---|---|---|---|---|---|---|
| Premature Mortality | 454 | 60 | 93 | 123 | $ 6,120,000.00 | $ 753,472,724 |
| Chronic Bronchitis | 302 | 40 | 62 | 82 | $ 331,000.00 | $ 27,107,858 |
| Acute Bronchitis | 839 | 111 | 171 | 228 | $ 57.38 | $ 13,055 |
| Hospital Admissions | 320 | 42 | 65 | 87 | $ 14,811.00 | $ 1,285,271 |
| ER Asthma Visits | 113 | 15 | 23 | 31 | $ 298.62 | $ 9,151 |
| Asthma Attacks | 9,540 | 1,266 | 1,947 | 2,587 | $ 40.79 | $ 105,527 |
| Upper Respiratory Symptoms | 9,420 | 1,250 | 1,923 | 2,555 | $ 23.83 | $ 60,874 |
| Lower Respiratory Symptoms | 8,820 | 1,170 | 1,800 | 2,392 | $ 15.07 | $ 36,045 |
| Work Days Lost | 84,000 | 11,143 | 17,146 | 22,779 | $ 105.80 | $ 2,410,045 |
| Minor Restricted Activity Days | 432,000 | 57,308 | 88,181 | 117,150 | $ 48.43 | $ 5,673,597 |
| Projected 2007 Population | 6,991,988 | 944,546 | | | | |
| % of CMSA | 100 | 13.51 | | | **Total** | **$ 790,174,146** |

| | | |
|---|---|---|
| Sulfate Component | 0.571 | (regional avg.) |
| Soil Component (non-transport) | 0.045 | (regional avg.) |
| Total Transportable Components | 0.955 | |
| Ratio of total to sulfate | 1.67 | |
| Transportable Pollutants from out of state | 0.92 | (Lowest NH rate) |
| Adjusted Ratio of power plants to all transported | 1.54 | |

| | |
|---|---|
| Hillsborough (Abt) | 374,566 |
| Merrimack (Abt) | 132,658 |
| Rockingham (Abt) | 308,542 |
| Strafford (Abt) | 128,780 |
| NH portion of Boston CMSA | 944,546 |
| Non-CMSA Counties | 355,454 |

| | |
|---|---|
| 2000 Statewide Census | 1,300,000 |
| Growth Rate Factor (assumed) | 1 |
| Estimated 2007 NH population | 1,300,000 |
| Ratio of state total to CMSA portion | 1.38 |

| | PM2.5 Mass | |
|---|---|---|
| | **% SO4-based** | **% Soil** |
| Lye Brook, VT | 57.4 | 4.5 |
| Acadia NP, ME | 56.8 | 4.5 |
| Average | 57.1 | 4.5 |
| IMPROVE Annual Average (1996-99) | | |

| | |
|---|---|
| Percent NH CMSA portion is lower than Massachusetts portion | Percent 1.8 |
| Percent northern NH is lower than NH-CMSA portion | 12.7 |

**Note: These adjustments were made because the Abt modeling used the year 1996 had larger than normal concentration changes between southern and northern New Hampshire (off by about 12%). Modeled results in the southern part of the Boston CMSA were fairly typical for 1996. Therefore, adjustments were made from Abt modeling Boston CMSA results using factors derived from 2000 - 2002 measured fine particles throughout the region.**

EPA analyses of the economic costs and benefits for the Clear Skies Act of 2003 (CSA), Clean Air Planning Act of 2002 (CAPA), and the Interstate Air Quality Rule (IAQR) are provided in Table B-4. This health benefit data was used to validate the estimates made in Table B-1. For this validation, premature mortality, chronic bronchitis and ER Asthma visits plus hospital admission incidents from Table B-1 (Total New Hampshire Estimated Incidents) were used as a benchmark to estimate what portion of EPA's total health benefits are attributable to New Hampshire. For example, using New Hampshire's 125 incidents of premature mortality to compare against the 6,400 incidents nationwide and a national $55 billion overall benefit, can give an approximated New Hampshire benefit by multiplying 125 by $55 Billion and then dividing by 6,400. Based on premature mortality factors, New Hampshire's portion of the national total health benefits is $1.07 billion per year in the year 2010. Continuing this process using the other factors for 2010

and 2020, provides a range of $1.07 to $1.17 billion for 2010, and $1.16 to $1.26 billion for 2020. These approximations are close to, but greater than the $804 million estimation provided in Table B-1, indicating that this report's best estimate is valid and conservative.

Uncertainties specific to the Abt study are summarized in Table B-5 and ranges of valuations used are listed in Table B-1.

**TABLE B-4: EPA Clear Skies and Interstate Air Quality Rule Cost and Benefit Estimations (1999$)**

| | 2010 | | | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|---|---|
| | **CSA** | **CAPA** | **IAQR** | | **IAQR** | | **CSA** | **CAPA** |
| Premature mortality | 6,400 | 9,600 | 9,622 | | 13,029 | | 11,900 | 17,800 |
| Chronic bronchitis | 3,900 | 5,800 | 5,200 | | 6,900 | | 7,400 | 10,900 |
| ER/Hospital admissions | 5,600 | 8,400 | 16,000 | | 22,500 | | 10,400 | 15,500 |
| Total Health Benefits | $55 billion | $65 billion | $57[1] billion | | $82[1] billion | | $110 billion | $140 billion |
| | | | | | | | | |
| Incremental Costs[2] | $4.4 billion | $5.6 billion | $2.9[3] billion | | $3.7[3] billion | | $6.3 billion | $8.7 billion |
| | | | | | | | | |
| Health Benefit to Cost Ratio | 13 : 1 | 12 : 1 | 20 : 1[1] | | 22 : 1[1] | | 18 : 1 | 16 : 1 |

*(Source: EPA Clear Skies 2003 and Interstate Air Quality Rule 2004 websites and NHDES)*

[1] EPA changed valuation methodology adjusting for inflation and downgrading the value of premature death by about 13%. This also affects benefit-to-cost ratios.

[2] Cost differentials are between controls already required under the Clean Air Act and completion of obligations under the proposed Act or Rule.

[3] The Interstate Air Quality Rule does not include emission controls for mercury.

**TABLE B-5: Key Areas of Uncertainty in Abt 2000 Report**

1. Uncertainties Associated with Concentration-Response Functions
   - The value of the PM-coefficient in each C-R function.
   - Application of a single C-R function to pollutant changes and populations in all locations.
   - Similarity of future year C-R relationships to current C-R relationships.
   - Correct functional form of each C-R relationship.
   - Extrapolation of C-R relationships beyond the range of PM concentrations observed in the study.

2. Uncertainties Associated with PM Concentrations
   - Estimating future-year baseline daily PM concentration.
   - Estimating the change in PM resulting from the control policy.

3. Uncertainties Associated with PM Mortality Risk
   - No scientific literature supporting a direct biological mechanism for observed epidemiological evidence.
   - Direct causal agents within the complex mixture of PM responsible for reported health effects have not been identified.
   - The extent to which adverse health effects are associated with low level exposures that occur many times in the year versus peak exposure.
   - Possible confounding in the epidemiological studies of $PM_{2.5}$ effects with other factors (e.g., other air pollutants, weather, indoor/outdoor air, etc.).
   - The extent to which effects reported in the long-term studies are associated with historically higher levels of PM rather than the levels occurring during the period of study.
   - Reliability of the limited ambient $PM_{2.5}$ monitoring data in reflecting actual $PM_{2.5}$ exposures.

4. Uncertainties Associated with Possible Lagged Effects
   - What portion of the PM-related long-term exposure mortality effects associated with changes in annual PM levels would occur in a single year, and what portion might occur in subsequent years.

5. Uncertainties Associated with Baseline Incidence Rates
   - Some baseline incidence rates are not location-specific (e.g., those taken from studies) and may therefore not accurately represent the actual location-specific rates.
   - Current baseline incidence rates may not well approximate what baseline incidence rates will be in the year 2030.
   - Projected population and demographics—used to derive incidences – may not well approximate future-year population and demographics.

6. Uncertainties Associated with Economic Valuation
   - Unit dollar values associated with health are only estimates of mean WTP and therefore have uncertainty surrounding them.
   - Mean WTP (in constant dollars) for each type of risk reduction may differ from current estimates due to differences in income on other factors.

7. Uncertainties Associated with Aggregation of Monetized Benefits
   - Health benefits estimates are limited to the available C-R functions. Thus, unquantified benefit categories will cause total benefits to be underestimated.

Source: Abt 2000

# TECHNICAL ATTACHMENT C

## OZONE HEALTH VALUATION CALCULATIONS

Table C-1 below represents the best estimate of health risk valuation for the State of New Hampshire. The estimated annual transport represents the difference between the natural (background) ozone and the actual ozone levels measured at the monitoring site. This difference can be translated into a health-related cost value using an established health valuation. A detailed methodology for the associated calculations follows this table.

**TABLE C-1: Projected Health Risk Values Due to Ozone Transport Into New Hampshire**

| County/Monitor | Estimated Annual Ozone (ppb) | Long-term Transport Factor[1] | Estimated Annual Transport (ppb)[2] | County Population (2000 census) | Estimated Annual Health Valuations for Ozone[3] (1999$) |
|---|---|---|---|---|---|
| Belknap / Laconia | 33.9 | 0.96[4] | 14.9 | 56,325 | $16,593,983 |
| Carroll / Conway | 27.5 | 0.92 | 8.4 | 43,666 | $7,242,563 |
| Cheshire / Keene | 25.6 | 0.99 | 7.1 | 73,825 | $10,360,398 |
| Coos / Pittsburg | 23.4 | 0.99 | 4.9 | 33,111 | $3,203,238 |
| Grafton / Haverhill | 27.8 | 0.99 | 9.3 | 81,743 | $15,035,162 |
| Hillsborough / Nashua | 27.3 | 0.97 | 10.4 | 380,841 | $78,630,147 |
| Merrimack / Concord | 22.0 | 0.96 | 5.3 | 136,225 | $14,241,506 |
| Rockingham / Portsmouth | 27.8 | 0.94[5] | 10.6 | 277,359 | $58,074,814 |
| Strafford / Rochester | 28.3 | 0.95 | 11.2 | 112,233 | $24,805,457 |
| Sullivan / Claremont | 27.0 | 0.99[6] | 8.5 | 40,458 | $6,780,115 |
| **State Totals** | **--** | **0.96** | **--** | **1,235,786** | **$234,967,382** |

1. *Based on 24-hour ozone mass-weighted averages derived from modeling of multiple ozone events.*
2. *Estimates for different counties were derived based on ozone season relative difference from Haverhill and Manchester.*
3. *Estimated health valuations based on $19.80 (Levy et al., 2001) applied per part per billion of annual ozone per person (1999$).*
4. *Used factor for Concord.*
5. *Used factor for Rye.*
6. *Used 0.99 as a conservative estimate since the actual factor rounded to 1.00.*

*(Sources of health data: Levy et al. December, 2001, ALA 2003)*

### Calculation Methodology

In order to apply the valuation factor calculated in the Harvard study (Levy, 2001), annual ozone concentrations are needed. New Hampshire began year-round ozone monitoring at two locations (Manchester and Haverhill) in 2001. The data collected from these locations provide the basis for interpolating annual ozone concentrations throughout the state. The data were also used to estimate how much of that ozone is naturally occurring and should, therefore, not be included in any transport calculations.

Table C-2 shows monthly ozone average concentrations at Manchester and Haverhill. In order to isolate the manmade component, the lowest daily ozone concentrations within that month were identified and shown in the table as the *low estimate of natural* ozone. This assumes that

circumstances were such that manmade ozone was not able to form under prevailing weather conditions, a conservative assumption that lessens the manmade impact valuation. Then, based on photochemical modeling of only naturally occurring emissions, maximum day-to-day ozone variations were identified to approximate the *high estimate of natural* ozone concentrations. Modeling indicated that this maximum variation was about 15 parts per billion, thus 15 ppb was added to the low-natural estimate, producing a high-natural estimate. Next, a mid-point between the high and low was calculated to approximate an average natural ozone concentration, shown as the *mid estimate of natural*. The difference between this mid-natural estimate and the monthly measured ozone concentrations (at both Manchester and Haverhill) is assumed to be the manmade component. Finally, percent transport factors determined by long-term photochemical modeling were applied to estimate the manmade ozone transported into New Hampshire at both locations.

**TABLE C-2: Estimation of Annual Ozone Transport (in parts per billion) for Haverhill and Manchester**

| **Manchester** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Avg** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measured at Manchester[1] | 20.5 | 22.5 | 27.0 | 33.0 | 30.5 | 32.8 | 31.8 | 29.8 | 22.2 | 17.5 | 14.5 | 18.0 | 25.0 |
| High Estimate of Natural[2] | 19 | 22 | 23 | 29 | 28 | 33 | 31 | 26 | 23 | 21 | 16 | 17 | 24 |
| Low Estimate of Natural[3] | 4 | 7 | 8 | 14 | 13 | 18 | 16 | 11 | 8 | 6 | 1 | 2 | 9 |
| Mid Estimate of Natural[4] | 11.5 | 14.5 | 15.5 | 21.5 | 20.5 | 25.5 | 23.5 | 18.5 | 15.5 | 13.5 | 8.5 | 9.5 | 16.5 |
| Difference of Measured and Mid Natural | 9.0 | 8.0 | 11.5 | 11.5 | 10.0 | 7.3 | 8.3 | 11.3 | 6.7 | 4.0 | 6.0 | 8.5 | 8.5 |
| Estimated transport to Manchester[5] (manmade) | 8.6 | 7.7 | 11.0 | 11.0 | 9.5 | 7.0 | 8.0 | 10.8 | 6.4 | 3.8 | 5.8 | 8.2 | **8.2** |
| **Haverhill** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Avg** |
| Measured at Haverhill[1] | 27.0 | 32.0 | 35.0 | 38.7 | 34.3 | 30.0 | 26.3 | 27.0 | 22.7 | 20.0 | 19.0 | 21.5 | 27.8 |
| High Estimate of Natural[2] | 32 | 35 | 25 | 37 | 27 | 25 | 26 | 22 | 23 | 25 | 15 | 19 | 26 |
| Low Estimate of Natural[3] | 17 | 20 | 10 | 22 | 12 | 10 | 11 | 7 | 8 | 10 | 0 | 4 | 11 |
| Mid Estimate of Natural[4] | 24.5 | 27.5 | 17.5 | 29.5 | 19.5 | 17.5 | 18.5 | 14.5 | 15.5 | 17.5 | 7.5 | 11.5 | 18.4 |
| Difference of Measured and Mid Natural | 2.5 | 4.5 | 17.5 | 9.2 | 14.8 | 12.5 | 7.8 | 12.5 | 7.2 | 2.5 | 11.5 | 10.0 | 9.4 |
| Estimated transport to Haverhill[5] (manmade) | 2.5 | 4.5 | 17.3 | 9.1 | 14.7 | 12.4 | 7.7 | 12.4 | 7.1 | 2.5 | 11.4 | 9.9 | **9.3** |

1. *Monthly average measured 24-hour ozone concentration.*
2. *High natural is assumed to be 15 ppb above the minimum (based on sensitivity DES modeling).*
3. *Low natural is derived from low measured concentration for monitor.*
4. *Mid estimate of natural is average of high and low estimates.*
5. *Transport factors for New Hampshire applied as 96% of the difference for Manchester and 99% for Haverhill and are used to assess manmade ozone (difference between mid-point estimate of natural ozone for the month and the measured amount). Calculated transport factors for each county, as determined by DES modeling of multiple ozone episodes, are used below to estimate transport of manmade ozone throughout the entire state.*

Because the majority of ozone monitors in New Hampshire operate only during the summer months when ozone is most likely to form, estimates of annual ozone are needed to better estimate statewide ozone transport. The first step in estimating annual ozone is to identify each monitor as either urban/suburban or rural in order to account for wintertime chemical reactions that can reduce ozone concentrations due to local NOx emissions. Counties in the southeast portion of the state were considered urban/suburban (Hillsborough, Merrimack, Rockingham, and Strafford). The remainder of the state was considered rural (Belknap, Carroll, Cheshire, Coos, Grafton, and Sullivan). The urban/suburban locations were linked to annual ozone monitoring at Manchester and the rural locations were linked to Haverhill. To estimate geographical ozone distribution, ratios were calculated of each county's summer ozone concentrations, relative to summer ozone levels at Manchester or Haverhill. Estimates of county specific annual ozone were determined by multiplying this ratio by the annual ozone measured at either Manchester or Haverhill. For example, the annual ozone estimate at Conway equals the Conway summer season average ozone concentration divided by the Haverhill summer season average ozone concentration and then multiplied by the Haverhill annual average ozone concentration. The mid-estimate of annual natural ozone for Manchester or Haverhill was subtracted from the annual ozone estimate to produce an estimate for the manmade ozone component in each county. Percent transport factors determined by long-term photochemical modeling were then applied to estimate the manmade ozone transported into New Hampshire. Finally, the transported manmade annual ozone component was multiplied by the Harvard valuation factor (of $19.80 per person per ppb of annual ozone) and then multiplied by the county population.

### TABLE C-3: Estimation of Annual Ozone Transport Throughout New Hampshire

Manchester 24-hour ozone — Transport percentage factor 0.96

| | Measured | Low Natural | High (Low +15) | Mid-Natural | Diff | Transported |
|---|---|---|---|---|---|---|
| jan | 20.5 | 4 | 19 | 11.5 | 9.0 | 8.6 |
| feb | 22.5 | 7 | 22 | 14.5 | 8.0 | 7.7 |
| mar | 27 | 8 | 23 | 15.5 | 11.5 | 11.0 |
| apr | 33 | 14 | 29 | 21.5 | 11.5 | 11.0 |
| may | 30.5 | 13 | 28 | 20.5 | 10.0 | 9.6 |
| jun | 32.8 | 18 | 33 | 25.5 | 7.3 | 7.0 |
| jul | 31.8 | 16 | 31 | 23.5 | 8.3 | 8.0 |
| aug | 29.8 | 11 | 26 | 18.5 | 11.3 | 10.8 |
| sep | 22.2 | 8 | 23 | 15.5 | 6.7 | 6.4 |
| oct | 17.5 | 6 | 21 | 13.5 | 4.0 | 3.8 |
| nov | 14.5 | 1 | 16 | 8.5 | 6.0 | 5.8 |
| dec | 18 | 2 | 17 | 9.5 | 8.5 | 8.2 |
| Avg | 25 | 9.0 | 24.0 | 16.5 | 8.5 | **8.2** |

Haverhill 24-hour ozone — Transport percentage factor 0.99

| | Measured | Low Natural | High (Low +15) | Mid-Natural | Diff | Transported |
|---|---|---|---|---|---|---|
| jan | 27 | 17 | 32 | 24.5 | 2.5 | 2.5 |
| feb | 32 | 20 | 35 | 27.5 | 4.5 | 4.5 |
| mar | 35 | 10 | 25 | 17.5 | 17.5 | 17.3 |
| apr | 38.7 | 22 | 37 | 29.5 | 9.2 | 9.1 |
| may | 34.3 | 12 | 27 | 19.5 | 14.8 | 14.7 |
| jun | 30 | 10 | 25 | 17.5 | 12.5 | 12.4 |
| jul | 26.3 | 11 | 26 | 18.5 | 7.8 | 7.7 |
| aug | 27 | 7 | 22 | 14.5 | 12.5 | 12.4 |
| sep | 22.7 | 8 | 23 | 15.5 | 7.2 | 7.1 |
| oct | 20 | 10 | 25 | 17.5 | 2.5 | 2.5 |
| nov | 19 | 0 | 15 | 7.5 | 11.5 | 11.4 |
| dec | 21.5 | 4 | 19 | 11.5 | 10.0 | 9.9 |
| Avg | 27.8 | 10.9 | 25.9 | 18.4 | 9.4 | **9.3** |

Ozone Season Ratio factor to Manchester (urban NOx scavenging)

| Concord | Nashua | Rochester | Rye | |
|---|---|---|---|---|
| 0.88 | 1.09 | 1.13 | 1.11 | Ratio factor |
| 22.0 | 27.3 | 28.3 | 27.8 | Est annual ozone |
| 16.5 | 16.5 | 16.5 | 16.5 | Mid-natural Manchester |
| 5.5 | 10.8 | 11.8 | 11.3 | Difference |
| 0.96 | 0.97 | 0.95 | 0.94 | Transport factor |
| **5.3** | **10.4** | **11.2** | **10.6** | Transported |

Ozone Season Ratio factor to Haverhill (rural NOx scavenging)

| Claremont | Conway | Keene | Laconia | Pittsburg | |
|---|---|---|---|---|---|
| 0.97 | 0.99 | 0.92 | 1.22 | 0.84 | Ratio factor |
| 27.0 | 27.5 | 25.6 | 33.9 | 23.4 | Est annual ozone |
| 18.4 | 18.4 | 18.4 | 18.4 | 18.4 | Mid-natural Haverhill |
| 8.5 | 9.1 | 7.2 | 15.5 | 4.9 | Difference |
| 0.99 | 0.92 | 0.99 | 0.96 | 0.99 | Transport factor |
| **8.5** | **8.4** | **7.1** | **14.9** | **4.9** | Transported |

Note: Annual ozone measured only at Manchester and Haverhill NH. Annual average ozone concentrations were estimated based on ratios established during ozone season. Urban and rural monitor areas were separated to account for NOx scavenging during winter inversions (urban areas have lower ozone). Transport factors determined by modeling.

# TECHNICAL ATTACHMENT D

## COMPARISON OF FEDERALLY PROPOSED ELECTRIC GENERATING UNIT MULTI-POLLUTANT LEGISLATION

| | $NO_x$ Caps (million tons) | $SO_2$ Caps (million tons) | Mercury Caps (tons) | $CO_2$ Caps (billion tons) | Impact on State's Rights | Estimated Annual Incremental Costs (1999$) | Estimated Annual Benefits (1999$)[4] to Health (H) and Visibility (V) |
|---|---|---|---|---|---|---|---|
| **2001 EPA Emissions[1]** (National) | 4.7 | 10.6 | 44.1[2] | 2.4 | -- | -- | -- |
| **Clear Skies of 2002** (S. 2815 & H.R. 5266) **(CSA 2002)** | 2.1 by 2008<br>1.7 by 2018 | 4.5 by 2010<br>3.0 by 2018 | 26 by 2010<br>15 by 2018 | None | Major | $3.69 Billion – 2010<br>$4.7 Billion – 2015<br>$6.49 Billion – 2020 | $43 Billion (H) – 2010<br>$93 Billion (H) - 2020 |
| **Clear Skies of 2003** (S. 485 & H.R. 999) **(CSA 2003)** | 2.1 by 2008<br>1.7 by 2018 | 4.5 by 2010<br>3.0 by 2018 | 26 by 2010<br>15 by 2018 | None | Major | $4.3 Billion – 2010<br>$4.4 Billion – 2015<br>$6.3 Billion – 2020 | $54 Billion (H) – 2010<br>$55 Billion (H) – 2015<br>$110 Billion (H) - 2020<br>$3 Billion (V) - 2020 |
| **Clean Air Planning Act** (Carper/Chafee/Gregg) (S. 3135) **(CAPA 2002)** | 1.87 by 2008<br>1.7 by 2012 | 4.5 by 2008<br>3.5 by 2012<br>2.25 by 2015 | 24 by 2008<br>10 by 2012<br>**(70% reduction at each facility)** | 2.564 by 2008<br>**(2005 levels)**<br>2.398 by 2012<br>**(2001 levels)** | Minor | $5.62 Billion – 2010<br>$8.68 Billion – 2020 | $65 Billion (H) – 2010<br>$140 Billion (H) - 2020 |
| **Clean Air Planning Act** (Carper/Chafee/Gregg/Bass) (S. 843 & H.R. 3093) **(CAPA 2003)** | 1.87 by 2009<br>1.7 by 2013 | 4.5 by 2009<br>3.5 by 2013<br>2.25 by 2016 | 24 by 2009<br>10 by 2013<br>**(70% reduction at each facility)** | 2006 levels by 2009<br>2001 levels by 2013 | Minor | $5.62 Billion – 2010<br>$8.68 Billion – 2020<br>(based on CAPA 2002) | $65 Billion (H) – 2010<br>$140 Billion (H) – 2020<br>(based on CAPA 2002) |
| **Clean Power Act (2003)** (Jeffords/Reed) (S. 366 & H.R. 2042) **(CPA 2003)** | 1.51 by 2009 | 2.25 by 2009 | 5 by 2009<br>**(with unit-by-unit controls)** | 2.05 by 2009 | None | Not Available | Not Available |
| **2001 EPA Based Emissions[1] 29-state[3]** | 3.9 | 9.7 | 35.4 | 1.9 | -- | -- | -- |
| **Clean Air Interstate Rule** (non-legislation) | 1.6 by 2010<br>1.3 by 2015 | 3.9 by 2010<br>2.7 by 2015 | None | None | None | $2.9 Billion[5] – 2010<br>$3.7 Billion[5] – 2015 | $57 Billion[6] – 2010<br>$82 Billion[6] – 2015 |

1. Clean Air Markets Division Emissions Scorecard 2001: National total for all electric generating units on EPA's Clean Air Market database including coal, oil and gas units available in Table B2. After audits and quality reviews, in April 2003 EPA revised the heat input values used to derive these emission estimates. The heat input values used to derive these emissions estimates reflect the April, 2003 update of the EPA's Clean Air Market database.

2. Mercury emissions were estimated by multiplying the EPA's revised 2001 national heat input value in the April, 2003 update of the EPA's Clean Air Market database by a national average mercury emission rate of 0.0035 lbs Hg/billion Btu from the Egrid database.

3. Under the EPA's proposed Clean Air Interstate Rule utility sources located in the State of Connecticut are controlled for ozone season NOx only.

4. (H) indicates health benefits. (V) indicates visibility benefits.

5. Does not include mercury emission controls.

6. EPA changed the valuation methodology for the Clean Air Interstate Rule from what was used for the Clear Skies Act.

# GLOSSARY
## TERMS & ACRONYMS

**AAL:** Ambient Air Limits, New Hampshire limits on ambient air pollutant concentrations of 750 regulated toxic air pollutants (RTAPs) set for the protection of public health

**Acid deposition**: the deposition of acidic chemicals onto water or land through precipitation, fog, or the settling of dry particles; the primary components of acid deposition are nitric acid ($HNO_3$) and sulfuric acid ($H_2SO_4$), which form through the reactions of nitrogen oxides (NOx) and sulfur dioxide ($SO_2$), respectively, with other chemicals in the air

**Acid Rain:** the common term for the wet forms of acid deposition

**Aerosols:** tiny liquid and/or solid particles suspended in the air

**AIRS:** Aerometric Information Retrieval System, an EPA air pollution database and information center

**ALA:** American Lung Association, a national health organization for fighting lung diseases, with emphasis on asthma, tobacco control, and environmental health

**Ambient:** the outdoor environmental conditions for the area of interest

**AMC:** Appalachian Mountain Club, an organization that promotes the protection and enjoyment of the Appalachian region through conservation, recreation, and education

**ANC:** Acid Neutralizing Capacity, a measurement of the ability of a solution to resist changes in pH by neutralizing acidic inputs; a lower ANC denotes greater sensitivity and less resistance to acidic inputs

**Anthropogenic:** made by humans, produced by human activities

**AQA:** Air Quality Analysis workgroup, an OTAG workgroup responsible for identifying, characterizing, and assessing air quality and meteorological data used to evaluate the effects of air pollution transport on ozone nonattainment in the eastern United States

**Attainment:** refers to areas in which the level of a criteria pollutant meets and does not significantly contribute to areas that do not meet the National Ambient Air Quality Standards (NAAQS) for human health

**Bioaccumulation:** the process by which a contaminant enters the body more quickly than the body can remove it

**Boundary Layer:** the lowest part of the atmosphere in which air flow is directly affected by heating and cooling processes near the surface and the presence of objects and terrain features at the surface; may vary in height depending on atmospheric conditions, particularly with respect to day/night differences in surface temperature; corresponds to the region in which pollutants are mixed

**BTU:** British thermal unit, a measure of heat; one Btu is the amount of heat required to raise one unit mass of water by one unit of temperature

**Buffering Capacity:** the ability of a solution to neutralize acidic or basic inputs and maintain its pH without becoming more acidic or basic

**CAA:** Clean Air Act, a federal law that sets air pollution limits and guides states in creating and enforcing air pollution regulations; the Clean Air Act was passed in 1963, but the current policies are based on the 1970 version and the amendments of 1990

**CAIR:** Clean Air Interstate Rule, multi-pollutant legislation proposed by EPA in December of 2003 for reducing emissions of nitrogen oxides and sulfur dioxide in District of Columbia and 29 eastern states, with a focus on states where power plant emissions significantly contribute to small particle and ozone pollution in downwind states; formally known as the Interstate Air Quality Rule (IAQR)

**CALEV:** California Low Emission Vehicle Program, emission reduction standards specific to California

**CALGRID:** California Photochemical Grid Model, a regional photochemical grid model

**CAMNET:** a network of hourly-updated, real-time visibility cameras located at scenic sites throughout the Northeast; organized by NESCAUM to raise public awareness of the effect of air pollution on visibility

**CAPA:** Clean Air Planning Act of 2003, multi-pollutant legislation proposed by Senators Carper, Chafee, and Gregg, and Congressman Bass for reducing emissions of nitrogen oxides, sulfur dioxide, mercury, and carbon dioxide through a national cap and trade program

**Cap and Trade:** a policy approach to controlling emissions that involves applying a cap, or limit, on the amount of total emissions of a specific pollutant from a group of affected sources; under this system, each source is provided a limited number of emissions allowances, each representing one ton of the pollutant, which the source may sell, trade, or save for future use

**Carbon Dioxide:** $CO_2$, a gas formed from the combustion of carbon where there is an excess of oxygen, may be produced by human activities that involve the burning of fossil fuels, forest fires, or other natural processes, such as the respiration or decay of living organisms; carbon dioxide is a major greenhouse gas that contributes to global warming through the greenhouse effect

**Carbon Monoxide:** CO, a poisonous gas formed from the combustion of carbon where there is an insufficient supply of oxygen, produced most commonly from incomplete combustion reactions in automobile engines and in smaller amounts from the incineration of organic matter; carbon monoxide inhibits oxygen uptake by red blood cells, elevated exposure can produce symptoms such as fatigue, reduced motor skills, and visual impairment, pose a risk to individuals with cardiovascular diseases, and, if concentrated without relief, can be fatal in a matter of minutes

**Channeled Flow:** middle elevation (650 to 2600 feet) air flow that may be interrupted by large-scale objects, such as mountains, hills, and valleys, but that are unaffected by lower, smaller objects, such as trees and buildings

**Class I Areas:** areas of special national interest for which the Clean Air Act provides the highest level of protection from visibility impairment; mandatory federal class I areas include national parks over 6,000 acres, wilderness areas over 5,000 acres, and international parks that existed as of August 7$^{th}$, 1977

**CMSA:** Consolidated Metropolitan Statistical Area, an area with a population of at least one million which may be divided into sub-metropolitan divisions consisting of highly urbanized areas with strong economic and social links internally and with other portions of the larger area; an example of a CMSA is the greater Boston area that includes parts of Connecticut, Maine, Massachusetts, and New Hampshire

**CO:** see "Carbon Monoxide"

**$CO_2$:** see "Carbon Dioxide"

**CPA:** Clean Power Act of 2003, multi-pollutant legislation proposed by Senators Jeffords and Reed for reducing emissions of nitrogen oxides, sulfur dioxide, and mercury, and carbon dioxide through a national cap and trade program

**Criteria Pollutants:** six principal pollutants for which EPA has established national ambient air quality standards for the protection of public health and the environment; the six criteria pollutants are ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, particulate matter, and lead

**Crustal Material:** particles of soil or dust made airborne by the grinding or stirring action of wind, weathering, construction, traffic, and other surface activities; crustal material contributes to regional haze, though, due to the larger size of these particles compared to the other haze-forming particles, it tends to drop out of the atmosphere more readily, reducing its relative contribution to haze in the eastern United States

**CSA:** Clear Skies Act of 2003, multi-pollutant legislation proposed by President Bush for reducing emissions of nitrogen oxides, sulfur dioxide, and mercury through a national cap and trade program

**Daylight Heating Hours:** the hours of the day when solar energy drives the vertical mixing of transport layers, generally 9am to 5pm

**DES:** see "NHDES"

**Diurnal Variation:** fluctuations within the day/night daily cycle

**Downwind:** in the direction toward which the wind is blowing

**EGRID:** Emissions and Generation Resource Integrated Database, an EPA database containing air quality information related to electric power generation in the United States

**EGU:** Electric Generating Unit, fossil fuel-fired combustion unit that has a generating capacity greater than 25 megawatts-electrical output (MWe) and serves a generator producing electricity for sale

**Elemental Carbon:** particles consisting of inorganic carbon compounds produced from fuel combustion, primarily as soot from diesel exhaust and wood smoke; elemental carbon contributes to regional haze, mostly through the absorption, rather than the scattering, of light, and can produce winter-time "brown clouds" visible over urban areas and in mountain valleys

**EPA:** Environmental Protection Agency, an agency of the United States federal government charged with leading the nation's environmental policy efforts

**Episode:** an air pollution incident in a given area caused by elevated concentrations of atmospheric pollutants causing a significant health hazard

**Exceedance:** pollutant levels that exceed the levels of the NAAQS and may or may not constitute a violation of the standard

**Greenhouse Effect:** the warming of the Earth's atmosphere due to the presence of certain atmospheric gases, called greenhouse gases; shorter-wavelength solar radiation from the Sun passes through greenhouse gases and is absorbed by the Earth's surface, part of the absorbed energy is then reradiated back into the

atmosphere as longer-wavelength infra-red radiation that cannot completely penetrate the greenhouse gases, these gases absorb some of the infra-red radiation, containing heat energy within the Earth's atmosphere and causing a warming effect

**Greenhouse Gas:** a gas that contributes to the warming of the Earth's atmosphere, called the greenhouse effect, by absorbing infra-red radiation radiated from the Earth's surface; the major greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and fluorocarbons

**Half-distance:** the distance traveled by a pollutant from where it is produced to the point at which its concentration has been reduced by one half; half-distance is similar to the concept of half-life in radioactivity

**HAP:** Hazardous Air Pollutants, toxic air pollutants known or suspected to cause serious health effects, such as cancer and birth defects, or have harmful environmental impacts; there are 188 EPA-regulated hazardous air pollutants, including benzene, cadmium, dioxin, and mercury

**Haze:** see "Regional Haze"

**Heavy-Duty Vehicles:** any motor vehicle, excluding passenger cars, with a weight over 6,000 lbs; examples include cargo vans, commercial trucks, and buses

**Heavy-Duty Diesel Standards:** Emissions standards set by EPA and effective in 2004 as part of a two-part strategy, the second stage beginning in 2007, for using advanced emissions controls to reduce emissions from heavy-duty vehicles, including highway trucks and buses

**Hg:** see "Mercury"

**$HNO_3$:** see "Nitric Acid"

**$H_2SO_4$:** see "Sulfuric Acid"

**IAQR:** Interstate Air Quality Rule, former name of the Clean Air Interstate Rule; see "CAIR"

**IMPROVE:** Interagency Monitoring of Protected Visual Environments, a monitoring program coordinated through a steering committee of federal, regional, and state organizations to evaluate visibility impairment in Class I areas of the United States by identifying sources and measuring the concentrations of visibility-reducing pollutants, assessing visibility conditions, and tracking progress toward national goals of visibility improvement

**Inversion:** an atmospheric condition in which temperature increases with elevation, creating a layer of warmer air that traps the underlying cooler air and is of interest because of the possibility of trapping and building up air pollutants near the ground that might otherwise be dispersed

**Jet Stream:** a relatively narrow band of strong winds that flows west to east in the upper troposphere in middle latitude and subtropical regions of both hemispheres and drives the movement of weather systems around the world

**Light-duty Vehicles:** any passenger vehicle that seats no more than 12 people; examples include passenger cars, mini-vans, and sport-utility vehicles

**LLJ:** see "Low-level Jet"

**Low-level Jet:** a ribbon of fast-moving air in the lower levels of the atmosphere; low-level jets common in the northeast generally consist of strong (40-50 mph) west to southwest winds developing during overnight and early morning hours, usually between 1,000 and 2,000 feet above ground level and flows along the eastern side of the Appalachian Mountains

**LRS:** Lower Respiratory Symptoms, such as wheezing and shortness of breath

**MACT:** Maximum Achievable Control Technology, a level of control specific to each industry source category that is required by the Clean Air Act for hazardous air pollutants based on the maximum degree of emissions reductions achievable with the available technologies for that source category

**MANE-VU:** Mid-Atlantic/Northeast Visibility Union, a regional state and tribal planning organization for coordinating regional haze planning activities in the northeastern and mid-Atlantic states established to improve visibility in Class I areas, thus meeting the EPA regional haze requirements; members include Connecticut, Delaware, District of Columbia, Maine Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, the Penobscot Indian Nation, Rhode Island, the St. Regis Mohawk Tribe, and Vermont

**MBTU:** one thousand British thermal units, a measure of heat

**MEDEP:** Maine Department of Environmental Protection

**Mercury:** a highly toxic heavy metal released into the air largely through coal and oil combustion in any of three forms: elemental mercury ($Hg_{(0)}$), oxidized mercury ($Hg_{(II)}$), and particle mercury ($Hg_{(P)}$); mercury can accumulate in the environment, especially through aquatic food chains; human ingestion of mercury, through fish consumption for example, can result in damage of the central nervous system and the brain and is a particular concern for pregnant women because mercury can reach the fetus and cause developmental problems

**MMBTU:** one million British thermal units, a measure of heat

**NAAQS:** National Ambient Air Quality Standards, national limits on ambient air pollutant concentrations set for the protection of public health and welfare by the EPA for the six criteria pollutants, including ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, particulate matter, and lead

**NARE:** North Atlantic Regional Experiment, an international research project on the effect of ozone on the chemistry of the atmosphere over the North Atlantic Ocean

**NARSTO/NE:** North American Research Strategy for Tropospheric Ozone – Northeast, the northeastern United States section of a tri-national, public-private partnership for dealing with multiple features of tropospheric pollution, including ozone and suspended particulate matter

**NASA:** National Aeronautics and Space Administration, a federal agency leading scientific and technological research and activities related to space and aeronautics

**Near Surface Flow:** low elevation (below 650 feet) air flow that is affected by nearly all surface frictional objects, including trees and buildings

**NESCAUM:** Northeast States for Coordinated Air Use Management, an interstate association of air quality control divisions in the Northeast states; member states include Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont

**NHDES:** New Hampshire Department of Environmental Services

**Nitrates:** (commonly ammonium nitrate), particles that form from reactions of nitrogen oxide gas, which is released from most combustion activities, such as through vehicle exhaust and power plant emissions; nitrates contribute to regional haze, especially in humid conditions when the accumulation of water causes the nitrate particles to grow in size and become more efficient at scattering light; nitrates may also transform into nitric acid in the atmosphere to become part of acid rain

**Nitric Acid:** $HNO_3$, produced by reactions between nitrogen oxide gases and water; a major component of acid rain

**Nitrogen Oxides:** (or oxides of nitrogen), NOx, the result of the oxidation of nitrogen, usually created by the intense heating of naturally occurring nitrogen in the air; a major component of photochemical smog, a precursor to the formation of ground level ozone, may lead to nitrate deposition and acid deposition

**Nocturnal Boundary Layer:** a fairly shallow (about 650 feet or less), stable layer with calm or light winds that forms low to the ground during the nighttime hours when surface cooling creates an inversion within which temperature increases with elevation

**Non-EGU:** Non-electric Generating Unit, a fossil fuel-fired combustion unit that has a maximum heat input rating greater than 250 million British thermal units per hour (mmBTU/hr) and does not serve a generator producing electricity for sale or that has a generating capacity of 25 MWe or less and serves a generator producing electricity for sale

**Non-road Engines:** mobile source engines that are not used for transport by road or highway; examples include agricultural equipment, construction equipment, utility generators and pumps, lawn and garden equipment, airport baggage transport vehicles, marine engines, snowmobiles, locomotives, and non-military aircraft; also called off-road engines

**Northeast Corridor:** a region along the East Coast that encompasses Washington DC, Baltimore, Philadelphia, New York, and Boston; the Northeast Corridor is a common path for ozone transport moving up the coast into the New England states

**Nonattainment:** refers to areas which measure or significantly contribute to areas that measure criteria pollutant concentrations failing to meet the National Ambient Air Quality Standards (NAAQS) for human health

**NOx:** see "Nitrogen Oxides"

**NOy:** total reactive nitrogen oxides, NOy includes aged and oxidized NOx species

**NSR:** New Source Review, a federal program under the Clean Air Act that sets control requirements and emission limits for the construction of new major sources and for major modifications to existing sources that will result in a significant increase in emissions; NSR requires facilities to obtain a clean air permit demonstrating use of the best available control technology on the new or modified source

**$O_3$:** see "Ozone"

**Off-road Engines:** see "Non-road Engines"

**Ohio River Valley:** the area surrounding the Ohio River, which follows the northern borders of West Virginia and Kentucky and the southern borders of Ohio, Indiana, and Illinois, flowing from Pittsburgh, Pennsylvania to Cairo, Illinois, where it meets the Mississippi River near the junction of the Illinois, Missouri, and Kentucky borders; this region has a high density of coal-fired power plants

**On-road Engines:** mobile source engines that are used for transport by road or highway; examples include

passenger cars, passenger vans, sport-utility vehicles, trucks, buses, and motorcycles

**Organic Carbon:** particles consisting of compounds in which carbon is bonded to hydrogen that may be emitted directly or produced through reactions of gaseous hydrocarbons that are emitted from sources such as vehicle exhaust, vehicle refueling, solvent evaporation, and industrial processes; organic carbon is the second largest contributor to regional haze in the eastern United States

**OTAG:** Ozone Transport Assessment Group, a national workgroup for addressing issues related to ground-level ozone and long-range air pollution transport across the eastern United States; formed in 1995 to investigate the existence and nature of ozone transport, OTAG conducted extensive modeling and statistical analyses to describe the patterns of transport and aid in the development of strategies for downwind areas to reach ozone attainment; OTAG members include the 37 eastern-most states and other interested stakeholders field area; the effort concluded in 1997

**OTC:** Ozone Transport Commission, a regional organization established by Congress in 1990 to address the problem of ozone transport in the northeastern and mid-Atlantic states; members include Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and a northeastern section of Virginia

**OTC NOx MOU:** Ozone Transport Commission NOx Memorandum of Understanding, an agreement signed in September of 1994 by members of the Ozone Transport Commission, except Virginia, for reducing regional NOx emissions through a cap and trade system applied to utilities and large industrial boilers in the Ozone Transport Region (OTR) for two target years, 1999 and 2003, for the purpose of lessening ozone pollution in the OTR

**OTR:** Ozone Transport Region, the portion of the northeastern and mid-Atlantic region of the United States that consists of the members of the Ozone Transport Commission

**Ozone:** $O_3$, a molecule consisting of three oxygen atoms bonded together; ozone exists naturally in the stratosphere as a protective and insulating layer that absorbs ultra violet (UV) radiation from the sun; ozone also occurs naturally in small amounts at ground level but most ground level ozone is the result of anthropogenic pollution and is generated through photochemical reactions among its precursors, volatile organic compounds and nitrogen oxides, in the presence of sunlight; ground level ozone is a major component of photochemical smog and can cause damage to the respiratory system

**Ozone Aloft:** Ozone present at about 2000 feet or more above ground level

**Ozone Response Curve:** a theoretical curve describing the relationship of how ozone responds to varying levels of its precursor species, nitrogen oxides and volatile organic compounds

**PAMS:** Photochemical Assessment Monitoring Stations, monitoring stations required under the 1990 Clean Air Act Amendments for serious, severe, and extreme ozone nonattainment areas that collect detailed data on ozone and its precursors, nitrogen oxides and volatile organic compounds

**pH:** a measurement of acidity or alkalinity on a scale of 1 to 14, where 7 is neutral, less than 7 is acidic, and greater than 7 is alkaline (basic); pH is the negative log10 of the hydrogen ion concentration

**Photochemical Smog:** a visible cloud of air pollution usually composed of ozone, organic compounds, nitrogen oxide gases, particles, and/or sulfate particles

**Photosynthesis:** the process of converting light energy into chemical energy; green plants and other photosynthetic organisms use light energy, carbon dioxide, and water to synthesize sugars and other energy-rich organic compounds and release oxygen as a by-product

**Plume:** a visible concentration of pollutants that appears as an elongated band, whose shape and behavior varies under different atmospheric conditions, that is released into the atmosphere from an identifiable point of origin

**$PM_{2.5}$:** suspended particles less than 2.5 micrometers in diameter; small particles can cause respiratory damage, may be toxic or carcinogenic, and are a component of regional haze

**$PM_{10}$:** coarse suspended particles between 2.5 and 10 micrometers in diameter; large particles of this size are small enough to be inhaled into the lungs, although less readily than the smaller $PM_{2.5}$, and can exacerbate respiratory problems, especially in areas close to the source, since the larger, heavier particles tend to stay airborne for shorter distances than the very fine particles

**Precursor:** a compound that, under the necessary conditions, will react to form a new product; for example, nitrogen oxides and volatile organic compounds will react in sunlight to create ozone and thus are both ozone precursors

**Regional Haze:** reduced visibility resulting from the scattering and absorption of light by particles and gases in the air; the five principal types of small particles contributing to haze in the eastern United States are

sulfates, organic carbon, nitrates, elemental carbon or soot, and crustal material

**Regulatory Certainty:** the passage of laws that aid businesses in planning cost-effective, long-term control strategies by providing insight into the types of control regulations that are expected to be put in place in future years based on the direction of current policy

**Residence Time:** the length of time a pollutant is present in the air in its current physical and chemical form

**ROM:** Regional Oxidant Model, a first generation photochemical model

**RTAP:** Regulated Toxic Air Pollutants, 750 toxic air pollutants that pose a significant risk to human health and/or the environment and for which the state of New Hampshire has set ambient air limits (AALs); this list of pollutants includes and expands upon the federally-regulated list of hazardous air pollutants (HAPs)

**Sea Breeze:** a coastal breeze blowing inland from the sea, caused by temperature differences between sea and land surfaces; when the land is warmed by the sun, the air begins to rise and is replaced by cooler air from over the water

**SeaWiFS:** Sea-viewing Wide Field-of-view Sensor Project, a NASA project that utilizes an Earth-orbiting ocean color sensor to collect quantitative data on global ocean bio-optical properties that is incorporated into a research data system for processing, calibrating, validating, archiving, and distributing the data to the Earth science community

**SIP:** State Implementation Plan, a set of regulations and planning materials assembled by a state and approved by the EPA that outlines the state strategy for implementing air pollution controls and meeting air quality standards and other requirements under the Clean Air Act

**Small Particles:** see "$PM_{2.5}$"

**Smog:** see "Photochemical Smog"

**Soot:** carbon-containing particles released during incomplete combustion of organic materials; see also "Elemental Carbon"

**STAPPA/ALAPCO:** State and Territorial Air Pollution Administrators/Association of Local Air Pollution Control Officials, two national associations that work closely together to enhance communication and coordination among air pollution officials of the federal, state, and local levels across the United States; STAPPA is an organization of the leadership of state, territorial, and tribal air pollution control agencies; ALAPCO is an organization of the leadership of city, county, and regional air pollution control agencies

**Stratosphere:** the layer of the atmosphere directly above the troposphere, usually between 10 and 30 miles above the Earth; this level contains the naturally-occurring ozone layer

**Sulfates:** (commonly ammonium sulfate), particles that form from reactions of sulfur dioxide gas, which is released from coal burning and other industrial sources; sulfates, primarily as ammonium sulfates, are the largest component of fine particulate matter contributing to haze in the eastern United States, especially in humid conditions when the accumulation of water causes the sulfate particles to grow in size and become more efficient at scattering light; sulfates may also transform into sulfuric acid in the atmosphere to become part of acid rain

**Sulfur Dioxide:** $SO_2$, the principally emitted form of the sulfur oxide gas; sulfur dioxide can cause or aggravate respiratory problems, and it is a major contributor to regional haze and acid deposition

**Sulfuric Acid:** $H_2SO_4$, produced by reactions between sulfur oxide gases and water; a major component of acid rain

**Synoptic Flow:** high elevation (above 2600 feet) air flow that is almost exclusively directed by large-scale weather systems and is unaffected by large-scale frictional ground level objects such as mountains, valleys, and lakes

**Tier II Standards:** Emissions standards set by EPA and effective in 2004 for all light-duty vehicles, including passenger cars, light trucks, minivans, and SUVs; the new standards average 0.07 grams per mile of nitrogen oxides and are a significant reduction from previous standards

**Trajectory:** the path followed a moving air mass, often used as a back trajectory to go back in time to see where the air came from

**TBTU:** one trillion British thermal units, a measure of heat

**Troposphere:** the lowest layer of the atmosphere, extending up to about ten miles above the Earth; this level contains most of the manmade air pollutants

**UAM-V:** Urban Airshed Model, a three-dimensional photochemical grid model and the primary model used in the OTAG analyses

**UMD:** University of Maryland

**Upwind:** in the direction <u>from</u> which the wind is blowing

**Urban Airshed:** an area surrounding a city or highly populated area in which the air is frequently confined with all parts of the area being subject to similar

conditions of urban air pollution derived mainly from motor vehicles, industrial plants, combustion and heating plants, etc.

**URS:** Upper Respiratory Symptoms, such as sore throat and runny or stuffed nose

**VA/HUD:** Veteran Affairs/Housing and Urban Development, departments of the United States Federal Government

**VOC:** see "Volatile Organic Compounds"

**Volatile Organic Compounds:** VOC, numerous species of organic compounds or hydrocarbons that change into a vapor at a relatively low temperature; may be hazardous by themselves and may contribute to ozone and haze formation

**VTDEC:** Vermont Department of Environmental Conservation

**Wind Field:** the speed and direction of the wind over an area at any given time, may be visually represented by wind flags overlaying a map

**WTP:** Willingness To Pay, the amount that someone is willing to pay to acquire a good or service or achieve a certain result

**Zero-threshold Pollutant:** a pollutant for which no level of exposure is considered safe due to health effects proven to occur at levels far below the current national ambient air quality standards; primary examples are ozone and small particles

# REFERENCES


1. Abt Associates Inc., ICF Consulting, E.H. Pechan Associates, Inc., *The Particulate Related Health Benefits of Reducing Power Plant Emissions*, Report prepared for Clean Air Task Force, October 2000
[Web address: http://www.catf.us/publications/reports/Abt_PM_report.pdf].

2. American Lung Association, *State of the Air: 2003*, 2003.

3. Blumenthal, D. L., F.W. Lurmann, N. Kumar, T. S. Dye, S. E. Ray, M. E. Korc, R. Londergan & G. Moore, *Assessment of Transport and Mixing and OTAG Model Performance for Northeast U.S. Ozone Episodes: Summary of Results,* March 1997 [Web address: http://capita.wustl.edu/otag/Reports/otagsum3.html].

4. Clinton, Memorandum for the Administrator of the Environmental Protection Agency, "Implementation of Revised Air Quality Standards for Ozone and Particulate Matter," July 16, 1997.

5. Colburn and MacGillivray, NHDES, "Answering the '2-6 ppb' Question: Do NOx Reductions Upwind Really Only Reduce Long-Range Transport That Little?," April 18, 1997.

6. Colburn, NHDES, "Apportioning Relative Culpability," May 14, 1997.

7. Driscoll, C., Lawrence, G., Bulger, A., Butler, T., Cronan, C., Eager, C., Lambert, K., Likens G., Stoddard, J., Weathers, K., "Acid Rain Revisited, Advances in Scientific Understanding Since the Passage of the 1970 and 1990 Clean Air Act Amendments", Hubbard Brook Research Foundation. Science Links Publication. Vol. 1, no.1.

8. Earth Tech, "Assessment of UAM-V Performance in Northeast Region for OTAG Episodes," March 1997.

9. Earth Tech, *Photochemical Grid Modeling of Four High Ozone Episodes in the New England Domain: CALGRID vs. UAM-IV, Draft*, 1997.

10. Ferullo, "Critique of OTAG Model Performance Related to Ozone Transport into the Northeast," April 16, 1997.

11. Florida Department of Environmental Protection, *"Integrating Atmospheric Mercury Deposition with Aquatic Cycling in South Florida"*, Oct. 2002, Revised Nov. 2003.

12. Gent, J., Triche, E., Holford, T., Belanger, K., Bracken, M., Beckett, W., Leaderer, B., "Association of Low-Level Ozone and Fine Particles With Respiratory Symptoms in Children With Asthma", JAMA, Vol. 290, No. 14, October 8, 2003.

13. Golomb, D., Ryan, D., Eby, N., Underhill, J., Zemba, S., "Atmospheric Deposition of Toxics Onto Massachusetts Bay – I. Metals", Atmospheric Environment, Vol. 31, No. 9, September 1997.

14. Golomb, D., Ryan, D., Underhill, Wade, T., J., Zemba, S., "Atmospheric Deposition of Toxics Onto Massachusetts Bay – II. Polycyclic Aromatic Hydrocarbons", Atmospheric Environment, Vol. 31, No. 9, September 1997.

15. Guinnup, D. & B. Collum, *Final Report*, *Vol. I: Executive Summary, OTAG Air Quality Analysis Workgroup: Telling the OTAG Ozone Story with Data,* June 2, 1997 [Web address: http://capita.wustl.edu/otag/Reports/aqafinvol_I].

16. Husar and Renard, "Ozone as a Function of Local Wind Direction and Wind Speed: Evidence of Local and Regional Transport," May 7, 1997.

17. Husar, R. B., *Spatial Pattern of Daily Maximum Ozone Over the OTAG Region*, 1996 [Web address: http://capita.wustl.edu/otag/Reports/Otagspat/otagspat.html].

18. Levy, J.; Carrothers, T.; Tuomisto, J.; Hammitt, J.; and Evans, J., *"Assessing the Public Health Benefits of Reduced Ozone Concentrations,"* Environmental Health Perspectives, Volume 109, No., 12, December 2001.

19. MacGillivray and Colburn, NHDES, "Assessment and Apportionment of Ozone Culpability," March 24, 1997.

20. Malm, W., "Introduction to Visibility", Cooperative Institute for Research in the Atmosphere (CIRA), National Park Service Program, Cooperative Agreement CA2350-97-001: T097-04, T098-06, May 1999.

21. Massachusetts Department of Environmental Protection, Div. of Air Quality Control (MA DEP), *Progress Report for the New England Domain Ozone Attainment Demonstration,* Feb. 1997.

22. ME DEP, *Overwhelming Transport Demonstration for the State of Maine,* 1996.

23. Miller, P., *An Approach to Estimating Downwind Ozone Contributions Based on OTAG UAM-V Subregional Modeling,* 1997.

24. Morris, R., *Review of Existing Ozone Measurement and Modeling Studies in the Eastern United States*, Environ, Inc., Feb. 1996.

25. National Research Council, *Rethinking the Ozone Problem in Urban and Regional Air Pollution,* National Academy Press, 1991.

26. NESCAUM, "The Long-Range Transport of Ozone and Its Precursors in the Eastern United States," February 1997.

27. NHDES, Mt. Washington Monitor Data Summaries, August 1997.

28. NHDES, *New Hampshire 1-Hour Ozone Attainment Demonstration*, http://www.des.state.nh.us/ard/sip.htm, 1998.

29. NHDES, *New Hampshire Clean Power Strategy, http://www.des.state.nh.us/ard/pdf/NHCPS.pdf, January, 2001.*

30. NHDES, *New Hampshire Petition Under Section 126 of the Clean Air Act for Abatement of Excessive Emissions*, http://www.des.state.nh.us/ard/126index.htm, August 14, 1997.

31. NHDES, Underhill, MacGillivray, Percent Culpability Plots - July 1995 Episode, July 22, 1997.

32. NHDES, Underhill, J, *CALGRID Modeling Overview, A First Look*, OTC Annual Meeting, Philadelphia, PA, July 22, 2003.

33. NHDES, Underhill, J, *Identifying Likely Source Regions for Air Pollution In and Near New England Class I Areas*, Regional Air Quality Modeling and Data Analysis Meeting, Baltimore, MD, January 23, 2002.

34. NHDES, Underhill, J, *Understanding Air Pollution Transport*, OTC Annual Meeting, Essex Junction, VT, August 6, 2002.

35. Northeast States for Coordinated Air Use Management (NESCAUM), *The Long- Range Transport of Ozone and its Precursors in the Eastern United States,* March 1997.

36. OTAG AQA Workgroup Final Report, Vol. I: Executive Summary, "Telling the OTAG Story with Data," June 1997.

37. OTAG Final Recommendations, June 1997.

38. OTAG, Round 2 Modeling, "Assessing the Role of Ozone Transport, Observational and Modeling Analysis," 1996.

39. Poirot, R., "Data Analyses for Contribution Assessments", presentation given at the MANE-VU State Implementation Plan Meeting in Manchester, NH, April 22-23, 2002.

40. Poirot, R., Wishinski, P., Hopke, P., Polissar, A., "Sources of Fine Particle Concentration and Composition in Northern Vermont," Presented at: International Symposium on Measuremetn of Toxic and Related Air Pollutants, Research Triangle Park, NC, September 12-14, 2000.

41. Poirot, R. & P. Wishinski, *VT DEC Air Trajectory Analysis of Long -Term Ozone Climatology: Status Report to OTAG AQA Workgroup*, Aug. 15, 1996 [Web address: http://capita.wustl.edu/otag/Reports/vtdecair.html].

42. Poirot, R. & P. Wishnski, *VT DEC Air Trajectory Analysis of Long -Term Ozone Climatology: Status Report to OTAG AQA Workgroup*, Nov. 7, 1996 [Web address: http://capita.wustl.edu/otag/Reports/VTTRAJ5/StatusReport1.html].

43. Poirot, R. & P. Wishinski, *VT DEC Air Trajectory Analysis of Long -Term Ozone Climatology: Status Report to OTAG AQA Workgroup*, Dec. 3, 1996 [Web address: http://capita.wustl.edu/otag/Reports/Status_Dec96/Status-Dec96.html].

44. Pope, A.; Burnett, R.; Thurston, G.; Thun, M.; Calle, E.; Krewski, D.; and Godleski, J. *"Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution. Epidemiological Evidence of General Pathological Pathways of Disease,"* Journal of the American Heart Association, December 15, 2003.

45. Porter, P.S., S. T. Rao, E. Zalewsky, I. Zurbenko, R. F. Henry & J. Y. Ku, *Statistical Characteristics of Spectrally-Decomposed Ambient Ozone Time Series Data*, 1996 [Web address: http://capita.wustl.edu/otag/Reports/StatChar/otagrep.html].

46. Ray, J.D., R.L. Heavner, Flores, M., & Michaelsen, C., *Surface Level Measurements of Ozone and Precursors at Coastal and Offshore Locations in the Gulf of Maine,* J. Geophys. Res. 101: 29,005, 1996.

47. Ryan, W.F.; Dodridge, B.G.; Dickerson, R.R.; Morales, R.M.; Hallock, K.A.; Roberts, P.T.; Blumenthal, D.L.; Anderson, J.A.; Civerolo, K.L. *"Pollutant Transport During a Regional $O_3$*

*Episode in the Mid-Atlantic States,"* Journal of the Air & Waste Managemet Association; 48, 786-797, 1998.

48. Sonoma Technology, Inc., Earth Tech, "Initial Results on Transport and Mixing Based on NARSTO-Northeast Data," January 28, 1997.

49. Smith, M., "*Transboundary Air Pollution: Enforcing the Clean Air Act,*" New Hampshire Bar Journal, December, 2001.

50. Sullivan, T., Lipfert, F., Morris, S., Renninger, S., "Assessing the Mercury Health Risks Associated with Coal-Fired Power Plants: Impacts of Local Depositions," Brookhaven National Laboratory report, 2004.

51. U.S. PIRG, *Darkening Skies, Trends Toward Increasing Power Plant Emissions*, March 2002.

52. UMD, Transport Presentation shared with OTC, 2003.

53. USEPA Staff Report, *Preliminary Assessment of States Making a Significant Contribution to Downwind Ozone Nonattainment,* April 1997.

54. USEPA, *S3135 Clean Air Planning Act of 2002 Presentation for Jeff Holmstead*, November 2002.

55. USEPA, Clear Skies website, http://www.epa.gov/clearskies/, 2003.

56. USEPA, *Criteria for Assessing the Role of Transported Ozone/Precursors in Ozone Nonattainment Areas*, EPA-450/4-91-015, May 1991.

57. USEPA, Office of Air and Radiation, "EPA's Revised Ozone Standard," July 17, 1997.

58. USEPA, Office of Air and Radiation, "EPA's Updated Clean Air Standards," July 16, 1997.

59. USEPA, Office of Air and Radiation, "Implementation of the Standards," June 25, 1997.

60. USEPA, "Study of Hazardous Air Pollutant Emissions from Electrical Utility Steam Generating Units – Final Report to Congress," 1998.

61. Van Atten, C, *Economic Modeling of MultiPollutant Legislation*, OTC Meeting, Philadelphia, PA, July 22, 2003.

62. White, W. H., J. A. Anderson, D. L. Blumenthal, R. B. Husar, N. V. Gillani, J. D. Husar, & W. E. Wilson, Jr., *Formation and Transport of Secondary Air Pollutants: Ozone and Aerosols in the St. Louis Urban Plume*, Science 194: 187, 1976.

63. Whitelaw, E. (editor), (with numerous University economist signatories), *"A letter from Economists to President Bush and the Governors of Eleven Western States Regarding the Economic Importance of the West's Natural Environment,"* December 3, 2003.

## Additional Contributors

The following provided support in providing graphics, research, or consultation beyond references listed above.

Tom Downs, Maine Department of Environmental Protection

Stephen Zemba, Cambridge Environmental
Jeffrey Stehr, University of Maryland
Philip Johnson, Gary Kleiman and George Allen, NESCAUM
Tad Aburn, Maryland Department of Environmental Protection

## Report Editors (NHDES)

Jeffrey Underhill
Kathleen Brockett
James Black
Andrew Bodnarik