

5. Assessment of Baseline and Natural Conditions (with Class I Areas)

5.1 Requirements, Data, and Methodology

Under the Clean Air Act, the Regional Haze SIPs must contain measures to make reasonable progress toward the goal of achieving natural visibility. Each state containing a Class I area must determine baseline and natural visibility conditions for their Class I area(s) in consultation with FLMs and states identified as containing sources whose emissions contribute to visibility impairment in Class I areas. Comparing baseline conditions to natural visibility conditions determines the uniform rate of progress that must be considered as states set reasonable progress goals for each Class I area.

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program was initiated in 1985 to establish current visibility conditions, track changes in visibility, and help determine the causes of visibility impairment in Class I Areas. IMPROVE stands for Interagency Monitoring and Protected Visual Environments. IMPROVE data was used to calculate baseline and natural conditions for MANE-VU Class I areas.

Data from the following IMPROVE monitors (see the table below) is representative of Class I Areas in Maine¹². As described in the Monitoring Section of this SIP, Maine accepts the IMPROVE designation of these sites as representative of Class I areas in Maine in accordance with 40 CFR Section 51.308(d)(2)(i).

Table 5-1
IMPROVE Information for Maine Class I Areas

Class I Area	IMPROVE Site	Location (latitude and longitude)
Acadia National Park	ACAD1	44.38, -68.26
Moosehorn Wilderness Area and Roosevelt Campobello International Park	MOOS1	45.13, -67.27

Source: VIEWS (<http://vista.circa.colostate.edu/views/>), prepared on 7/06/06

In September 2003, EPA issued guidance for the calculation of natural background and baseline visibility conditions. The guidance provided a default method and describes certain refinements that states may wish to evaluate in order to tailor these estimates to a

¹² The IMPROVE program has utilized representative monitoring since its inception, since man-made structures such as monitoring sites are restricted in national wilderness areas. Since regional haze sources and impacts are distributed over broad geographic regions, a representative monitoring site does not need to be located in close proximity to the Class I area being represented. For additional information see "Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States: Report III, Chapter 1 (<http://vista.cira.colostate.edu/improve/Publications/Reports/2000/2000.htm>).

specific Class I area if it is poorly represented by the default method. At that time, NESCAUM calculated natural visibility for each of the MANE-VU Class I areas using the default method for the 20 percent best and worst days. NESCAUM also evaluated ways to refine the estimates. Potential refinements included: increasing the multiplier used to calculate impairment attributed to carbon, adjusting the formula used to calculate the 20 percent best and worst visibility days, and accounting for visibility impairment due to sea salt at coastal sites. However, MANE-VU found that these refinements did not significantly improve the accuracy of the estimates and MANE-VU states desired a consistent approach. Therefore, default estimates were used with the understanding that use of the default methodology would be reconsidered as better scientific understanding warranted.

Once the technical analysis was complete, MANE-VU provided an opportunity to comment to federal agencies and stakeholders. The proposed approach was posted on the MANE-VU website on March 17, 2004 and a stakeholder briefing was held on the same day. Comments were received by Electric Power Research Institute, Midwest Ozone Group, the Appalachian Mountain Club, the National Parks Conservation Association, the National Park Service, and the U.S. Forest Service.

Several commenters supported the proposal and other comments addressed four main topics: the equation used to calculate visibility, the statistical technique used to estimate the 20 percent best and worst visibility days, the inclusion of transboundary effects and fires, and the timing of when new information should be included. All comments were reviewed and summarized by MANE-VU, and member state's Air Directors were briefed on comments, proposed response options, and implications.

The MANE-VU position on natural background conditions was issued in June 2004, and stated that, "Refinements to other aspects of the default method (e.g., refinements to the assumed distribution or treatment of Rayleigh extinction, inclusion of sea salt, and improved assumptions about the chemical composition of the organic fraction) may be warranted prior to submission of SIPs depending on the degree to which scientific consensus is formed around a specific approach..."

In 2006, the IMPROVE Steering Committee adopted an alternative reconstructed extinction equation to revise certain aspects of the default method. The aspects revised were scientifically well understood, and the Committee determined that revisions improved the performance of the equation at reproducing observed visibility at Class I sites.

In 2006, NESCAUM conducted an assessment of the default and alternative approaches for calculation of baseline and natural background conditions at MANE-VU Class I areas, and the baseline and natural conditions reported herein were calculated using the alternative method approved by the IMPROVE Steering Committee in 2006 (See the MANE-VU document, "Baseline and Natural Background Visibility Conditions: Considerations and Proposed Approach to the Calculation of Baseline and Natural Background Visibility Conditions at MANE-VU Class I Areas", (Attachment G).

MANE-VU will continue to participate in further research efforts on this topic and will reconsider the calculation methodology as scientific understanding evolves.

5.2 Maine Baseline Visibility

The IMPROVE program has calculated the 20 percent worst baseline (2000-2004) and 20 percent best baseline conditions for each IMPROVE monitoring site at MANE-VU Class I Areas. These values are posted on the Visibility Information Exchange Web System (VIEWS) operated by the Regional Planning Organizations (available online at <http://vista.cira.colostate.edu/views/>). The values for the Maine Class I areas can be seen below in Table 5-2. Table 5-2 lists the baseline visibility for the 20 percent worst visibility days as a five-year average for 2000-2004 using the alternative IMPROVE algorithm approved in 2006 by the IMPROVE Steering Committee.

Table 5-2
Baseline Visibility for the 20 Percent Worst Days and 20 Percent Best Days for Five Years (from 2000-2004) in Maine Class I Areas

Class I Area (IMPROVE Monitor)	Year	20 Percent Worst Days Deciviews (dv)	20 Percent Best Days Deciviews (dv)
Acadia National Park	2000	21.64	8.89
	2001	23.28	8.87
	2002	23.91	8.77
	2003	23.65	8.77
	2004	21.98	8.56
	<i>Five Year Average</i>		22.89
Moosehorn Wilderness Area and Roosevelt Campobello International Park	2000	20.63	8.93
	2001	22.13	9.3
	2002	23.06	9.12
	2003	22.5	9.48
	2004	20.28	8.93
	<i>Five Year Average</i>		21.72

Source: VIEWS (<http://vista.cira.colostate.edu/views>), prepared on 10/16/07

5.3 Natural Visibility

A five year average (2000 to 2004) visibility in deciviews was calculated for each MANE-VU Class I area for the 20 percent best and 20 percent worst days in accordance with 40 CFR 51.308(d)(2) and detailed in the NESCAUM Baseline and Natural Background document found in Attachment G. The deciview visibility for the worst and best days are based on calculations and data included in Attachment G of this SIP.

Natural visibility represents the visibility for each Class I area representative of the conditions before human activities affected air quality in the area. Certain natural phenomena can reduce visibility. The Clean Air Act goal is to remedy visibility impairment resulting from human activity.

Table 5-3 displays the baseline visibility for the 20 percent worst and the 20 percent best visibility days based on the five-year average for 2000-2004, natural visibility for the 20 percent worst and the 20 percent best visibility days, and the difference between baseline and natural visibility conditions for the Maine Class I areas.

**Table 5-3
Summary of Baseline Visibility and Natural Conditions for the 20 Percent Worst
and 20 Percent Best Visibility Days for Maine Class I Areas**

Class I Area	2000-2004 Baseline (dv)		Natural Conditions (dv)		Difference (dv)	
	Worst 20 %	Best 20 %	Worst 20 %	Best 20 %	Worst 20 %	Best 20 %
Acadia National Park	22.89	8.77	12.43	4.66	10.46	4.11
Moosehorn Wilderness Area and Roosevelt Campobello International Park	21.72	9.15	12.01	5.01	9.71	4.14

Source: VIEWS (<http://vista.circa.colostate.edu/views/>), prepared on 6/22/2007

6. Monitoring Strategy

In the mid-1980's, the IMPROVE program (Interagency Monitoring of Protected Visual Environments) was established to measure visibility impairment in mandatory Class I areas throughout the United States. The monitoring sites are operated and maintained through a formal cooperative relationship between the U.S. EPA, National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Forest Service. In 1991, several additional organizations joined the effort: State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials (which now goes by The National Association of Clean Air Agencies), Western States Air Resources Council, Mid-Atlantic Regional Air Management Association, and Northeast States for Coordinated Air Use Management.

Data collected at these sites are used by land managers, industry planners, scientists, public interest groups, and air quality regulators to understand and protect the visual air quality resource in Class I areas. Most importantly, the IMPROVE program scientifically documents for American citizens, the visual air quality of their wilderness areas and national parks. Program objectives include:

- Establish current visibility and aerosol conditions in mandatory Class I areas.
- Identify chemical species and emission sources responsible for existing anthropogenic visibility impairment.
- Document long-term trends for assessing progress towards the national visibility goals.
- Provide regional haze monitoring representing all visibility-protected federal Class I areas where practical, as required by EPA's Regional Haze Rule.

6.1 Federal Regional Haze Monitoring Requirements

Section 51.308(d)(4) of EPA's Regional Haze Rule requires a monitoring strategy for measuring, characterizing, and reporting regional haze visibility impairment that is representative of all mandatory Class I Areas within the State of Maine. The monitoring strategy relies upon participation in the Interagency Monitoring of Protected Visual Environments (IMPROVE) network.

The State of Maine participates in IMPROVE network, and will evaluate the monitoring network periodically and make those changes needed to be able to assess whether reasonable progress goals are being achieved in each of Maine's mandatory Class I Areas. Maine is committing to continued support of the IMPROVE network at Acadia National Park and Moosehorn National Wildlife Refuge.

40 CFR 51.308(d)(4)(i) requires states to establish additional monitoring sites or equipment as needed to assess whether reasonable progress goals are being achieved

toward visibility improvement at mandatory Class I areas. At this time, the current monitors are sufficient to make this assessment. Maine's commitment to maintain the current level of monitoring, and to expand monitoring and/or analysis should such action become necessary, will remain contingent on federal funding assistance.

40 CFR Section 51.308(d)(4)(ii) requires the inclusion of procedures by which monitoring data and other information are used in determining the contribution of emissions from within the State to regional haze visibility impairment at mandatory Class I Federal areas both within and outside the State. MANE-VU and the State of Maine accept the contribution assessment analysis completed by NESCAUM entitled, "Contributions to Regional Haze in the Northeast and Mid-Atlantic States." (See Attachment A). We agree that NESCAUM is providing quality technical information by using the IMPROVE program data and the VIEWS site. Information about the use of the default and alternative approaches to the calculation of baseline and natural background conditions can be found in Section 5 "Assessment of Baseline, Natural and Current Conditions" of this SIP.

Maine commits to meet the requirements under 40 CFR Section 51.308(d)(4)(iv) to report to EPA visibility data for each of Maine's Class I Areas annually.

40 CFR Section 51.305 requires each state containing a mandatory Class I Federal area to include in its SIP a strategy for evaluating reasonably attributable visibility impairment (RAVI) in any such Class I Area by visual observation or other appropriate monitoring techniques. The plan must provide for the consideration of available visibility data and must provide a mechanism for its use. This requirement does not apply to the State of Maine because no specific sources have been identified as subject to RAVI requirements.

40 CFR Section 51.308(d)(4)(v) requires a statewide inventory of emissions of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in mandatory Class I Federal areas within the State of Maine. The Emissions Inventory Section (Section 8) of this SIP addresses this requirement.

EPA's Regional Haze Rule (40 CFR Section 51.308(d)(4)(vi)) requires the inclusion of other monitoring elements, including reporting, recordkeeping, and other measures, necessary to assess and report visibility. While the State of Maine feels that the current IMPROVE network provides sufficient data to adequately measure and report progress toward the goals set for MANE-VU Class I sites that we contribute to, Maine has also found additional monitoring information useful to assess visibility and fine particle pollution in the region in the past. Examples of these data include results from the MANE-VU Regional Aerosol Intensive Network (RAIN), which provides continuous, speciated information on rural aerosol characteristics and visibility parameters; the EPA Clean Air Status and Trends Network (CASTNET), which has provided complementary rural fine particle speciation data at non-class I sites; the EPA Speciation Trends Network (STN), which provides speciated, urban fine particle data to help develop a comprehensive picture of local and regional sources; state-operated rural and urban speciation sites using IMPROVE or STN methods; and the Supersites program, which has provided information through special studies that generally expands our

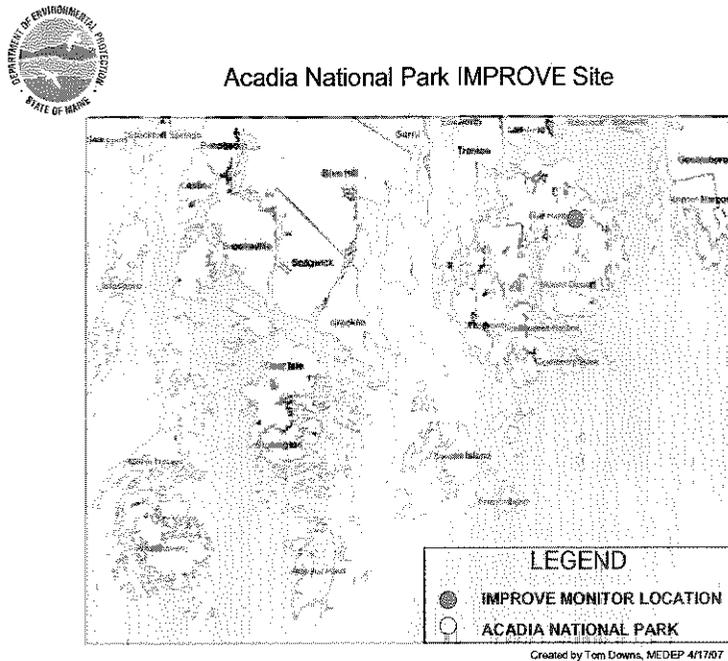
understanding of the processes that control fine particle formation and transport in the region. Maine will continue to utilize these and other data -- as they are available and fiscal realities allow -- to improve our understanding of visibility impairment and to document progress toward our reasonable progress goals under the Regional Haze Rule.

6.2 Monitoring Information for MANE-VU Class I Areas

6.2.1. Acadia National Park, Maine

The IMPROVE monitor for Acadia National Park (indicated as ACAD1) is located at Acadia National Park Headquarters in Maine at an elevation of 157 meters, a latitude of 44.38° and a longitude of -68.26°. The haze data for Acadia National Park is collected by an IMPROVE monitor (ACAD1) that is operated and maintained by the National Park Service. The State considers the ACAD1 site as adequate for assessing reasonable progress goals of Acadia National Park and no additional monitoring sites or equipment are necessary at this time. The State routinely participates in the IMPROVE monitoring program by sending regional representatives to the IMPROVE meetings.

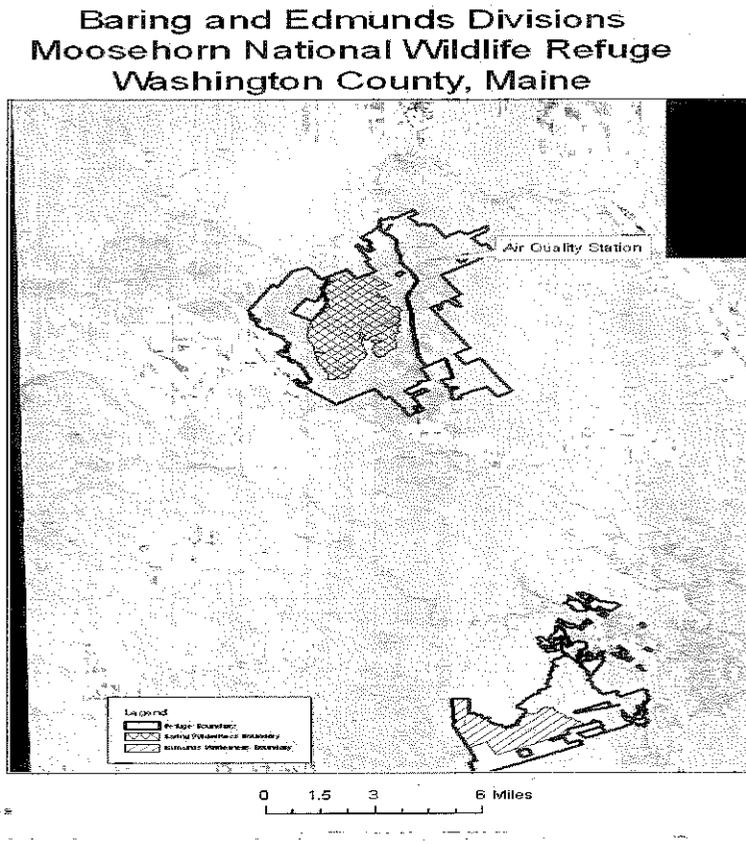
Figure 6-1
Map of Acadia National Park



6.2.2. Moosehorn Wilderness Area, Maine

The IMPROVE monitor for the Moosehorn Wilderness Area (indicated as MOOS1) is located near McConvey Road, about one mile northeast of the National Wildlife Refuge Baring Unit Headquarters in Maine at an elevation of 78 meters, a latitude of 45.13° and a longitude of -67.27°. This monitor also represents the Roosevelt Campobello International Park in New Brunswick, Canada. The haze data for Moosehorn Wilderness Area is collected by an IMPROVE monitor (MOOS1) that is operated and maintained by the Fish & Wildlife Service. The State considers the MOOS1 site as the only current IMPROVE monitoring site in Maine adequate for assessing reasonable progress goals of the Moosehorn Wilderness Area and no additional monitoring sites or equipment are necessary at this time. The State routinely participates in the IMPROVE monitoring program by sending regional representatives to the IMPROVE meetings.

Figure 6-2
Map of the Baring and Edmunds Divisions of the Moosehorn National Wildlife Refuge and the IMPROVE Monitor

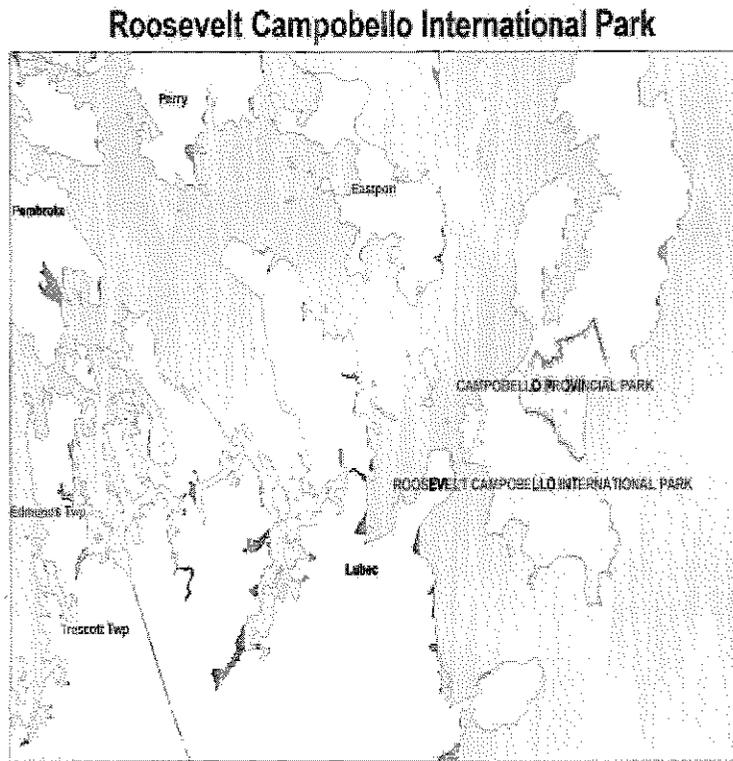


(source: The Refuge Manager at Moosehorn Wilderness Area)

6.2.3. Roosevelt Campobello International Park, New Brunswick, Canada

The IMPROVE monitor for the Moosehorn Wilderness Area is also the monitor for Roosevelt Campobello International Park (indicated as MOOS1) (see section 6.2.2, above). The State considers the MOOS1 site as the only current IMPROVE monitoring site in Maine or Canada adequate for assessing reasonable progress goals of Roosevelt Campobello International Park. No additional monitoring sites or equipment are necessary.

**Figure 6-3
Map of Roosevelt Campobello International Park**



7. Sources of Visibility Impairing Pollutants and Contribution Assessment

7.1 Visibility Effects of Particulate Matter

Visibility impairment in the eastern United States is primarily due to the presence of fine particles in the atmosphere which absorb and scatter light. Visibility impairing particle-light interactions are sensitive to the chemical composition of the particles involved, and also depend strongly on ambient relative humidity. Secondary particles, which form in the atmosphere through chemical reactions, are generally smaller than one micrometer (μm) which is the size range that is most effective at scattering visible light¹³.

The degree of visibility impairment is expressed in deciviews, a unit-less value. The calculation of visibility impairment utilizes two equations, one to calculate light extinction coefficient (B_{ext}), and then its transformation into visibility impairment as expressed in deciviews (dv). The latest equation,¹⁴ approved by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Steering Committee, to calculate light extinction coefficient is:

The Extinction Equation

$$\begin{aligned} B_{\text{ext}} = & 2.2 \times f_s(\text{RH}) \times [\text{Small Sulfate}] + 4.8 \times f_L(\text{RH}) \times [\text{Large Sulfate}] \\ & + 2.4 \times f_s(\text{RH}) \times [\text{Small Nitrate}] + 5.1 \times f_L(\text{RH}) \times [\text{Large Nitrate}] \\ & + 2.8 \times [\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}] \\ & + 10 \times [\text{Elemental Carbon}] + 1 \times [\text{Fine Soil Mass}] \\ & + 1.7 \times f_{\text{ss}}(\text{RH}) \times [\text{Sea Salt Mass}] + 0.6 \times [\text{Coarse Mass}] \\ & + \text{Rayleigh Scattering (Site Specific)} + 0.33 \times [\text{NO}_2 \text{ (ppb)}] \end{aligned}$$

Where:

B_{ext} = The light extinction coefficient in inverse megameters [Mm^{-1}]

$f_s(\text{RH})$ and $f_L(\text{RH})$ = Humidity factor associated with small and large mode mass size distributions

$f_{\text{ss}}(\text{RH})$ = Humidity factor associated with Sea Salt

The on-site air monitoring of visibility causing pollutants by the IMPROVE monitoring network is discussed in more detail in Section 6 of this document. In the extinction equation, total sulfate, nitrate and organic carbon compound concentrations are each divided into two particle size fractions, representing small and large size particle components. Site-specific Rayleigh scattering is calculated by IMPROVE for the

¹³ The particles that contribute most to visibility impairment are also of concern under the health-based National Ambient Air Quality Standard (NAAQS) for fine particulate matter, which is defined as all particles with an aerodynamic diameter less than 2.5 μm .

¹⁴ Review of the IMPROVE Equation for Estimating Ambient Light Extinction Coefficients - Final Report Jenny L. Hand and William C. Malm, March 2006

elevation of the site as well as annual average temperature of each IMPROVE monitoring site.

Once light extinction is calculated, visibility levels (in deciviews (dv)) can be calculated. The deciview equation is as follows:

The Deciview Equation

$$\text{Deciviews (dv)} = 10 \ln (b_{\text{ext}}/10)$$

Where:

\ln is the natural log function and B_{ext} is calculated using the IMPROVE equation previously described. The calculated deciviews are unit-less values where the higher the value, the greater amount of visibility impairment exists.

The extinction and deciview equations were used to calculate the baseline and projected visibility impairment at Acadia National Park, Moosehorn Wilderness Area and Roosevelt Campobello International Park, and to set the progress goals as established in this Document.

7.2 Pollutants Contributing to Visibility Impairment at Class I Areas

The pollutants primarily responsible for fine particle formation, and contributing to regional haze, include SO_2 , NO_2 , VOCs, NH_3 , PM_{10} , and $\text{PM}_{2.5}$. The MANE-VU Contribution Assessment (Attachment A) develops a conceptual model for regional haze in the Northeast and Mid-Atlantic states that identifies sulfate as the single most important constituent of haze forming fine particle pollution, and the principal cause of visibility impairment across the Northeast region. Sulfate alone accounts for anywhere from one-half to two-thirds of total fine particle mass on the 20 percent haziest days at all MANE-VU Class I sites, and 40 percent or more of total fine particle mass on the 20 percent clearest days.

After sulfate, organic carbon (OC) consistently accounts for the next largest fraction of total fine particle mass, contributing from 20-30 percent of total fine particle mass on the haziest days. Relative contributions to overall fine particle mass from nitrate (NO_3), elemental carbon, and fine crustal material (i.e., soil) are all smaller, generally under 10 percent of the total, with relative ranking of the three species varying with location. Nitrate plays a noticeably more important role at urban sites compared to Northeastern and Mid-Atlantic Class I sites.

Almost all particle sulfate originates from sulfur dioxide (SO_2) oxidation¹⁵ and typically associates with ammonium (NH_4) in the form of ammonium sulfate ($(\text{NH}_4)(\text{SO}_4)$).

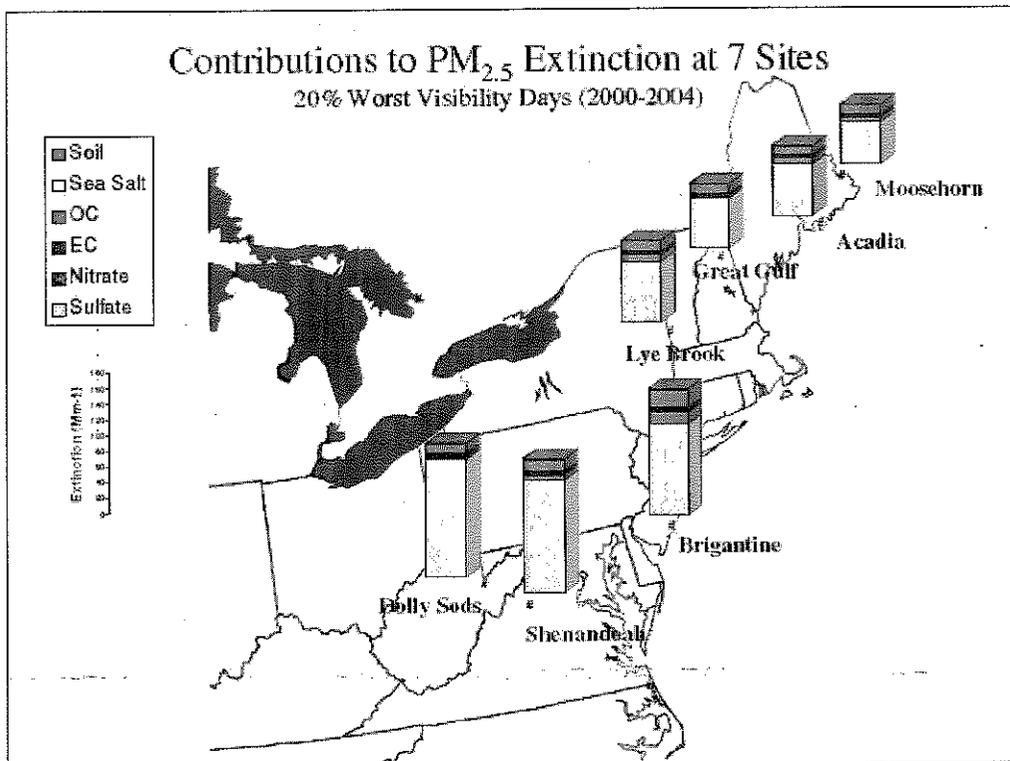
¹⁵ Sulfate is produced from SO_2 in the atmosphere under two major pathways. In the gas phase, SO_2 is oxidized to sulfuric acid (H_2SO_4), ammonium bisulfate (NH_4HSO_4), or ammonium sulfate, depending on the availability of ammonia (NH_3). In the presence of small wet particles (typically smaller than fog), an aqueous phase process can oxidize SO_2 to sulfate extremely quickly (@ 10 percent per hour).

Approximately 95 percent of SO₂ emissions are from anthropogenic sources (primarily fossil fuel combustion), while the majority of ammonium comes from agricultural activities.

Sulfate is not only the dominant contributor to fine particle mass in the region, but also accounts for anywhere from 60 percent to almost 80 percent of the difference between fine particle concentrations on the clearest and haziest days at Northeastern and Mid-Atlantic Class I sites, including those in Maine. Some of the dominant components of total fine particle mass have an even larger effect when considering the differential visibility impacts of different particle species. Sulfate typically accounts for more than 70 percent of estimated particle-induced light extinction at Northeastern and Mid-Atlantic sites. Organic carbon is the second most important contributor to particle-induced light extinction on days with the greatest visibility impairment, with nitrate being the third greatest contributor to regional haze at Class I sites in the MANE-VU region, including those in Maine.

Figure 7-1 shows the dominance of sulfate in visibility extinction calculated from 2000-2004 baseline data for seven Northeast Class I Areas.

Figure 7-1
Contributions to PM_{2.5} Extinction at Seven Class I Areas



Given the dominant role of sulfate in the formation of regional haze in the Northeast and Mid-Atlantic Regions, MANE-VU concluded that an effective emissions management approach would rely heavily on broad-based regional SO₂ control measures in the eastern United States. The focus on SO₂ as MANE-VU's first priority makes sense not only because of its dominant role in regional haze but also because its emission sources are well understood. Moreover, the control measures needed for SO₂ emission reductions are readily available, cost-effective, and could be implemented quickly. On the basis of the scientific evidence, it is apparent that the bulk of haze-causing pollution can be eliminated by pursuing SO₂ emission controls.

Organic carbon was found to be the next largest contributor to haze after sulfate, however, in comparison with sulfate, the emission sources of organic carbon are diverse, variable, more diffuse, and less well understood. Organic carbon particulates can be emitted as a primary organic aerosol, or they can be formed as a secondary organic aerosol. Secondary organics are formed when volatile organic compound (VOC) emissions react with oxides of nitrogen in the presence of sunlight to form ozone, which acts as a catalyst for particulate formation. VOCs may also condense to form particulate organic carbon. For these reasons, MANE-VU considered organic carbon to be the subject of possible future control measures but not a specific target pollutant in the initial strategy to mitigate regional haze.¹⁶

7.3 Geographic Considerations and Haze Contribution Attribution

As noted in the Contribution Assessment (Attachment A), high levels of particle pollution in the eastern United States often causes hazy conditions extending over thousands of square kilometers (km²). As a result, visibility is often impaired at even the most remote and pristine Class I areas.

To better identify the sources of visibility impairing pollutants, the MANE-VU Contribution Assessment utilized a variety of modeling, air quality data analysis, and emissions inventory analysis techniques to identify source categories and states that contribute to visibility impairment in MANE-VU and nearby Class I areas. The analytical and assessment tools utilized for the Contribution Assessment include Eulerian (grid-based) source models, Lagrangian (air parcel-based) source dispersion models, and a variety of data analysis techniques including source apportionment models, back trajectory calculations, and the use of monitoring and inventory data. Table 7-2 below, summarizes the methodological approaches of these analytical tools.

¹⁶ Although sulfur is the primary regional haze pollutant of concern for this SIP, Maine has taken measures to address organic carbon emissions, primarily from residential wood burning activities. These measures are discussed in Section 12 "Long-Term Strategy."

Table 7-2
Summary of Technical Approaches for Attributing State Contributions to
Observed Sulfate in MANE-VU Class I Areas

Analytical Technique	Approach
Emissions/distance	Empirical
Incremental probability	Lagrangian trajectory technique
Cluster-weighted probability	Lagrangian trajectory technique
Emissions × upwind probability	Empirical/trajectory hybrid
Source apportionment approaches	Receptor model/trajectory hybrid
REMSAD tagged species	Eulerian source model
CALPUFF with MM5-based meteorology	Lagrangian source dispersion model
CALPUFF with observation-based meteorology	Lagrangian source dispersion model

7.3.1 Review of Technical Approaches

The MANE-VU Contribution Assessment and Appendices (Attachments A, A-1, A-2, A-3 and A-4) provide a detailed description of the multiple technical approaches used to assess regional haze (sulfate) contributions to the MANE-VU region. Following is a summary of four of these techniques.

I. Emissions/Distance

The emissions/distance empirical technique calculates the ratio of annual emissions (Q) to source-receptor distance (d), with the ratio (Q/d) which is then multiplied by a factor to account for the frequency effect of prevailing winds.¹⁷ The geographic domain of the sources included in the Q/d study consisted of U.S. states in the CENRAP, MANE-VU, VISTAS, and MRPO regions. Canadian provinces in the lower eastern region were also included. The categories of SO_2 emission sources included in this analysis were area sources (e.g., residential boilers and heaters), non-road mobile sources (e.g., tractors and construction vehicles), and point sources (e.g., industrial smokestacks and power

¹⁷ Aggregated over long periods of time and large geographic areas, the total atmospheric sulfate contribution from a specific source, state, or region should be approximately proportionate to its SO_2 emissions. For specific receptor locations, like a Class 1 visibility area, relative impacts decrease with increasing distance from the source. Impacts diminish over distance as pollutants are dispersed in the atmosphere and removed through deposition. For non-reactive primary pollutant emissions, the relationship between atmospheric concentrations and distance (d) can be approximated as a function of $1/d^2$. For secondary pollutants like sulfate, reductions in ambient concentrations that occur as a result of dispersion and deposition mechanisms are partially offset by the formation of secondary aerosol such that an increasing fraction of the remaining downwind sulfur is converted to aerosol sulfate. In these cases, the effects of distance are better characterized by the function $1/d$. During regional sulfate episodes when sulfur conversion rates are enhanced by the presence of gas and aqueous-phase oxidants, pollutant concentrations decline even less rapidly with distance as accelerated aerosol formation rates work to both generate more sulfate and reduce the remaining sulfur available for deposition (deposition rates are roughly an order of magnitude slower for sulfate than for SO_2).

generation facilities). Results were calculated for seven receptors in the MANE-VU and VISTAS regions including: Acadia National Park, Brigantine Wilderness in the Forsythe Wildlife Preserve, Dolly Sods Wilderness, Lye Brook Wilderness, Moosehorn Wilderness, Presidential Range-Dry River Wilderness, and Shenandoah National Park.

To calculate the impact that each state had on a given receptor, the area and nonroad SO₂ emission sources were summed across the entire state, and the distance to the receptor site for those emission sources was calculated based on that state's geographic center, adjusted for population density. In this way, the area and non-road emissions were treated as a single point source located at the population-weighted center of each state. These impacts were then added to the impact of the point sources that were calculated individually. The sum of area, non-road, and point source impacts for each state was used to compare the contributions relative to other states in the eastern U.S. and parts of Canada.

The principal contributors to the MANE-VU receptors, according to this method, include the Midwestern states of Indiana and Ohio, as well as Pennsylvania and New York. This is due not only to the large emissions from these states, but also to the predominantly westerly winds that carry Midwest pollution eastward. Table 7-3 shows the relative contribution of eastern states and Canadian provinces on several receptor sites in the region.

Table 7-3
Annual average Sulfate Impact from Q/D (%)

RPO	STATE	ACADIA	BRIGANTINE	DOLLY SODS	GREAT GULF	LYE BROOK	MOOSEHORN	SHENANDOAH
CANADA		8.89	7.11	3.90	14.84	12.43	7.85	4.75
CENRAP		0.88	1.12	1.58	1.65	1.67	0.82	1.48
MANE-VU		36.17	34.83	14.81	27.83	31.78	30.08	20.59
MANE-VU	Connecticut	0.75	0.53	0.04	0.46	0.55	0.55	0.06
	Delaware	0.96	3.20	0.30	0.63	0.93	0.71	0.61
	District of Columbia	0.01	0.04	0.01	0.01	0.02	0.01	0.04
	Maine	6.54	0.16	0.01	2.33	0.31	6.01	0.02
	Maryland	2.29	4.96	2.39	1.82	2.68	1.80	4.64
	Massachusetts	10.11	2.73	0.13	3.11	2.45	6.78	0.35
	New Hampshire	2.25	0.60	0.04	3.95	1.68	1.74	0.06
	New Jersey	1.49	4.04	0.27	0.69	1.44	1.05	0.46
	New York	4.74	5.57	1.32	5.66	9.02	3.63	2.03
	Pennsylvania	6.81	12.64	10.23	8.30	11.72	5.55	12.05
	Rhode Island	0.28	0.10	0.01	0.11	0.06	0.19	0.01
Vermont	0.13	0.06	0.00	0.41	0.95	0.09	0.01	
MIDWEST		11.98	18.16	20.26	20.10	21.48	10.40	26.84
MIDWEST	Illinois	1.37	1.62	2.56	2.62	2.42	1.50	2.47
	Indiana	2.13	3.29	5.40	3.94	3.93	2.02	5.23
	Michigan	2.02	2.77	3.24	3.66	3.67	1.74	3.20
	Ohio	5.62	9.11	17.95	6.33	9.95	4.62	14.67
	Wisconsin	0.35	1.16	1.08	1.42	1.49	0.72	1.07
VISTAS		8.48	21.99	36.75	12.04	13.66	6.69	33.86
VISTAS	Alabama	0.32	1.07	2.13	0.65	0.81	0.25	1.77
	Georgia	0.67	2.32	3.71	1.27	1.31	0.56	3.47
	Kentucky	1.17	2.22	4.59	1.69	2.22	0.96	4.34
	Mississippi	0.01	0.04	0.03	0.03	0.04	0.01	0.07
	North Carolina	1.45	4.19	4.29	1.86	1.89	1.14	4.76
	South Carolina	0.43	1.69	1.04	0.64	0.58	0.58	1.30
	Tennessee	0.61	1.56	3.41	1.11	1.23	0.50	2.73
	Virginia	1.48	4.30	2.82	1.52	1.95	1.43	6.20
West Virginia	2.35	4.59	14.39	2.96	3.64	1.75	9.19	
OTHER		33.79	16.78	12.70	23.54	18.99	44.17	12.48
TOTAL (ug/m ³)		2.026	3.444	3.667	1.780	2.137	1.767	3.919

From: Table 8.2 of *Contributions to Regional Haze in the Northeast and Mid-Atlantic United States, NESCAUM, 2006*

II. Emissions Times Upwind Probability

Another empirical approach utilized in the Contribution Assessment is the emissions times upwind probability technique, which multiplies the back-trajectory calculated residence time probability for a grid cell with the total emissions (over the same time period) for that grid cell¹⁸. This technique results in an emissions-weighted probability field that can be integrated within state boundaries to calculate the relative probabilities of each state contributing to pollution transport. Table 7-4 illustrates the average ranked contributions to several MANE-VU and VISTAS Class I areas.

**Table 7-4
Annual Average Sulfate Impact from the Emissions x Upwind Probability
Technique**

RPO	STATE	ACACIA	BRIGANTINE	DOLLY SODS	GREAT GULF	LYE BROOK	MOOSEHORN	SHENANDOAH
CANADA		15.24	6.70		19.29	15.91	13.45	4.33
CENRAP		1.89	1.77		1.73	1.66	1.52	1.72
CENRAP	Arkansas	0.12	0.24		0.15	0.15	0.15	0.20
	Iowa	0.38	0.27		0.27	0.26	0.26	0.25
	Kansas	0.00	0.00		0.00	0.00	0.00	0.00
	Louisiana	0.04	0.06		0.06	0.04	0.04	0.09
	Minnesota	0.56	0.33		0.38	0.44	0.44	0.23
	Missouri	0.20	0.65		0.37	0.75	0.62	0.95
	Texas	0.00	0.00		0.00	0.00	0.00	0.00
MANE-VU		18.33	25.63		20.94	25.36	15.23	11.36
MANE-VU	Connecticut	0.51	0.27		0.52	0.59	0.40	0.10
	Delaware	0.20	1.26		0.34	0.42	0.28	0.24
	District of Columbia	0.12	0.29		0.11	0.14	0.12	0.24
	Maine	1.48	0.06		0.68	0.26	1.53	0.05
	Maryland	1.22	3.06		1.31	1.21	0.96	2.29
	Massachusetts	1.10	0.33		0.88	0.81	0.90	0.10
	New Hampshire	1.21	0.17		1.48	0.72	0.77	0.08
	New Jersey	1.02	0.01		0.99	1.29	0.76	0.49
	New York	4.80	3.48		6.80	9.06	4.23	1.44
	Pennsylvania	6.21	10.71		7.10	19.26	5.07	6.33
	Rhode Island	0.11	0.05		0.08	0.06	0.09	0.02
Vermont	0.14	0.03		0.37	0.23	0.10	0.01	
MIDWEST		17.36	19.55		20.87	21.63	15.56	22.03
MIDWEST	Illinois	3.79	3.47		3.31	3.74	3.22	3.76
	Indiana	3.37	4.26		4.33	4.13	3.21	5.09
	Michigan	2.73	2.07		3.03	3.27	2.34	1.80
	Ohio	6.19	8.65		8.73	8.23	5.77	10.64
	Wisconsin	1.26	1.00		1.25	1.25	1.02	0.76
VISTAS		13.40	29.37		14.14	16.43	10.07	48.06
VISTAS	Alabama	0.72	1.32		0.63	0.71	0.39	2.14
	Georgia	1.46	3.21		1.06	1.54	0.72	4.73
	Kentucky	2.65	4.71		3.59	3.83	2.31	7.82
	Mississippi	0.04	0.10		0.06	0.06	0.03	0.12
	North Carolina	1.26	4.25		0.92	0.59	1.16	6.11
	South Carolina	0.72	1.64		0.42	0.41	0.44	1.62
	Tennessee	1.05	1.91		1.04	1.16	0.65	2.67
	Virginia	1.80	4.63		1.43	1.67	1.32	6.45
West Virginia	3.74	7.31		4.94	6.05	2.81	16.39	
OTHER SM		33.79	16.78	12.70	23.54	18.99	44.17	12.48

From: Table 8.5 of Contributions to Regional Haze in the Northeast and Mid-Atlantic United States, NESCAUM, 2006

¹⁸ A back trajectory is the path that an air parcel is calculated to have taken prior to arriving at a given receptor. The back trajectories utilized in this analysis were 72 hours in length, and have calculated endpoints, or locations, that specify the air mass path at hourly intervals. The endpoints from all trajectories were mapped into a matrix of residence times spent in the individual grid cells over the five year study period, with the result providing the likelihood that air spent time in a particular grid cell. By then multiplying the "residence time" by the MANE-VU SO₂ emission inventory for the grid cell, the contribution of each grid cell (and state) can be calculated.

III. REMSAD Tagged Species Modeling

Table 7-5 displays the results of an Eulerian source model (the REMSAD model) used to assess state-by-state and regional contributions to annual sulfate impacts in nine Class I areas. The Regional Modeling System for Aerosols and Deposition (REMSAD) is a three-dimensional Eulerian model designed to support a better understanding of the distributions, sources, and removal processes relevant to fine particles and other airborne pollutants. It calculates the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations. The basis for the model is an atmospheric diffusion equation representing a mass balance in which all of the relevant emissions, transport, diffusion, chemical reactions, and removal processes are expressed in mathematical terms.

Table 7-5
Average Annual Sulfate Impact at Northeast Class I Areas as Modeled Using REMSAD

RPO	STATE	ACADIA	BRIGANTINE	DOLLY SODS	GREAT GULF	LYE BROOK	MOOSEHORN	SHENANDOAH
CANADA		8.69	7.11	3.90	14.84	12.43	7.85	4.75
CENRAP		0.88	1.12	1.58	1.65	1.67	0.82	1.48
MANE-VU		36.17	34.83	14.81	27.83	31.78	30.08	26.59
MANE-VU	Connecticut	0.76	0.53	0.04	0.48	0.55	0.56	0.08
	Delaware	0.98	3.20	0.30	0.63	0.93	0.71	0.61
	District of Columbia	0.01	0.04	0.01	0.01	0.02	0.01	0.04
	Maine	6.54	0.16	0.01	2.38	0.31	8.01	0.02
	Maryland	2.20	4.88	3.39	1.92	2.66	1.60	4.84
	Massachusetts	10.11	2.73	0.18	3.11	2.45	6.78	0.35
	New Hampshire	2.25	0.60	0.04	3.95	1.68	1.74	0.06
	New Jersey	1.49	4.04	0.27	0.69	1.44	1.03	0.48
	New York	4.74	5.57	1.32	5.65	9.09	3.83	2.03
	Pennsylvania	6.81	12.84	10.23	6.30	11.72	5.53	12.05
	Rhode Island	0.23	0.10	0.01	0.11	0.06	0.19	0.01
Vermont	0.13	0.06	0.00	0.41	0.95	0.09	0.01	
MIDWEST		11.98	18.16	30.26	20.10	21.48	10.40	26.84
MIDWEST	Illinois	1.37	1.82	3.56	2.52	2.42	1.30	2.47
	Indiana	2.13	3.29	5.40	3.94	3.92	2.02	5.23
	Michigan	2.02	2.77	3.24	3.66	3.67	1.74	3.20
	Ohio	5.62	9.11	17.98	6.33	8.98	4.62	14.87
	Wisconsin	0.85	1.16	1.88	1.42	1.43	0.72	1.07
VISTAS		8.49	21.99	36.75	12.04	13.65	6.69	33.86
VISTAS	Alabama	0.32	1.07	2.13	0.55	0.81	0.25	1.77
	Georgia	0.87	2.33	3.71	1.27	1.31	0.56	3.47
	Kentucky	1.17	2.22	4.89	1.99	2.22	0.96	4.34
	Mississippi	0.01	0.04	0.08	0.03	0.04	0.01	0.07
	North Carolina	1.45	4.19	4.29	1.88	1.89	1.14	4.78
	South Carolina	0.43	1.69	1.04	0.64	0.55	0.56	1.30
	Tennessee	0.61	1.56	3.41	1.11	1.23	0.50	2.73
	Virginia	1.43	4.30	2.82	1.52	1.95	1.13	6.20
	West Virginia	2.35	4.59	14.38	2.98	3.84	1.75	9.19
OTHER		33.79	16.78	12.70	23.54	16.99	44.17	12.48
TOTAL (ug/m ³)		2.026	3.444	3.867	1.789	2.137	1.767	3.919

From: Table 8.1 of Contributions to Regional Haze in the Northeast and Mid-Atlantic United States, NESCAUM, 2006.

As in the empirical analytical techniques, the REMSAD model identifies the States of Ohio, New York, and Pennsylvania as the predominant contributors to visibility impairment at MANE-VU Class I areas, including those in Maine. Unlike the

previously-described empirical approaches, the REMSAD model identifies Maine as the single greatest contributor to visibility impairment at Maine Class I areas.¹⁹

IV. CALPUFF

A fourth approach to contribution assessment is the use of a dispersion model such as CALPUFF. CALPUFF is commonly used to study the impacts of pollutant plumes or specific point source emissions on surrounding areas. While the geographic scale of these models has traditionally been limited to a few hundred kilometers because of a perceived lack of ability to accurately reproduce horizontal dispersion beyond these distances, recent advances in the CALPUFF system have resulted in improved performance over much greater distances. The Contribution Assessment provides specific information related to two CALPUFF platforms that have been developed for MANE-VU by the Vermont Department of Environmental Conservation (VT DEC) Air Pollution Control Branch and by the State of Maryland's Department of the Environment (MDE) and Department of Natural Resources (MDNR). The two platforms, one using MM5 meteorological inputs, and the other National Weather Service (NWS)-based meteorological data, were used to model the entire 2002 calendar year. These simulations have been configured to provide estimates for both individual source impacts and cumulative state impacts, and to allow for inter-platform comparisons.²⁰ The following table (Table 7-6) illustrates the contribution of emissions from individual states to overall sulfate levels at Acadia National Park.²¹ Once again, Ohio, New York, Indiana and Pennsylvania are among the greatest contributors to sulfate levels at Maine Class I areas. Unlike the previous contribution assessment techniques, Massachusetts is identified as a major contributor to visibility impairment in Maine by the CALPUFF modeling.

7.3.2 Summary of Analytical Techniques for Contribution Assessment

By normalizing the results of the four different empirical and modeling techniques summarized above, MANE-VU was able to identify those states having the largest influence on sulfate levels at each Class I site. Figure 7-2, below, compares the normalized results using different techniques for ranking state contributions to sulfate levels at Acadia National Park. While there is some variation in the contribution estimates among the different assessment techniques employed, there is a general consistency of results from one method to another.

¹⁹ It should be pointed out that the listed values for VISTAS, CenRAP, and Canada understate the actual percentage contributions from those regions because they count only emissions originating within the modeling domain (see Table 7-5). Actual contributions, especially in the case of CenRAP, would be considerably higher than stated. Differences between actual and stated values are aggregated into "Other" category. These findings highlight the importance of emissions from outside MANE-VU to visibility impairment inside the region.

²⁰ Overall, the CALPUFF modeling results to date demonstrate reasonably good comparability between the two platforms but they also suggest a consistent pattern of under prediction for one platform relative to the other.

²¹ See Attachment A-4 for the ranked contribution of emissions from individual states to overall sulfate levels at Moosehorn NWR and other MANE-VU Class I areas.

Table 7-6
Contribution to Sulfate Levels at Acadia National Park Using the CALPUFF Model

STATE	NWS-based Meteorology (VI DEC)				MAE-based Meteorology (A, D, E, A, D, N, E)			
	CEM FT	Non-CEM FT	Area/ Molec	TOTAL FT	CEM FT	Non-CEM FT	Area/ Molec	TOTAL FT
AL(a)	0.0008	0.0013	0.0002	0.0023	0.0139	0.0009	0.0011	0.0159
AR(a)	0.0009	0	0	0.0009	0.0004	0.0000	0.0010	0.0008
CT	0.0041	0.0012	0.0003	0.0056	0.0074	0.0011	0.0072	0.0156
DC	0.0001	0.0001	0.0002	0.0004	6.9E-01	0.0001	0.0003	0.0004
DE	0.0007	0.0002	0.0002	0.0011	0.0093	0.0000	0.0010	0.0119
GA(a)	0.0140	0.0000	0.0000	0.0140	0.0200	0.0000	0.0019	0.0299
IA	0.0007	0.0002	0.0001	0.0010	0.0140	0.0000	0.0000	0.0159
IL	0.0040	0.0007	0.0004	0.0051	0.0486	0.0172	0.0000	0.0638
IN	0.0700	0.0000	0.0001	0.0701	0.1000	0.0119	0.0000	0.1119
KS(a)	0.0001	0	0	0.0001	0.0007	0.0000	0.0010	0.0017
KY	0.0411	0.0004	0.0002	0.0417	0.0000	0.0000	0.0000	0.0417
MA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MD	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ME	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MO	0.014	0	0	0.014	0.0010	0.0000	0.0000	0.0150
MS(a)	0	0.0002	0.0000	0.0002	0	0.0000	0.0000	0.0002
NC	0.0040	0.0001	0.0004	0.0045	0.0000	0.0000	0.0000	0.0045
ND(a)					0	0.0000	0.0000	0.0000
NE(a)	0.0017	0	0	0.0017	0.0000	0	0.0000	0.0017
NH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NJ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NY	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
OH	0.1400	0.0001	0.0000	0.1401	0.2000	0.0000	0.0000	0.2000
OK(a)	0.0000	0	0	0.0000	0.0000	0.0000	0.0000	0.0000
PA	0.1500	0.0000	0.0000	0.1500	0.2000	0.0000	0.0000	0.2000
RI	0	0	0.0000	0.0000	3.9E-01	0.0000	0.0000	0.0000
SC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SD(a)	0.0000	0	0	0.0000	0.0000	2.9E-01	0.0000	0.0000
TN	0.0100	0.0000	0.0000	0.0100	0.0000	0.0000	0.0000	0.0100
Texas	0	0	0	0	1.1E-01	0	1.3E-01	1.1E-01
VA	0.0010	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0010
VT	0	0.0000	0.0000	0.0000	4.9E-01	0.0000	0.0000	0.0000
WV	0.0100	0.0000	0.0000	0.0100	0.0000	0.0000	0.0000	0.0100
WY	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Canada(a)	0	0.0014	0	0.0014				
Total	0.9651	0.3854	0.2183	1.5688	1.45	0.44	0.28	2.17

Notes:
 (a) Only sources in that portion of the state within the RFO modeling domain were modeled.
 (b) 92 Canadian point sources > 250 tons/yr SO₂ emissions during 2002 (from Canadian KPIRI).

From: Table 7-2a of Contributions to Regional Haze in the Northeast and Mid-Atlantic United States, NESCAUM, 2006.

An alternative means of displaying the above results is in Table 7-7, which shows the individual state rankings produced by different assessment techniques for Acadia National Park, Maine. In the left-side column of Table 7-7, states are colored according to their average ranking across the different assessment methods. Those states that are ranked in the top five on average, across all techniques are colored red, while states ranked in the top six through ten are colored magenta, and so on for each group of five going down the left-side column. Through this color scheme, one can see how the states' average ranking compares to their rankings under each individual assessment method given in the other columns of the table. The fact that all techniques tend to come to consistent conclusions about which states are top contributors provides confidence that the source regions with the most influence on sulfate levels at MANE-VU Class I sites can be correctly identified. Note that the CENRAP states and several other states along the border of the analysis domain represent only partial state contributions.

**Table 7-7
Individual State Rankings Produced by Different Assessment Techniques for
Acadia National Park**

Average	REMSAD	Q/d	CALPUFF	CALPUFF	Ex RTP
CANADA	MA	CANADA	(VT)	(MD)	CANADA
PA	CANADA	PA	PA	CANADA	PA
OH	PA	OH	OH	OH	OH
MA	ME	NY	MA	PA	NY
NY	OH	IN	NY	NY	IL
IN	NY	MA	IN	IN	WV
WV	WV	MI	MI	WV	IN
ME	VR	WV	WV	CENRAP	MI
MI	MD	IL	ME	MI	KY
IL	IN	GA	IL	NY	CENRAP
KY	MI	NC	CENRAP	NY	VA
CENRAP	VA	KY	KY	IL	ME
MD	NC	VA	PA	NC	GA
NH	NJ	MD	MD	ME	WV
NC	IL	CENRAP	NC	ME	MD
VA	NY	ME	VA	VA	NC
WI	DE	TN	WI	TN	DE
GA	CENRAP	SC	TN	WI	MA
TN	WI	AL	NJ	NJ	TN
NJ	CT	WI	VT	GA	NJ
SC	GA	NH	GA	DE	AL
AL	TN	NJ	SC	SC	SC
DE	SC	DE	CT	AL	CT
CT	AL	CT	DE	CT	DE
VT	RI	MS	AL	RI	VT
RI	VT	RI	RI	VT	DC
MS	MS	VT	DC	DC	RI
DC	DC	DC	MS	MS	MS

8. Emissions Inventory

8.1 Sources of Visibility Impairing Pollutants in MANE-VU

This section explores the origin and quantity of haze-forming pollutants emitted in the Eastern and the mid-Atlantic United States.

Section 51.308(d)(4)(v) of EPA's Regional Haze Rule requires a statewide emission inventory of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any mandatory Class I area. The pollutants inventoried by Maine that affect fine particle formation, and thus contribute to regional haze, are sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOC), ammonia (NH₃), and particles with an aerodynamic diameter less than or equal to 10 and 2.5 μm (i.e., primary PM₁₀ and PM_{2.5}).

The emissions dataset illustrated below is the 2002 MANE-VU Version 3 regional haze emissions inventory. The emission inventories include carbon monoxide (CO), but it is not considered here as it does not contribute to regional haze. The MANE-VU regional haze emissions inventory version 3.0, released in April 2006, has superseded version 2.0 for modeling purposes. This inventory update was developed through the Mid-Atlantic Regional Air Management Association (MARAMA) for the MANE-VU RPO. This section describes emission characteristics by pollutant and source type (e.g., point, area, and mobile).

8.1.1 Sulfur Dioxide (SO₂)

SO₂ is the primary precursor pollutant for sulfate particles. Sulfate particles commonly account for more than 50 percent of particle-related light extinction at northeastern Class I areas on the clearest days and for as much as or more than 80 percent on the haziest days. Hence, SO₂ emissions are an obvious target of opportunity for reducing regional haze in the eastern United States. Combustion of coal and, to a lesser extent, of certain petroleum products accounts for most anthropogenic SO₂ emissions. In fact, in 1998 a single source category, coal-burning power plants, was responsible for two-thirds of total SO₂ emissions nationwide (NESCAUM, 2001a).

Figure 8-1 shows SO₂ emissions trends in the MANE-VU states as extracted from the 2002 MANE-VU inventory (EPA, 2005). Most states in the region showed declines in annual SO₂ emissions through 2002 compared with those in previous inventories. This decline can be attributed in part to implementation of Phase 2 of the Acid Rain Program, which in 2000 further reduced allowable emissions below Phase I levels and extended emission limits to a greater number of power plants.

The bar graph in Figure 8-2 shows the percent contribution from different source categories to overall, annual 2002 SO₂ emissions in the MANE-VU states. The graph shows that point sources dominate SO₂ emissions, which primarily consist of stationary

Figure 8-1
State Level Sulfur Dioxide Emissions

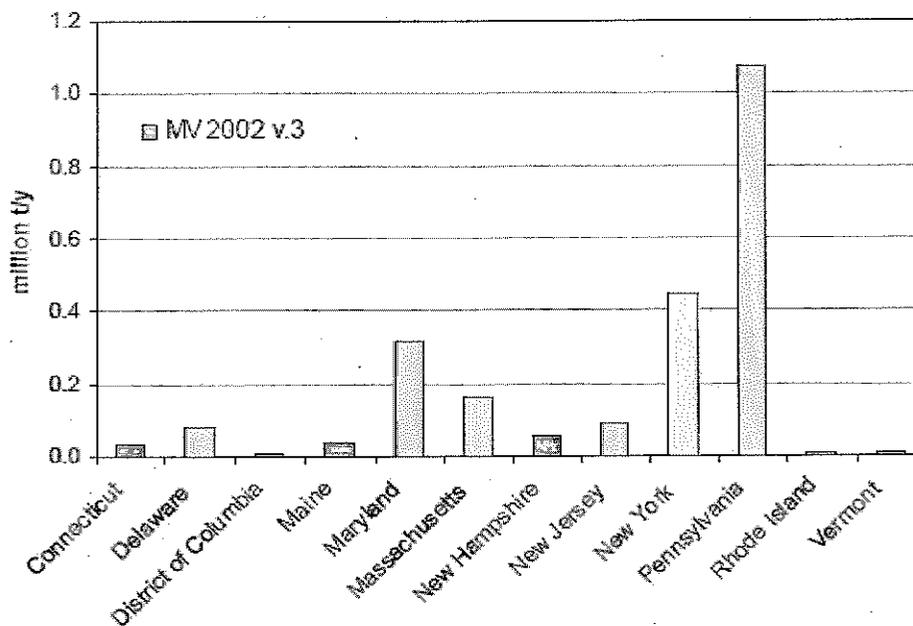
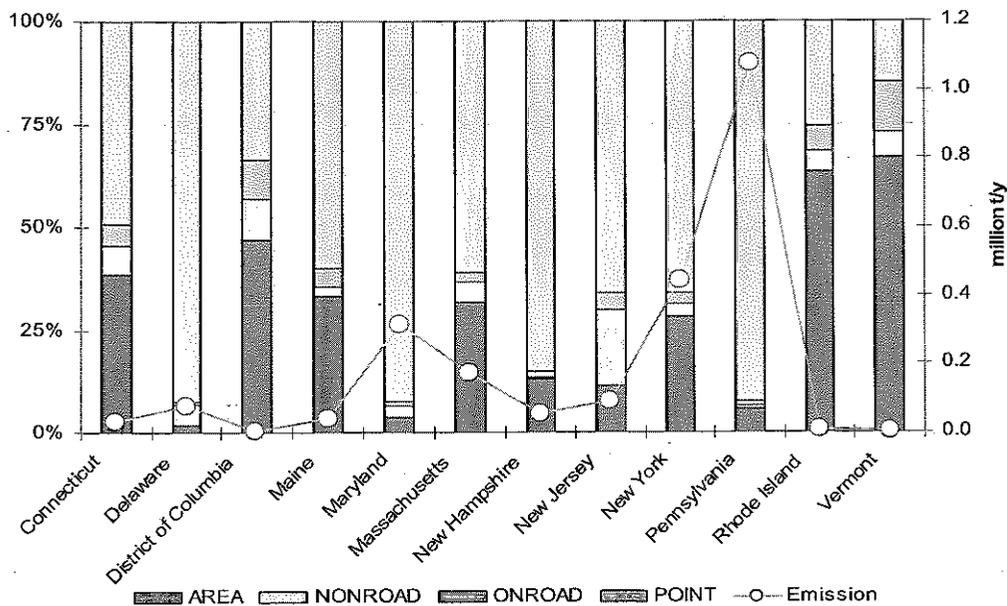


Figure 8-2
2002 SO₂

(Bar graph: Percentage fraction of four source categories, Circle: Annual emissions amount in 10⁶ tons per year)



combustion sources for generating electricity, industrial energy, and heat. Smaller stationary combustion sources called “area sources” (primarily commercial and

residential heating, and smaller industrial facilities) are another important source category in the MANE-VU states. By contrast, on-road and non-road mobile sources make only a relatively small contribution to overall SO₂ emissions in the region (NESCAUM, 2001a).

8.1.2 Volatile Organic Compounds (VOC)

Existing emission inventories generally refer to “volatile organic compounds” (VOCs) for hydrocarbons whose volatility in the atmosphere makes them particularly important from the standpoint of ozone formation. From a regional haze perspective, there is less concern with the volatile organic gases emitted directly to the atmosphere and more with the secondary organic aerosol (SOA) that the VOCs form after condensation and oxidation processes. Thus the VOC inventory category is of interest primarily from the organic carbon perspective of PM_{2.5}.

After sulfate, organic carbon generally accounts for the next largest share of fine particle mass and particle-related light extinction at northeastern Class I sites. The term organic carbon encompasses a large number and variety of chemical compounds that may come directly from emission sources as a part of primary PM or may form in the atmosphere as secondary pollutants. The organic carbon present at Class I sites includes a mix of species, including pollutants originating from anthropogenic (i.e., manmade) sources as well as biogenic hydrocarbons emitted by vegetation. Recent efforts to reduce manmade organic carbon emissions have been undertaken primarily to address summertime ozone formation in urban centers. Future efforts to further reduce organic carbon emissions may be driven by programs that address fine particles and visibility.

Understanding the transport dynamics and source regions for organic carbon in northeastern Class I areas is likely to be more complex than for sulfate. This is partly because of the large number and variety of OC species, the fact that their transport characteristics vary widely, and the fact that a given species may undergo numerous complex chemical reactions in the atmosphere. Thus, the organic carbon contribution to visibility impairment at most Class I sites in the East is likely to include manmade pollution transported from a distance, manmade pollution from nearby sources, and biogenic emissions, especially terpenes from coniferous forests.

Organic carbon emissions in the form of smoke from both natural (wildfire) and anthropogenic (prescribed and agricultural burning activities) have been shown to have a significant impact on visibility in Class I areas. In the western United States, organic carbon is responsible for a significant portion of visibility impacts at Class I areas, with wildfire and prescribed burning the principal emissions sources. In the eastern United States, organic carbon emissions play a lesser, but still important role in visibility degradation, with fire (both wildfire and anthropogenic) responsible for a smaller proportion of organic carbon emissions.

The National Park Service investigated the impact of fire on regional air quality using several modeling and air quality analysis techniques²². One of the more interesting

²² “Fire Effects on Regional Air Quality Including Visibility,” Draft Report, National Park Service, Air Resources Division, August 1, 2006.

approaches analyzed the ratio of organic carbon to black (or elemental) carbon at IMPROVE monitor sites. The ratio of organic to elemental carbon (OC/EC) can be used to identify the likely source of organic carbon emissions, since this ratio displays significant variability, depending on the source of combustion. For example, internal combustion engines, which burn relatively efficiently, typically have a ratio of about 3, while less efficient combustion, which is characteristic of open fires, result in OC/EC ratios on the order of 10 or more. Using this approach, researchers estimated that fire was responsible for approximately 55% of all organic carbon monitored in the eastern United States.²³ An alternative apportionment method utilizing a fire occurrence database and back trajectories was also utilized to estimate fire impacts on observed organic carbon measurements. This approach estimated that approximately 20% of organic carbon observed at eastern United States IMPROVE sites was due to wildland fires, but likely is an underestimation of the impact of fire on visibility, since the fire activity datasets and back trajectory databases are incomplete.

Although organic carbon is responsible for approximately 13 percent of the baseline worst visibility (throughout the MANE-VU region), sulfates account for approximately 75 percent of baseline visibility degradation.²⁴ Conversely, for natural background visibility conditions, organic carbon is estimated to be responsible for approximately 50 percent of visibility degradation, while sulfates are responsible for only about 20 percent of the visibility degradation on the worst visibility days. This result arises from the fact that organic carbon concentrations under worst day baseline conditions differ relatively little from estimated worst day concentrations under natural background conditions. Sulfate concentrations, however, are approximately 90 percent higher under worst day baseline conditions. With sulfates being responsible for the preponderance of visibility degradation, and many organic carbon emissions being biogenic in nature (as confirmed by the minimal difference between baseline and natural background estimated concentrations), it makes sense to target sulfate levels for the first (and perhaps subsequent rounds) of regional haze controls. As noted above, organic carbon could be the subject of future control measures to mitigate regional haze, but is not the focus of initial planning efforts.

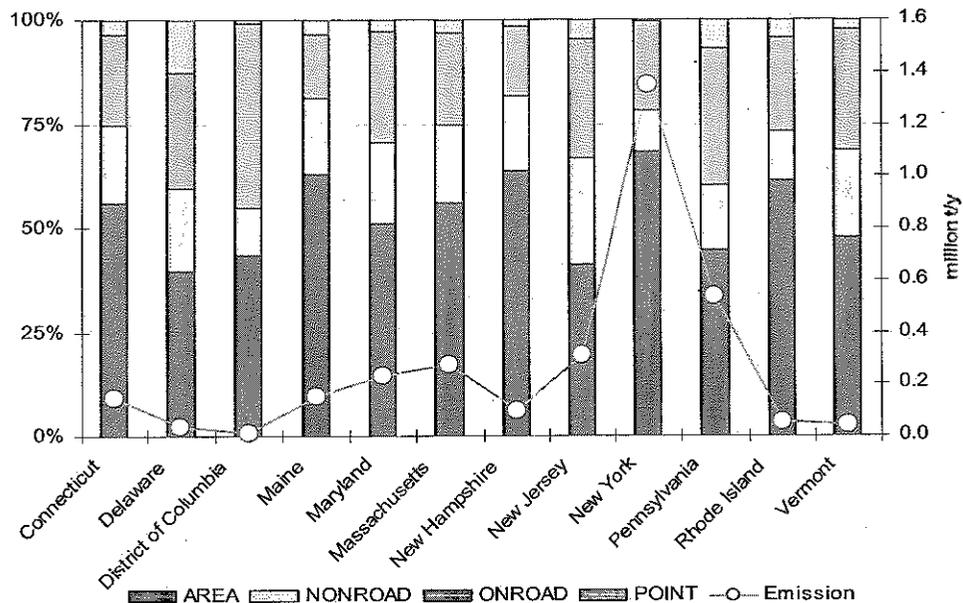
As shown in Figure 8-3, the VOC inventory is dominated by mobile and area sources. On-road mobile sources of VOCs include exhaust emissions from gasoline passenger vehicles and diesel-powered heavy-duty vehicles as well as evaporative emissions from transportation fuels. VOC emissions may also originate from a variety of area sources (including solvents, architectural coatings, and dry cleaners) as well as from some point sources (e.g., industrial facilities and petroleum refineries).

²³ This technique tends to overestimate the OC/EC ratio due to the presence of secondary organic aerosols, that are not associated with elemental carbon.

²⁴ Nitrate and elemental carbon at 8% and 4%, respectively, account for most of the rest of the visibility degradation on the 20 percent worst days.

Figure 8-3
2002 VOC

(Bar graph: Percentage fraction of four source categories,
Circle: Annual emissions in million tons per year)



Biogenic VOCs may play an important role within the rural settings typical of Class I sites. The oxidation of hydrocarbon molecules containing seven or more carbon atoms is generally the most significant pathway for the formation of light-scattering organic aerosol particles (Odum et al., 1997). Smaller reactive hydrocarbons that may contribute significantly to urban smog (ozone) are less likely to play a role in organic aerosol formation, though it was noted that high ozone levels can have an indirect effect on visibility by promoting the oxidation of other available hydrocarbons, including biogenic emissions (NESCAUM, January 2001). In short, further work is needed to characterize the organic carbon contribution to regional haze in the Northeast and Mid-Atlantic states and to develop emissions inventories that will be of greater value for visibility planning purposes.

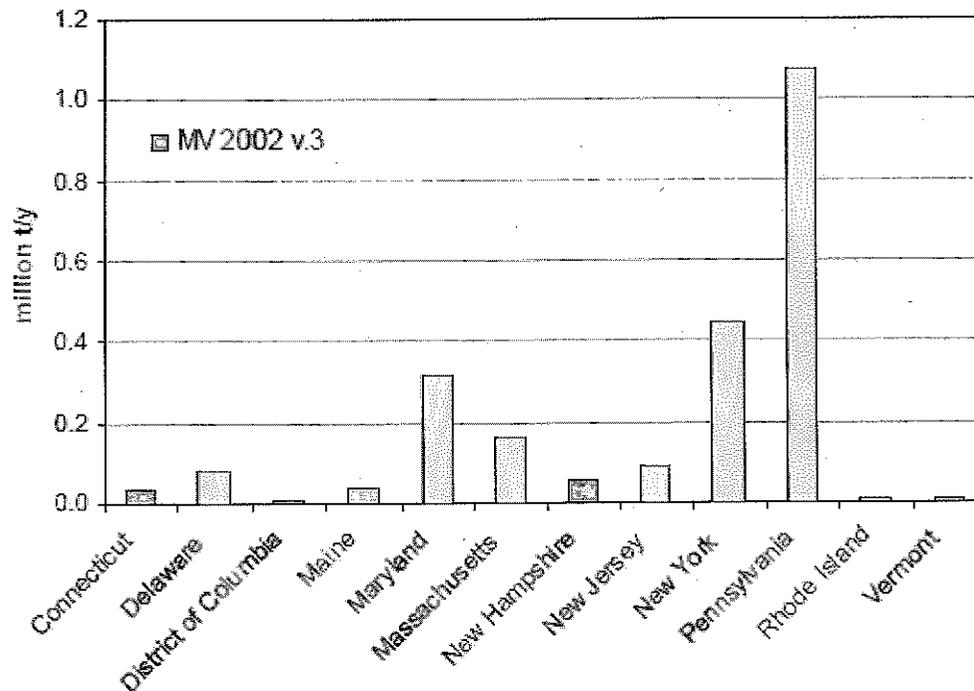
8.1.3 Oxides of Nitrogen (NO_x)

NO_x emissions contribute to visibility impairment in the eastern U.S. by forming light-scattering nitrate particles. Nitrate generally accounts for a substantially smaller fraction of fine particle mass and related light extinction than sulfate and organic carbon at northeastern Class I sites. Notably, nitrate may play a more important role at urban sites and in the wintertime. In addition, NO_x may have an indirect effect on summertime visibility by virtue of its role in the formation of ozone, which in turn promotes the formation of secondary organic aerosols (NESCAUM 2001a).

Since 1980, nationwide emissions of NO_x from all sources have shown little change. To a large extent, increases from the industrial and power plant combustion sectors have been offset by emission reductions from mobile source controls implemented during the

same time period. Figure 8-4 shows NO_x emissions in the MANE-VU region at the state level. In the several years just prior to 2002, most MANE-VU states experienced declining NO_x emissions.

Figure 8-4
State Level Nitrogen Oxides Emissions



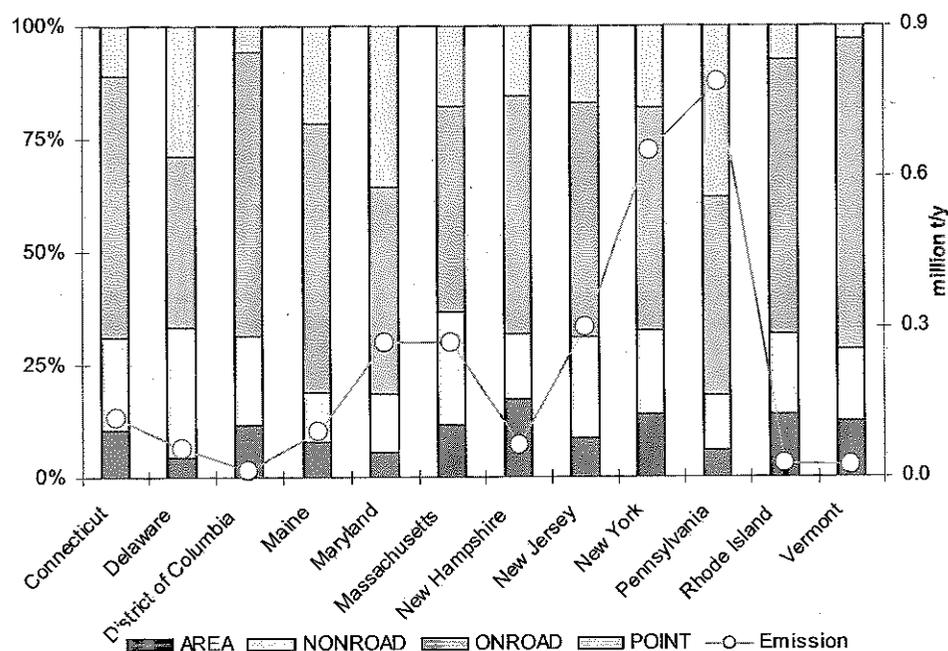
Power plants and mobile sources generally dominate state and national NO_x emissions inventories. Nationally, power plants account for more than one-quarter of all NO_x emissions, amounting to over six million tons. The electric sector plays an even larger role, however, in parts of the industrial Midwest where high NO_x emissions have a particularly significant power plant contribution. By contrast, mobile sources dominate the NO_x inventories for more urbanized Mid-Atlantic and New England states to a far greater extent, as shown in Figure 8-5. In these states, on-road mobile sources - a category that mainly includes highway vehicles - represent the most significant NO_x source category. Emissions from non-road (i.e., off-highway) mobile sources, primarily diesel-fired engines, also represent a substantial fraction of the inventory. While there are fewer uncertainties associated with available NO_x estimates than in the case of other key haze-related pollutants - including primary fine particle and ammonia emissions - further efforts could improve current inventories in a number of areas (NESCAUM, 2001a).

In particular, better information on the contribution of area and non-highway mobile sources may be of most interest in the context of regional haze planning. First, available emission estimation methodologies are weaker for these types of sources than for the large stationary combustion sources. Moreover, because SO₂ and NO_x emissions must mix with ammonia to participate in secondary particle formation, emissions that occur

over large areas at the surface may be more efficient in secondary fine particulate formation than concentrated emissions from isolated tall stacks (Duyzer, 1994).

Figure 8-5
NO_x

(Bar graph: Percentage fraction of four source categories, Circle: Annual emissions amount in 10⁶ tons per year)



8.1.4 Primary Particle Matter (PM₁₀ and PM_{2.5})

Directly-emitted or “primary” particles (as distinct from secondary particles that form in the atmosphere through chemical reactions involving precursor pollutants like SO₂ and NO_x) can also contribute to regional haze. For regulatory purposes, a distinction is made between particles with an aerodynamic diameter less than or equal to 10 micrometers and smaller particles with an aerodynamic diameter less than or equal to 2.5 micrometers (i.e., primary PM₁₀ and PM_{2.5}, respectively).

Figure 8-6 and Figure 8-7 show PM₁₀ and PM_{2.5} emissions, respectively, for the MANE-VU states as reported for the 2002 base year. Most states showed a steady decline in annual PM₁₀ emissions over this time period. By contrast, emission trends for primary PM_{2.5} are more variable.

Crustal sources are significant contributors of primary PM emissions. This category includes fugitive dust emissions from construction activities, paved and unpaved roads, and agricultural tilling. Typically, monitors estimate PM₁₀ emissions from these types of sources by measuring the horizontal flux of particulate mass at a fixed downwind sampling location within perhaps 10 meters of a road or field. Comparisons between

estimated emission rates for fine particles using these types of measurement techniques and observed concentrations of crustal matter in the ambient air at downwind receptor sites suggest that physical or chemical processes remove a significant fraction of crustal

Figure 8-6
State Level Primary PM₁₀ Emissions

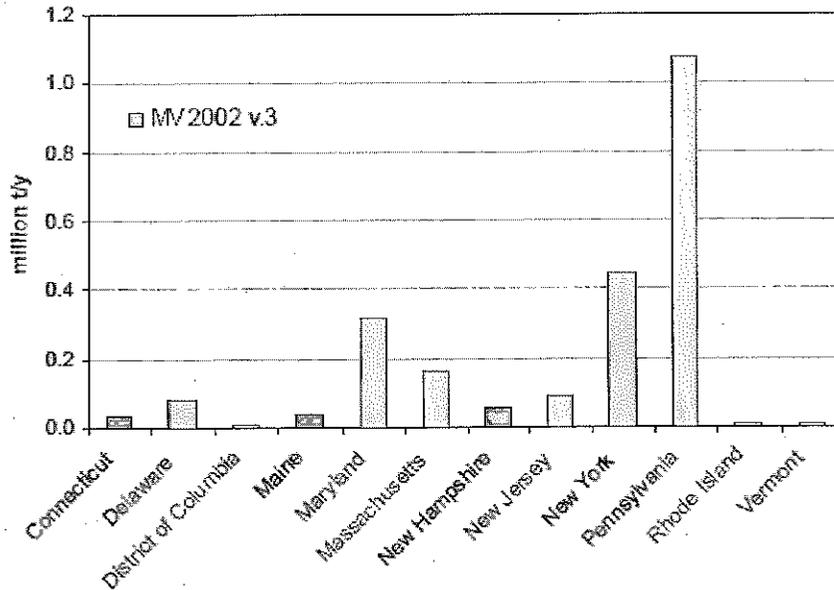
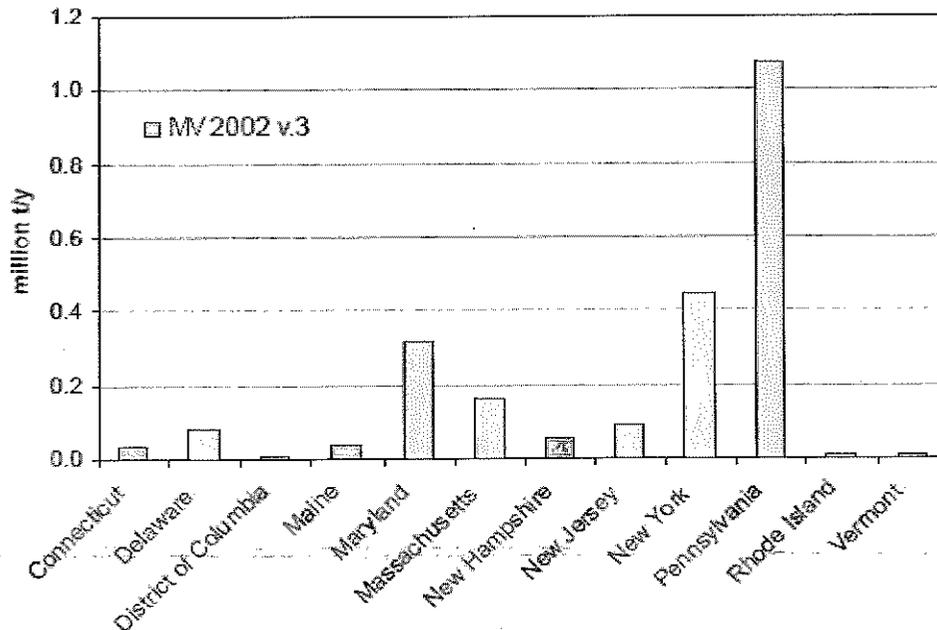


Figure 8-7
State Level Primary PM_{2.5} Emissions*



* 1996 and 1999 Maine PM_{2.5} data augmented.

material relatively quickly. As a result, it rarely entrains into layers of the atmosphere where it can transport to downwind receptor locations. Because of this discrepancy between estimated emissions and observed ambient concentrations, modelers typically reduce estimates of total PM_{2.5} emissions from all crustal sources by applying a factor of 0.15 to 0.25 to the total PM_{2.5} emissions before including it in modeling analyses.

From a regional haze perspective, crustal material generally does not play a major role. On the 20 percent best-visibility days during the baseline period (2000-2004), it accounted for six to eleven percent of particle-related light extinction at MANE-VU Class 1 sites. On the 20 percent worst-visibility days, however, crustal material generally plays a much smaller role relative to other haze-forming pollutants, ranging from two to three percent. Moreover, the crustal fraction includes material of natural origin (such as soil or sea salt) that is not targeted under the Haze Rule. Of course, the crustal fraction can be influenced by certain human activities, such as construction, agricultural practices, and road maintenance (including wintertime salting). Thus, to the extent that these types of activities are found to affect visibility at northeastern Class I sites, control measures targeted at crustal material may prove beneficial and are within the purview of EPA and state agencies.

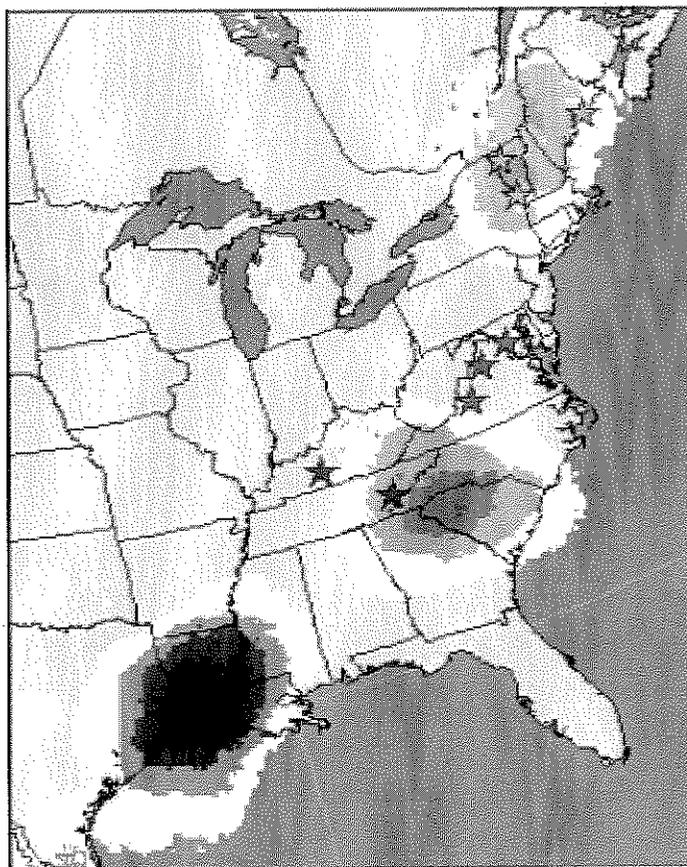
Experience from the western United States, where the crustal component has generally played a more significant role in driving overall particulate levels, may be helpful to the extent that it is relevant in the eastern context. In addition, a few areas in the Northeast, such as New Haven, Connecticut and Presque Isle, Maine, have some experience with the control of dust and road-salt as a result of regulatory obligations stemming from their past non-attainment status with respect to the NAAQS for PM₁₀.

Current emissions inventories for the entire MANE-VU area indicate residential wood combustion represents 25 percent of primary fine particulate emissions in the region. This finding implies that rural sources can play an important role in addition to the contribution from the region's many highly populated urban areas. An important consideration in this regard is that residential wood combustion occurs primarily in the winter months, while managed or prescribed burning activities occur largely in other seasons. The latter category includes agricultural field-burning activities, prescribed burning of forested areas and other burning activities such as construction waste burning. Particulate emissions from many of these sources can be managed by limiting allowed burning activities to times when favorable meteorological conditions can efficiently disperse the emissions.

Although the data are currently limited, Maine and the other MANE-VU states are concerned about the growing use of residential woodstoves and outdoor wood boilers by homeowners seeking alternatives to petroleum-based fuels for home heating. Over the next several years, Maine will continue to evaluate monitored particulate matter levels in the state and in particular, assess the smoke component of the monitored particulate matter to determine if there is any trend in smoke levels in Maine. If smoke levels increase significantly, that might be cause for evaluating whether additional control measures for this source category may be necessary.

Figure 8-8, taken from Appendix B of the MANE-VU Contribution Assessment (Attachment A), represents the results of source apportionment and trajectory analyses on wood smoke in the region extending from the Gulf States to the Northeast. The green-highlighted portion of the map depicts the wood smoke source region in the northeast states. The stars on the map represent air monitoring sites (including those at several Class I areas) whose data sets were determined to be useful to the modeling analysis.

Figure 8-8
Wood Smoke Source Regional Aggregation



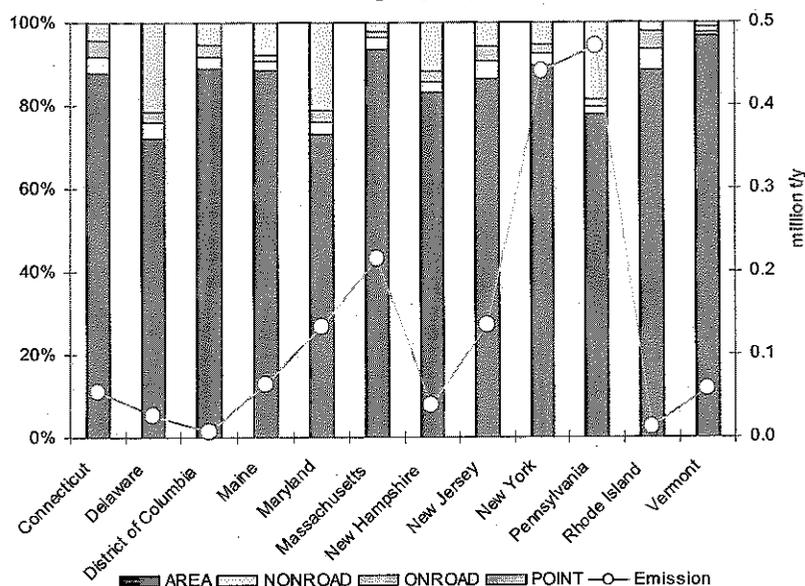
Northeast: ACAD, PMRC, LYBR
Mid-Atlantic: WASH, SHEN, JARI
Southeast: GRSM, MACA

MANE-VU's "Technical Support Document on Agricultural and Forestry Smoke Management in the MANE-VU Region, September 1, 2006 (Attachment Y), concluded that fire from land management activities was not a major contributor to regional haze in the MANE-VU Class I areas, and that the majority of emissions from fires were from residential wood combustion.

Figures 8-9 and Figure 8-10 show that area and mobile sources dominate primary PM emissions. (The NEI inventory categorizes residential wood combustion and some other combustion sources as area sources.) The relative contribution of point sources is larger

in the primary PM_{2.5} inventory than in the primary PM₁₀ inventory since the crustal component (which consists mainly of larger or “coarse-mode” particles) contributes mostly to overall PM₁₀ levels. At the same time, pollution control equipment commonly installed at large point sources is usually more efficient at capturing coarse-mode particles.

Figure 8-9
Primary PM₁₀
 (Bar graph: Percentage fraction of four source categories, Circle: Annual emissions amount in 106 tons per year)

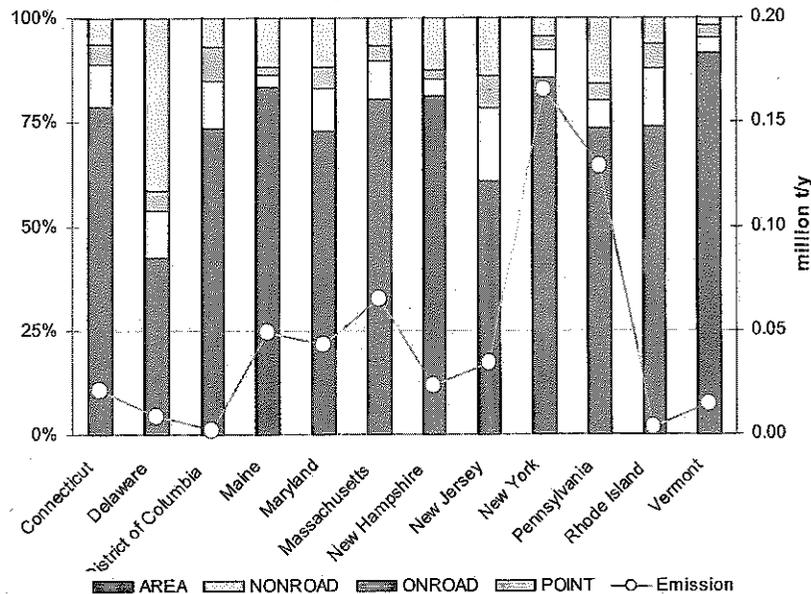


8.1.5 Ammonia Emissions (NH₃)

Knowledge of ammonia emission sources will be necessary in developing effective regional haze reduction strategies because of the importance of ammonium sulfate and ammonium nitrate in determining overall fine particle mass and light scattering. According to 1998 estimates, livestock agriculture and fertilizer use accounted for approximately 86 percent of all ammonia emissions to the atmosphere (EPA, 2000b). However, improved ammonia inventory data are needed as inputs to the photochemical models used to simulate fine particle formation and transport in the eastern United States. States were not required to include ammonia in their emissions data collection efforts until fairly recently (See Consolidated Emissions reporting rule, 67 CFR 39602, June 10, 2002). Therefore, emissions data for ammonia do not exist at the same level of detail or reliability as exist for other pollutants.

Figure 8-10
Primary PM_{2.5}

(Bar graph: Percentage fraction of four source categories, Circle: Annual emissions amount in 106 tons per year)



Ammonium ion (formed from ammonia emissions to the atmosphere) is an important constituent of airborne particulate matter, typically accounting for 10–20 percent of total fine particle mass. Reductions in ammonium ion concentrations can be extremely beneficial because a more-than-proportional reduction in fine particle mass can result. Ansari and Pandis (1998) showed that a one $\mu\text{g}/\text{m}^3$ reduction in ammonium ion could result in up to a four $\mu\text{g}/\text{m}^3$ reduction in fine particulate matter. Decision makers, however, must weigh the benefits of ammonia reduction against the significant role it plays in neutralizing acidic aerosol.²⁵

To address the need for improved ammonia inventories, MARAMA, NESCAUM and EPA funded researchers at Carnegie Mellon University (CMU) in Pittsburgh to develop a regional ammonia inventory (Davidson et al., 1999). This study focused on three issues with respect to current emissions estimates: (1) a wide range of ammonia emission factor values, (2) inadequate temporal and spatial resolution of ammonia emissions estimates, and (3) a lack of standardized ammonia source categories.

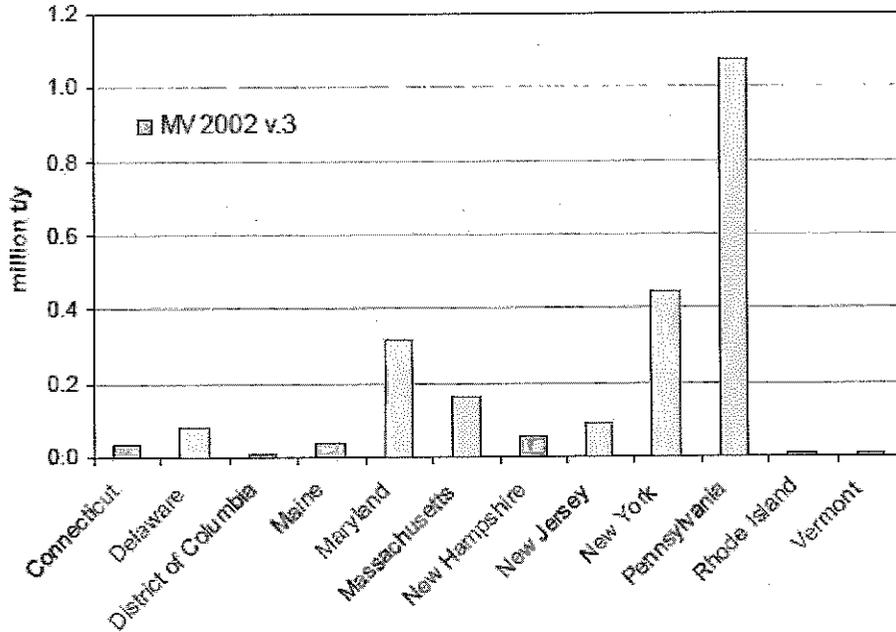
The CMU project established an inventory framework with source categories, emissions factors, and activity data that are readily accessible to the user. With this framework, users can obtain data in a variety of formats²⁶ and can make updates easily, allowing additional ammonia sources to be added or emissions factors to be replaced as better information becomes available (Strader et al., 2000; NESCAUM, 2001b).

²⁵ SO₂ reacts in the atmosphere to form sulfuric acid (H₂SO₄). Ammonia can partially or fully neutralize this strong acid to form ammonium bisulfate or ammonium sulfate. If planners focus future control strategies on ammonia and do not achieve corresponding SO₂ reductions, fine particles formed in the atmosphere will be substantially more acidic than those presently observed.

²⁶ For example, the user will have the flexibility to choose the temporal resolution of the output emissions data or to spatially attribute emissions based on land-use data.

Figure 8-11 shows that estimated ammonia emissions for the MANE-VU states in 2002. Area and on-road mobile sources dominate according to Figure 8-12. Specifically, emissions from agricultural sources and livestock production account for the largest share of estimated ammonia emissions in the MANE-VU region, except in the District of

Figure 8-11
State Level Ammonia Emissions



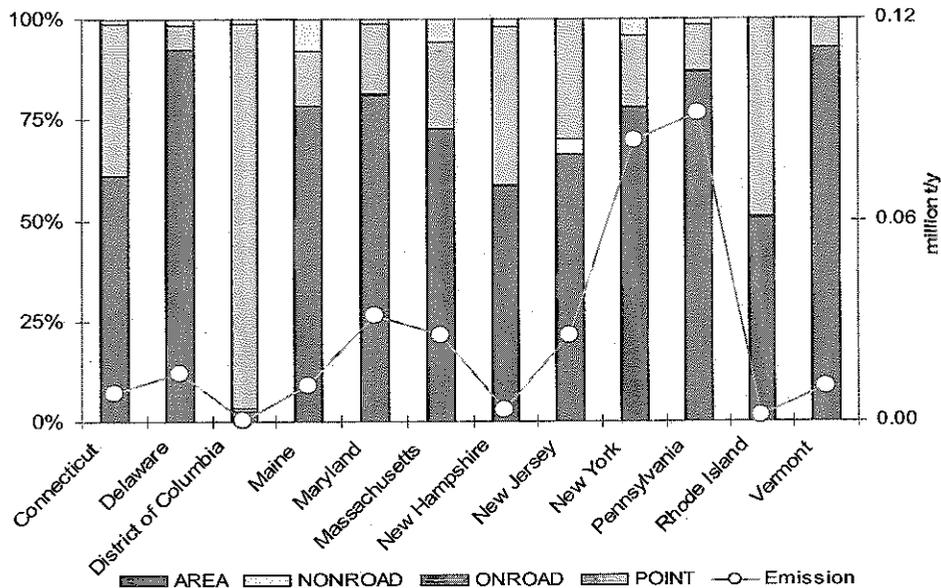
Columbia. The two remaining sources with a significant emissions contribution are wastewater treatment systems and gasoline exhaust from highway vehicles.

8.2 Baseline and Future Year Emission Inventories for Modeling

40 CFR Section 51.308(d) (3) (iii) requires the State of Maine to identify the baseline emission inventory on which strategies are based. The baseline inventory is intended to be used to assess progress in making emission reductions. Based on EPA guidance entitled, "2002 Base Year Emission Inventory SIP Planning: 8-hour Ozone, PM_{2.5}, and Regional Haze Programs" which identifies 2002 as the anticipated baseline emission inventory year for regional haze, all of the MANE-VU states are using 2002 as the baseline year for regional haze inventories

With contractor assistance, MARAMA developed a 2002 baseline modeling inventory using the inventories that Maine and other states submitted to EPA to meet their SIP obligations and the requirements of the Consolidated Emissions Reporting Rule (CERR). To create the 2002 baseline inventory for modeling, MARAMA and its contractor quality-assured and augmented states' inventories and generated the necessary input files for the emissions processing model.

Figure 8-12
State Ammonia Emissions by Source Category
 (Bar graph: Percentage fraction of four source categories)
 (Circle: Annual emissions amount in 10^6 tons per year)



Future-year inventories for 2009, 2012, and 2018 were projected from the 2002 base year. These future-year emissions inventories include emissions growth due to projected increases in economic activity as well as emissions reductions expected from the implementation of control measures. While the 2009 and 2012 emissions projections were originally developed in support of participating state's ozone attainment demonstrations, the inventory for 2018 (the year targeted by the Regional Haze Rule) was developed for the specific purposes of regional haze SIP planning. Therefore, although the 2009 and 2012 projected inventories are mentioned in subsequent sections, only the 2002 baseline inventory and 2018 projected inventory are described below in Section 7.5, Summary of Emissions Inventories.

Accurate baseline and future-year emissions inventories are crucial to the analyses required for the regional haze SIP process. These emissions inventories were used to drive the air quality modeling simulations undertaken to assess the visibility improvements that would result from possible control measures. Air quality modeling was also used to perform a pollution apportionment, which evaluates the contribution to visibility impairment by geographic region and emission source sector.

To be compatible with the air quality modeling simulations, the baseline and future-year emissions inventories were processed with the Sparse Matrix Operator Kernel Emissions (SMOKE) emissions pre-processor for subsequent input into the CMAQ and REMSAD air quality models. Further description of the base and future-year emissions inventories is provided below.

8.2.1 Baseline Inventory

The starting point for the 2002 baseline emissions inventory was the 2002 inventory submittals that were made to EPA by state and local agencies as part of the Consolidated Emissions Reporting Rule (CERR). With contractor assistance (E.H. Pechan & Associates), MANE-VU then coordinated and quality-assured the 2002 inventory data, and prepared it for input into the SMOKE emissions model. The 2002 emissions from non-MANE-VU areas within the modeling domain were obtained from other Regional Planning Organizations for their corresponding areas. These Regional Planning Organizations included the Visibility Improvement State and Tribal Association of the Southeast (VISTAS), the Midwest Regional Planning Organization (MRPO), and the Central Regional Air Planning Association (CENRAP).

The 2002 baseline inventory went through several iterations. Work on Version 1 of the 2002 MANE-VU inventory began in April 2004, and the final inventory and SMOKE input files were completed during January 2005. Work on Version 2 (covering the period of April through September 2005) involved incorporating revisions requested by some MANE-VU state/local agencies on the point, area, and on-road categories. Work on Version 3 (covering the period from December 2005 through April 2006) included additional revisions to the point, area, and on-road categories as requested by some states. Thus, the Version 3 inventory for point, area, and on-road sources was built upon Versions 1 and 2. This work also included development of the biogenic inventory. In Version 3, the non-road inventory was completely redone because of changes that EPA made to the NONROAD2005 non-road mobile emissions model.

Version 3 of the MANE-VU 2002 baseline emissions inventory was used in the regional air quality modeling simulations, including performance testing of the air quality models used in the development of this SIP. Further description of the data sources, methods, and results for this version of the 2002 baseline inventory is presented in E.H. Pechan & Associates, Inc. "Technical Support Document for 2002 MANE-VU SIP Modeling Inventories, Version 3, November 20, 2006" (Attachment H). Emissions inventory data files are available on the MARAMA website at: http://www.marama.org/visibility/EI_Projects/index.html.

8.2.2 Future Year Emission Control Inventories

Future-year emissions inventories are provided in MACTEC's technical support document "Development of Emissions Projections for 2009, 2012, and 2018 for NonEGU Point, Area, and Nonroad Sources in the MANE-VU Region," Final Report, February 28, 2007, (Attachment I). This document describes the data sources, methods, and modeling results for three future years, five emission source sectors, two emission control scenarios, seven pollutants, and eleven states plus the District of Columbia. The following summarizes the basic framework of the future-year inventories that were developed:

- **Projection years:** 2009, 2012, and 2018;

- **Emission source sectors:** point-source electric generating units (EGUs), point-source non-electric generating units (non-EGUs), area sources, non-road mobile sources, and on-road mobile sources.
- **Emission control scenarios:**
 - A combined on-the-books/on-the-way (OTB/OTW) control strategy accounting for emission control regulations already in place as of June 15, 2005, as well as some emission control regulations that are not yet finalized but are expected to achieve additional emission reductions by 2009.
 - A beyond-on-the-way (BOTW) scenario to account for controls from potential new regulations that may be necessary to meet attainment and other regional air quality goals, mainly for ozone.
 - An updated scenario (referred to as the “final modeling inventory”) to account for additional potentially reasonable control measures. For the MANE-VU region, these include: SO₂ reductions at a set of 167 EGUs which were identified as contributing to visibility impairment at northeast Class I areas; implementation of a low-sulfur fuel strategy for non-EGU sources; and implementation of a BART strategy for BART-eligible sources not controlled under other programs. The final modeling inventory was used to develop the reasonable progress goals in this SIP.
 - Pollutants: ammonia, carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO₂), volatile organic compounds (VOCs), fine particulate matter (PM_{2.5}, sum of filterable and condensable components), and coarse particulate matter (PM₁₀, sum of filterable and condensable components).
- **States:** The states are those that comprise the MANE-VU region. In addition to the District of Columbia, the 11 MANE-VU states are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

8.3 Emission Processor Selection and Configuration

The Sparse Matrix Operator Kernel Emissions (SMOKE) model (Version 2.1) was used by the New York State Department of Environmental Conservation (NYSDEC) to format the emissions inventories for use with the air quality models that are discussed in Chapter 9. SMOKE is principally an emissions processing system, as opposed to a true emissions inventory preparation system, in which emissions estimates are simulated from “first principles.” This means that, with the exception of mobile and biogenic sources, its purpose is to provide an efficient, modern tool for converting emissions inventory data into the formatted emissions files required for a photochemical air quality model. A detailed description of all SMOKE input files such as area, mobile, fire, point and biogenic emissions files and the SMOKE model configuration are provided in Attachment I.

As discussed in detail in Chapter 11, the MANE-VU member states selected several control strategies for inclusion in the modeling. Emission reduction requirements mandated by the Clean Air Act were also included in projecting future year emissions. In addition, 40 CFR Section 51.308(d)(3)(v)(D) requires the State of Maine to consider source retirement and replacement schedules in developing the future inventories and long-term strategy.

8.4 Inventories for Specific Source Types

There are five emission source classifications in the emissions inventory as follows:

- 1) Stationary point,
- 2) Stationary area,
- 3) Off-road mobile,
- 4) On-road mobile, and
- 5) Biogenic.

Stationary point sources are large sources that emit greater than a specified tonnage per year. **Stationary area sources** are those sources whose emissions are relatively small but due to the large number of these sources, the collective emissions could be significant, i.e., dry cleaners, service stations, agricultural sources, fire emissions, etc. **Off-road mobile sources** are equipment that can move but do not use the roadways, i.e., lawn mowers, construction equipment, railroad locomotives, aircraft, etc. **On-road mobile sources** are automobiles, trucks, and motorcycles that use the roadway system. The emissions from these sources are estimated by vehicle type and road type. **Biogenic sources** are natural sources like trees, crops, grasses and natural decay of plants. **Stationary point sources** emission data is tracked at the facility level. For all other source types emissions are summed on the county level.

The subsections below provide an overview of each of the source categories and the methods that were used to develop their corresponding baseline and future-year emissions estimates. All emissions data were prepared for modeling in accordance with EPA guidance.

8.4.1 Stationary Point Sources

Point source emissions are emissions from large individual sources. Generally, point sources have permits to operate and their emissions are individually calculated based on source specific factors on a regular schedule. Emissions estimates for point sources are usually made on a regular basis, with the largest point sources inventoried annually. Sources with emissions greater than or equal to 100 tons per year (tpy) of a criteria pollutant, 10 tpy of a single hazardous air pollutant (HAP), or 25 tpy total HAP are considered to be major sources. Emissions from smaller sources are also calculated individually but less frequently. Point sources are grouped into EGU sources and other industrial point sources, termed as non-EGU point sources.

8.4.1.1 Electric Generating Units

The base-year inventory for EGU sources were based on 2002 continuous emissions monitoring (CEM) data reported to EPA in compliance with the Acid Rain Program or 2002 state emissions inventory data. The CEM data provided actual hourly emission values used in the modeling of SO₂ and NO_x emissions from these large sources. Emissions of other pollutants (e.g., VOCs, CO, NH₃, and PM_{2.5}) were provided by the states in most instances.

Future-year inventories of EGU emissions for 2009, 2012 and 2018 were developed using ICF International's Integrated Planning Model (IPM) to forecast growth in electric demand and replacement of older, less efficient and more polluting power plants with newer, more efficient and cleaner units. This effort was undertaken by an inter-RPO workgroup. While the output of the IPM model predicts that a certain number of older plants will be replaced by newer units to meet future electric growth and state-specific NO_x and SO₂ caps, the MANE-VU/Maine inventory did not directly rely on the closure of any particular plant in establishing the 2018 inventory upon which the reasonable progress goals were set.

The IPM model results do not provide a reliable basis upon which to predict EGU closures. Specific plant closures in the Maine inventory are addressed in Chapter 12, Reasonable Progress Goals. Preliminary modeling was performed with unchanged IPM 2.1.9 model results. However, prior to the most recent modeling, future-year EGU inventories were adjusted as follows:

- First, IPM predictions were reviewed by permitting and enforcement staff of the MANE-VU states. In many cases, staff believed that the IPM shutdown predictions were unlikely to occur. In particular, many oil-fired EGUs in urban areas were predicted to be shut down by IPM. Similar source information was solicited from states in both VISTAS and MRPO. As a result of this model validation, the IPM modeling output was adjusted before the most recent modeling to reflect staff knowledge of specific plant status in MANE-VU, VISTAS, and MRPO states. Where expected EGU operating status was contrary to what was predicted by IPM modeling, the future-year emissions inventory was adjusted to reflect the expected operation of those plants.
- Second, as a result of inter- and intra-RPO consultations, MANE-VU agreed to pursue certain emission control measures (see Section 3.0, Regional Planning). For EGUs, the agreed-upon approach was to pursue emission reductions from each of the top 167 stacks located in MANE-VU, MRPO, and VISTAS that contributed the most to visibility impairment at any Class I area in the MANE-VU region. This approach, known as the targeted EGU strategy, is further described in Section 11.0 of this SIP.

8.4.1.2 Non-EGU Point Sources

The non-EGU category used annual emissions as reported by state and local agencies pursuant to the Consolidated Emission Reporting Rule (CERR) for the base year 2002

(or MANE-VU Version 3). As described in section 8.2, MANE-VU's contractor, E.H. Pechan & Associates (Pechan), coordinated the quality assurance of the inventory and prepared the necessary files for input into the SMOKE emissions model. Further information on the preparation of the MANE-VU 2002 baseline point source modeling emissions inventory can be found in Chapter II of the Baseline Emissions Report (Attachment I). Projected non-EGU point source emissions were developed for the MANE-VU region by MACTEC Federal Programs, Inc. under contract to the Mid-Atlantic Regional Air Management Association (MARAMA). The specific methodologies that were employed are described in Section 2 of the Emissions Projections Report (Attachment I). MACTEC used state-supplied growth factor data, where available, to project future-year emissions. Where state-supplied data were not available, MACTEC used EPA's Economic Growth and Analysis System, Version 5.0 (EGAS 5.0) to develop applicable growth factors for the non-EGU component. MACTEC also incorporated the applicable federal and state emissions control programs to account for the expected emissions reductions that will take place under the OTB/OTW and BOTW scenarios.

8.4.2 Stationary Area Sources

Stationary area sources include sources whose individual emissions are relatively small, but due to the large number of these sources, the collective emissions are significant. Some examples include solvent cleaning, service stations and residential heating. Area source emissions are estimated by multiplying an emission factor by some known indicator of collective activity, such as fuel usage, or number of households or population.

The area source emissions inventory submittals made for the CERR became the basis for the area source portion of the 2002 baseline inventory. MANE-VU's consultant, Pechan, prepared the area source modeling inventory using the CERR submittals as a starting point. Pechan quality-assured the inventory and augmented it with additional data, including MANE-VU sponsored inventories for categories such as residential wood combustion and open burning. Details on the preparation of MANE-VU's 2002 baseline area source emissions inventory can be found in Chapter III of the Baseline Emissions report (Attachment H).

In a similar fashion, MACTEC prepared future-year area source emission projections for the MANE-VU region. The specific methodologies employed are described in Section 3 of the Emissions Projection Report (Attachment I). MACTEC applied growth factors to the 2002 baseline area source inventory using state-Supplied data, where available, or using the EGAS 5.0 growth factor model. MACTEC also accounted for the appropriate control strategies in the future year projections.

8.4.2.2 Non-Road Mobile Sources

Non-road mobile sources are equipment that can move but do not use the roadways, such as construction equipment, aircraft, railroad locomotives, lawn and garden equipment. For the majority of the non-road mobile sources, the emissions for base year 2002 were

estimated using the EPA's NONROAD Model contained within the Mobile6 model. Aircraft, railroad locomotives, and commercial marine vessels are not included in the NONROAD model; their emissions are estimated using applicable references and methodologies. Again, Pechan prepared the 2002 baseline modeling inventory using the state and local CERR submittals as a starting point. Details on the preparation of the 2002 baseline non-road inventory are described in Chapter IV of the Baseline Emissions Report (Attachment H).

Future-year non-road mobile source emissions were projected for the MANE-VU region by MACTEC. The methodologies employed are discussed in Section 4 of the Emission Projections Report (Attachment I). MACTEC used EPA's NONROASD2005 non-road vehicle emissions model as contained in EPA's National Mobile Inventory Model (NMIM). Since the calendar year is an explicit input into the NONROAD model, future-year emissions for non-road vehicles could be calculated directly for the applicable projection years. For the non-road vehicle types that are not included in the NONROAD model (i.e., aircraft, locomotives and commercial marine vessels), MACTEC used the 2002 baseline inventory and the projected inventories that EPA developed for these categories for the Clean Air Interstate Rule (CAIR) to develop emission ratios and subsequent combined growth and control factors. Since the future years for the CAIR projections did not precisely match those required for the purposes of ozone, particulate matter and the regional haze analyses (i.e., 2009, 2012, and 2018), MACTEC used linear interpolation to develop factors for the required future years.

8.4.3 On-Road Mobile Sources

The on-road emissions source category consists of vehicles that are meant to travel on public roadways, including cars, trucks, buses and motorcycles. The basic methodology used for on-road mobile source calculations is to multiply vehicle-miles-travelled (VMT) by emission factors developed using EPA's MOBILE6.2 motor vehicle emission factors model. The on-road mobile category requires that SMOKE model inputs be prepared instead of the SMOKE/IDA emissions data format that is required by the other emission source categories. Therefore, for the 2002 baseline inventory, Pechan prepared the necessary VMT and MOBILE6 inputs in SMOKE format.

Projected on-road mobile source inventories were developed by NESCAUM for the MANE-VU region for ozone, particulate matter, and regional haze SIP purposes. As with other emission source categories, projected on-road mobile inventories were developed for calendar years 2009, 2012, and 2018. As part of this effort, MANE-VU member states were asked to provide VMT data and MOBILE6 emissions model inputs for the applicable calendar years. Using the inputs supplied by the MANE-VU member states, NESCAUM compiled and generated the required SMOKE/MOBILE6 emission model inputs. Further details regarding the on-road mobile source projections can be found in NESCAUM's "Technical Memorandum, Development of MANE-VU Mobile Source Projection Inventories for SMOKE/MOBILE6 Application," June 2006 (Attachment J).

8.4.4 Biogenic Emission Sources

Biogenic emissions for the 2002 baseline modeling emissions inventory were calculated for the modeling domain by the New York State Department of Environmental Conservation (NYSDEC). NYSDEC used the Biogenic Emissions Inventory System (BEIS) Version 3.12 as contained within the SMOKE emissions processing model. Biogenic emissions estimates were made for CO, nitrous oxide (NO_x) and VOCs. Further details about the biogenic emissions processing can be found in NYSDEC's technical support document TSD-1c, "Emission Processing for the Revised 2002 OTC Regional and Urban 12 km Base Case Simulations," September 19, 2006, and in Chapter VI: Biogenic Sources, of the "Technical Support Document for 2002 MANE-VU SIP Modeling Inventories," Version 3, November 20, 2006 (Attachment H). Biogenic emissions were assumed to remain constant for the future-years analysis, a reasonable approximation reflecting the expectation that most of the region will remain heavily forested for the duration of the planning period.

8.5 Summary of Maine's 2002 and 2018 Emissions Inventory

Tables 8-1 through 8-4, below, summarize the Maine baseline and future-year emission inventories. As previously discussed in section 8.2.2, there are three projected control scenarios for the 2018 inventory. The on-the-books/on-the-way (OTB/OTW) control strategy scenario accounts for emission control regulations that were already in place as of June 15, 2005, as well as some regulations that are not yet finalized, but are expected to achieve additional emission reductions by 2009. The beyond-on-the-way (BOTW) scenario includes emission controls that may be necessary to for attainment of the ozone and PM NAAQS, along with meeting other regional air quality goals. The final modeling emission inventory accounts for additional potentially reasonable control measures for reducing regional haze as discussed in Section 11 and 12 of this SIP, and was used to generate Maine's reasonable progress goals.

Table 8-1
2002 Emissions Inventory for Maine
(tons per year)

	CO	NH ₃	NO _x	PM ₁₀	PM _{2.5}	SO ₂	VOC
Mobile	410,958	1,468	54,687	1,239	934	1,804	23,037
Nonroad	153,424	11	9,820	1,437	1,329	917	31,144
EGU Point	7,962	145	7,831	1,169	888	9,299	842
Non-EGU Point	9,043	700	12,108	6,120	4,899	14,412	4,477
Area	109,223	8,747	7,360	168,953	32,774	13,149	100,621
Biogenics	64,936		2,018				600,205
Total	755,545	11,071	93,824	178,919	40,825	39,581	760,327

Table 8-2
2018 OTB/OTW Emissions Inventory for Maine
 (tons per year)

	CO	NH ₃	NO _x	PM ₁₀	PM ₂₅	SO ₂	VOC
Mobile	237,170	1,715	12,828	272	266	894	10,414
Nonroad	166,679	15	6,543	1,086	978	82	21,988
EGU Point	4,057	139	1,827	296	279	5,436	53
Non-EGU Point	11,433	859	15,753	7,496	5,935	18,794	5,709
Area	94,181	12,312	7,424	189,619	33,820	13,901	92,410
Biogenics	64,936		2,018				600,205
Total	578,456	15,041	46,393	198,768	41,278	39,107	730,779

Table 8-3
2018 BOTW Emissions Inventory for Maine
 (tons per year)

	CO	NH ₃	NO _x	PM ₁₀	PM ₂₅	SO ₂	VOC
Mobile	237,170	1,715	12,828	272	266	894	10,414
Nonroad	166,679	15	6,543	1,086	978	82	21,988
EGU Point	4,057	139	1,827	296	279	5,436	53
Non-EGU Point	11,433	859	14,137	7,477	5,922	18,692	5,708
Area	94,181	12,312	7,036	188,928	33,201	4,940	90,866
Biogenics	64,936		2,018				600,205
Total	578,456	15,041	44,389	198,058	40,646	30,044	729,234

Table 8-4
2018 Final Modeling Emissions Inventory for Maine
 (tons per year)

	CO	NH ₃	NO _x	PM ₁₀	PM ₂₅	SO ₂	VOC
Mobile	237,170	1,715	12,828	272	266	894	10,414
Nonroad	166,679	15	6,543	1,086	978	82	21,988
EGU Point	4,057	139	1,827	296	279	6,806	53
Non-EGU Point	11,433	859	14,137	7,477	5,922	13,082	5,708
Area	94,181	12,312	7,036	57,411	18,877	1,127	90,866
Biogenics	64,936		2,018				600,205
Total	578,456	15,041	44,390	66,542 ²⁷	26,321	21,991	729,235

²⁷ An adjustment factor was applied during the processing of emissions data to restate fugitive particulate matter emissions. Grid models have been found to overestimate fugitive dust impacts when compared with ambient samples; therefore, an adjustment is typically applied to account for the removal of particles by vegetation and other terrain features. The summary emissions for PM₁₀ in Table 8.4 reflect this adjustment. Comparable adjustments were not made to PM₁₀ values listed in Tables 8.1 through 8.3.