[FRONT COVER]

The Southern Appalachian Mountains Initiative

Final Technical Report

[INSERT PHOTO OF AZALEA]

August 2002

The Southern Appalachian Mountains Initiative

Final Technical Report

Prepared by the Southern Appalachian Mountains Initiative

August 2002

Table of Contents

Acknowledgements

[MORE CONTENT TO BE ADDED]

Dedicated to Arthur Smith who personified the SAMI approach of a dedication to his values while respecting the viewpoints of others, insistence on good science, and somehow finding the middle ground when it was needed most. [THIS DEDICATION MY BE ADDED TO FRONT OR BACK COVER]

Executive Summary

[EXECUTIVE SUMMARY TO BE WRITTEN AFTER SAMI ALL SECTIONS DRAFTED AND PHASE I REPORT REVIEW]

Introduction to the Southern Appalachian Mountains Initiative

SAMI'S MISSION

The Southern Appalachian Mountains Initiative is a public-private regional partnership working to improve air quality. The SAMI Mission is:

> *Through a cooperative effort, identify and recommend reasonable measures to remedy existing – and to prevent future – adverse effects from human-induced air pollution on the air quality related values of the Southern Appalachians, primarily, those of Class I parks and wilderness areas, weighing the environmental and socioeconomic implications of any recommendations***.**

SAMI Background

Eight southeastern states lead SAMI (Figure 1.1). They are Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. Other participants include the U.S. Environmental Protection Agency, U.S. Forest Service, National Park Service, industries, environmental organizations, and interested citizens.

[INSERT FIGURE 1.1 – SAMI Geographic Domain]

SAMI uses a consensus-based approach to regional strategy development, which provides a forum for stakeholders with diverse viewpoints to work together constructively to conduct the technical and policy assessments necessary for regional solutions.

SAMI was created in 1992 in response to concerns about permitting new emissions sources near Class I parks and wilderness areas in the Southern Appalachian mountains. (Refer to Figure 1.2 for a description and list of "Class I" Areas). State air quality agencies were receiving conflicting recommendations on permits for new or expanded emissions sources near these Class I areas. SAMI was established to examine the present and future effects of air pollution on these parks and wilderness areas. It was also to recommend ways to deal with any adverse effects that were found.

[INSERT FIGURE 1.2 – FEDERAL LEGISLATION & CLASS I AREAS]

SAMI designed and carried out an Integrated Assessment of air quality in the Southeast with a particular focus on the mountainous areas of the Southern Appalachians. A series of linked computer models predicted future emissions and the response of those emissions to a series of control strategies. In contrast to many air quality studies that focus on human health in urban areas, SAMI's focus is ecosystem effects in rural parks and wilderness areas. One goal of this assessment was to determine if the programs established by the Clean Air Act are adequate to protect the air quality of the Class I areas. A series of new federal air quality programs were introduced as SAMI developed its assessment (Figure 1.2) While the full effect of those programs is difficult to predict since they will be implemented over decades, SAMI concludes that additional measures beyond the Clean Air Act are needed as described in the sections on conclusions and recommendations.

SAMI'S INTEGRATED ASSESSMENT

SAMI's Integrated Assessment (Figure1.3) estimated the environmental effects and selected socioeconomic costs and benefits of SAMI-designed emissions reductions strategies. The Assessment used computer models to: track air emissions from their sources across the eastern United States; simulate the complex chemical and physical processes that occur in the atmosphere; project air pollutant exposures across the SAMI region; and estimate environmental and socioeconomic impacts. The assessment focused simultaneously on the environmental and socioeconomic effects of ozone, fine particles, and acid deposition. Following is a brief description of each of the Assessment areas:

[INSERT FIGURE 1.3: INTEGRATED ASSESSMENT]

Emissions Inventories characterized pollutants and their sources. SAMI inventories project the emissions that contribute to ozone, fine particles, and acid deposition in the eastern United States. The projected emissions are based on various emission reduction strategies for current and future years to 2040. Direct costs of emissions reduction controls were also assessed. See Chapter 3 for a more information on emissions inventories and reduction strategies.

Atmospheric Modeling simulated air quality conditions for nine week-long episodes during 1991-1995. Each episode consists of contiguous days chosen to represent a range of meteorological, emissions, and atmospheric chemistry conditions that contribute to air quality in the SAMI region. Atmospheric model simulations for the 1991-1995 episodes, 2010, and 2040 generated air quality response data for each emissions reduction strategy.

Environmental Effects Modeling evaluated the response of forests, streams, and visibility to changes to acid deposition, ozone levels, and fine particles. From this response data, SAMI has described how air quality and natural resources respond to changes in emissions.

Socioeconomic Analysis examined some of the social and economic implications of SAMI emissions reduction strategies. Of the large number of socioeconomic indicators possible, SAMI focused on: Fishing; Recreational/Residential Visibility; Stewardship/Sense of Place; and Lifestyles.

SAMI Accomplishments

[May be side-bar, not an actual section in Introduction?]

Voluntary/Consensus Process. A voluntary, consensus-based organization composed of a variety of stakeholders investigated a complex environmental topic. Using conclusions drawn from this analysis, SAMI recommended actions to address air quality problems in the Southern Appalachian Class I parks and wilderness areas.

Integrated Assessment. SAMI successfully applied an integrated, one-atmosphere model that addressed fine particles, ozone, and acid deposition simultaneously. Previous studies addressed these topics separately.

Atmospheric Episode Selection. SAMI demonstrated a method to reduce modeling time by selecting episodes to represent all types of emission regimes and weather patterns over the period with air quality records.

Emissions Geographic Sources. SAMI identified the states and regions contributing to the air quality impacts on Class I national parks and wilderness areas in the Southern Appalachians.

Environmental Effects. SAMI projected future changes in air quality and estimated the effect of those changes on streams, forests and visibility.

Visibility Tool. SAMI developed a tool to visually simulate the effect of proposed changes in aerosols.

Visibility Status. SAMI estimated natural background visibility and rate of progress under the SAMI strategies.

SAMI did NOT address carbon emissions, global warming, mercury emissions, mercury effects, human health effects, National Ambient Air Quality Standards attainment. While important, these topic were determined by SAMI to be outside the SAMI mission.

The Nature of the Problem

[SECTION UNDER DEVELOPMENT, WILL BE SENT OUT IN BATCH 2 ON MAY 31, 2002. WILL GENERALY BE A SUMMARY OF PROBLEMS STATEMENTS FROM EFFECTS SECTIONS, PLUS DISCUSSION REGARDING SAMI'S RESEARCH SCOPE]]

Emissions Inventories and Reduction Strategies

INTRODUCTION

To assess the impact of ozone, fine particles and acid deposition of the forest, streams and vistas of the Southern Appalachians, SAMI quantified the amount of precursor pollutants being emitted into the atmosphere. the emission inventory is the backbone of the SAMI analysis. This inventory quantifies the emissions of several different pollutants from all human activities. Those activities are divided into five source sectors:

Deleted: Thus,

Deleted:

- Utility Sector - facilities that burn fossil fuels to generate electricity, Hydroelectric, nuclear or other non- fossil fuel sources of electricity were not considered in the inventory
- Industrial Point Source Sector - large industrial facilities that manufacture goods,
- Highway Vehicle Sector which includes gasoline powered and diesel powered vehicles designed to operate on the roadways,
- Non-Road Engine Sector which includes planes, trains, boats, recreational vehicles and construction equipment;
- Area source sector, which includes: agricultural sources, small industrial, commercial and paved and unpaved roads.

Deleted: s

The pollutants quantified are the chemical precursors to acid formation, ozone and fine particulates, NO_x, VOC, SO_2 and NH_3. Also quantified were other pollutants that were themselves fine particles ($PM_{2.5}$ and PM_{10}) or were important to the overall atmospheric chemistry that had to be modeled to achieve the integrated assessment. This chapter discusses the methods used to create the emissions inventory and the resultant inventories for the most significant pollutants.

This inventory had to meet several objectives. Because SAMI's goals include predicting what future conditions might be like given different levels of emission controls it was essential to develop a baseline inventory and then vary that inventory according to the year and conditions being projected. The baseline contained emissions for all source sectors in 1990. This year was chosen because EPA had already developed an inventory for most of the pollutants and activities of interest to SAMI for 1990. While the primary area of interest is the 8 states that contain the 10 Class 1 wilderness areas of the Southern Appalachian Mountains (Figure 3.1), the initial inventory had to be much more extensive covering essentially the eastern two thirds of the country. Once the baseline year data was accumulated, reference cases were developed based on a specific level of emission control that could be foreseen for 2010 and 2040. Once this work was completed it was possible to create potential alternative control strategies and calculate what the emissions would be assuming the levels of control created for each strategy. These are collectively referred to as the B-group strategies. This chapter will detail the controls assumed for each of these strategies and the resultant levels of the most important pollutants. Uncertainty inherent to the analysis will also be discussed along with the discussion of the development of each phase of the inventory.

[INSERT FIGURE 3.1: SAMI GEOGRAPHIC DOMAIN]

OBJECTIVES

The emission inventory provides the foundation for all further analysis. Thus, the overarching objective is to provide that foundational information. That purpose can be organized into the following objectives:

> Establish baseline 1990 emission data from the five source sectors for a variety of pollutants including NOx, SO2, NH3, PM2.5, PM10, VOC, CO. From the emission estimates of particles (PM10 & PM2.5), estimates of elemental carbon, organic carbon, primary sulfates, primary nitrates and base cations (calcium, magnesium potassium and sodium) were derived. The emissions were both quantified in terms of daily emissions and located at the county level. This chapter will summarize these result as annual averages (in most cases) at the state or region level.
>
> Provide emissions for the nine week-long time periods between 1990 and 1995 that were selected as the episodes to use in the model. The inventory was adapted to the model which then used this data to determine ozone concentration, fine particle concentration and acid deposition at specific locations (see Chapter 4 for more information on atmospheric modeling). During each episode, the modeled results could then be compared to actual monitoring data. This allowed for verification of the model prior to using it to predict the future. The episodes selected were from different seasons representing different atmospheric conditions and required inventories that were very specific in their temporal and spatial distribution of emissions.
>
> Project emission inventories for a reference case for the years 2010 and 2040. A reference strategy of specific, anticipated regulations was selected and then the inventory was calculated based on those regulations and the growth in population and energy demand in the SAMI states.
>
> Project emission levels for the B-group strategies representing differing levels of controls in each of the source sectors for the years 2010 and 2040.
>
> Provide emissions for use in other SAMI air quality and effects models.
>
> The emission inventory provides the foundation of the cost estimates for various levels of emission reduction effort in the projected cases. It also provides the foundation for socio-economic analysis.

1990 BASELINE

The 1990 Baseline emission inventory took information from several other inventories which had already been developed. The inventory developed by the Ozone Transport Assessment Group (OTAG) was the starting point for the SAMI inventory. The OTAG inventory quantified emissions of ozone precursors for the District of Columbia and the 37 states which form the eastern two-thirds of the United States (Figure 3.2), which. This was the same geographic area necessary for SAMI's modeling. The OTAG inventory was also chosen because the data for all the SAMI states and most of the other states was actually provided by the states themselves. Additionally, the inventory was developed in 1995 and 1996 providing a good source of data regarding 1990. The OTAG inventory included NOx, VOC and CO emissions only, therefore SAMI obtained the remaining pollutant data from EPA's NET (National Emissions Trends) inventory. These two inventories were melded and then enhancements were made specific to the SAMI inventory.

[INSERT FIGURE 3.2: ATMOSPHERIC MODELING DOMAIN]

Essential to the SAMI emissions inventory was a rigorous quality assurance process that included both internal and external review. Internally, the inventory was compared with existing inventories to assure that the SAMI estimates were in line with previous studies and to find and include any missing categories of emissions. Once this process was complete the inventory was made available to states, local governments, utility, industry and other stakeholders. Three iterations of review and correction were conducted. The resulting inventory is perhaps the best and most comprehensive inventory conducted to date, however there are still areas of this inventory in which there is much greater confidence than other areas.

Uncertainty

It is important to note that the process of quantifying emissions from all human activity is not an easy task that provides unambiguous answers. Emissions from electricity producing utilities and industrial facilities (these are often referred to as point source emissions because the pollutant is released from a smokestack at a known non-moving point) are relatively easy to quantify. Pollutants from a variety of other activities, including trucks and automobiles, other combustion engines, farming activities, commercial activities etc. can be much more difficult to quantify. Often the task is a complicated mathematical activity that assumes we know the level of an emission that is generated and released by a certain activity and then how much of that activity is conducted over a certain period of time.

Deleted: e

For example, how much air pollution is generated by chainsaws? The answer depends on the emission factors of a chainsaw, how many there are in the area, how much they are operated over what period of time and where the are operated. In order to estimate that number requires making many assumptions. Each assumption leads to uncertainties in the analysis. Table 3.1 provides a qualitative comparison of confidence between certain pollutants based on their source sector.

[INSERT TABLE 3.1: 1990 BASE YEAR CONFIDENCE LEVLELS]

This ranking was developed by SAMI as a qualitative aid to understand both the strength and limitations of the emission inventory and is consistent with the levels of confidence inherent to all emission inventories developed to date. The assessment of this ranking is supported by a more rigorous analysis that was conducted (reference the DARS report).

Deleted: are

It is much easier to estimate point source emissions with a high degree of confidence than it is highway vehicle and non-road engine emissions. Likewise it is extremely difficult to estimate area emissions with much confidence. The uncertainties of the baseline emission remain throughout the analysis. Estimates of future pollutants are by necessity more uncertain than the baseline for that pollutant. The SAMI process has highlighted the need for an estimate of ammonia emissions that can be used for this type of analysis with a higher degree of confidence.

From Inventory to Model

A three-step process was used to integrate the baseline inventory with the modeling effort. First the data was grown to the appropriate year in which the particular modeled episode occurred (1993, 1994 or 1995). Second, the emissions were allocated to average daily emissions for the episode season. And third, the data was formatted as model input data.

DEVELOPMENT OF REFERENCE STRATEGIES

To develop the reference strategies for 2010 and 2040, SAMI projected from the baseline various scenarios with differing levels of future pollutant-producing activities and control programs. Population in the eight-state SAMI area is projected to increase in the period from 1990 to 2040. Electricity demand and vehicle miles traveled will increase even more rapidly. It is anticipated that vehicle miles traveled will increase by 70% from the 1990-level by 2010 and 170% by 2040. Likewise it is anticipated that electricity demand will increase by 50% in 2010 and by 100% by 2040. The source of these projections are ***** (Figure 3.3).

[INSERT FIGURE 3.3: POPULATION, ELECTRICITY, AND VEHICLE PROJECTIONS]

It was assumed that the current land use and lifestyle trends continue into the future. Also, no technology that is not already existing or anticipated was considered. It was assumed that increases in electrical generation would occur at the same location as the increase in demand. Utility plants were assumed to retire after 65 years of life, if electricity generation was still projected at that location then it was assumed that the plant would be "re-powered" or converted to a different, cleaner, energy source.

Two potential reference strategies were developed - A1 and A2. The A1 emission inventory assumed that the regulations promulgated at the time the inventory was developed would remain unchanged into the future. The A2 emission inventory included regulations that had been proposed but not yet promulgated at the time the inventory was developed. Over time it became clear that the A2 strategy more closly predicted the baseline conditions expected in 2010 or 2040, so it became the reference strategy to which other strategies were compared. To the extent possible, SAMI predicted in the A2 strategy the regulations that would be in force in 2010 and 2040 if no further actions were taken. Thus, the controls that are assumed to exist in the reference strategy, referred to as A2, are the acid rain controls (Title IV of the 1990 CAA), the 1-hour ozone standard, the Tier II highway vehicle and fuel rules, the 7-10 year MACT rules and the NOx SIP call. A2 does not include the regional haze rules, the 8-hour ozone standard, or the NAAQS for PM2.5.

Deleted: e

Resultant emissions of the Reference Strategies

The regulations assumed by the A2 strategy have the greatest impact on SO2 and NOx emissions. Despite the increases in activity, the A2 strategies predict decreases in both NOx and SO2. Figure 3.4 presents the comparison between the base year and the reference strategy for 2010 and 2040 for the five key pollutants of NOx, SO2, VOC, PM2.5 and NH3 in the entire SAMI region as an aggregate. Each bar is segmented into the five source sectors. The utility source is the source sector that generates the largest quantity of SO2 and experiences the greatest reduction in SO2 emissions. Over all the SAMI states and sectors, SO2 is reduced by 23% by 2010 and by 61% by 2040. The utility and highway vehicle source sectors generate most of the NOx emissions. Annual NOx emissions are reduced by 24% by 2010 and by 37% by 2040. The VOC emissions in the SAMI states experience a reduction between 1990 and 2010 but then experience a 39% increase between 2010 and 2040. The NH3 and primary fine particle levels increase over time, which would be expected since the controls assumed do not effect these pollutants and there is an increase in activity.

[INSERT FIGURE 3.4: EMISSIONS PROJECTIONS]

The inventory database is available at the SAMI archive [MORE INFORMATION WILL BE ADDED]. The inventory can be viewed at the state level for each of the seven pollutants broken out by source sector.

If SO2 is considered at the state level (Figure 3.5), SO2 emissions are projected to rise in NC, SC, and VA between 1990 and 2010. Emissions in all states are projected to fall below 1990 levels by 2040. Utility plans vary state to state in terms of increased production and controls thus accounting for the difference in state emission trends. Based on information from Utility representatives to the SAMI process, it was determined that the eight SAMI states would exceed the SO2 cap allowed by Title IV by 1 million tons of SO2. Utilities in the SAMI states indicated that they would buy allowances under the Title IV trading program. The inventory modeled this behavior by assuming that scrubbers would be installed on 106 sources outside the eight SAMI states. For other pollutants, the reductions within all states are consistent with the regional trend.

[INSERT FIGURE 3.5: ANNUAL SO2 EMISSIONS-8 SAMI STATES]

Uncertainty

The following tables identify the percentage of pollutant in each year that comes from each source sector. This allows for an understanding of the significance of each source sector in the inventory of a specific pollutant. For example, for SO2 the source sector of preeminent concern is the utility sector. Likewise for NH3 and primary PM2.5, only the Area source is significant, meaning that our understanding of and confidence in these inventories is significantly less than in the inventories of NOx, VOC and SO2. This refers to primary PM2.5, only. The majority of PM2.5 in the atmosphere is produced through reaction of other primary pollutants, especially SO2, NOx and NH3.

Table 3.2
Percentage of Emissions Contributed by Sector and Pollutant in 2010 A2

	Annual Emission Contributions					NO_x
Sector	**VOC**	**NO_x**	**SO_2**	**$PM_{2.5}$**	**NH_3**	**OSD**
Utility	0	30	70	3	0	16
Highway	25	24	1	2	11	35
Nonroad	9	15	3	6	0	22
Area	45	14	11	79	85	11
Point	21	17	14	10	4	18
Total	***100***	***100***	***100***	***100***	***100***	***100***

Table 3.3
Percentage of Emissions Contributed by Sector and Pollutant in 2040 A2

	Annual Emission Contributions					NO_x
Sector	**VOC**	**NO_x**	**SO_2**	**$PM_{2.5}$**	**NH_3**	**OSD**
Utility	0	19	43	2	0	17
Highway	26	27	2	2	13	30
Non-road	8	16	10	5	0	20
Area	44	18	23	82	83	13
Point	23	20	22	10	4	20
Total	***100***	***100***	***100***	***100***	***100***	***100***

DEVELOPMENT OF THE STRATEGIES:

One of SAMI's major contributions to Air Quality planning is the development of a series of control scenarios that allow for the development of inventories and the subsequent modeling of those inventories under comparative conditions. These strategies were not based on existing or anticipated regulations but were based on potential course of actions that the SAMI states and the stakeholders could take in the future. These strategies were developed to determine what the effects on the environment would be at different emission levels. Three strategies with increasingly stringent emission controls were developed for both 2010 and 2040, these strategies are referred to as B1, B2 and B3. [NEED A FOOTNOTE PERHAPS THAT LINKS THE B DESIGNATIONS WITH THE OLD BOLD NAMES?] In general, the SAMI participants designed these three strategies from these conceptual starting points:

- B1 - state-of-the-art controls applied to all sources. Logistic constraints and other practical considerations are considered.
- B2 - state-of-the-art controls applied to all sources as soon as possible.
- B3 - The most advanced controls for 2010 and prototype controls for 2040 applied to all sources as soon as possible.

Appendix A outlines all the B-group strategies by sector. Brief discussions of the methods used to approach the concepts outlined above are offered below. In general, any given strategy will be more stringent in the year 2040 than in the year 2010. It is also important to note that these controls and the resulting inventories were calculated for the eight SAMI states only. Working on the assumption that greater controls would only be adopted by the participants in this process, the inventory of emissions for the remaining states remained the same for all the subsequent work determining effects of these strategies in the southern Appalachian mountains. This is a brief description of those control assumptions for all of the details please reference the Pechan report.

Utilities

For SO2 removal for existing units it was assumed that more efficient scrubbers would be put on more units in each of the more stringent strategies. In 2010 B1, 50% of the unscrubbed units were assumed to have scrubbers installed that had 90% control efficiency. Likewise all scrubbers, of less than 90% efficiency, were assumed to be upgraded to that efficiency. The same strategy was used in the B2 case, however the new scrubber efficiency was set at 95%. In the B3 case all unscrubbed units of greater than 25MW capacity were assumed to have 95% efficiency scrubbers. In 2040, 100% of the unscrubbed units with capacity greater than 25MW and any units having scrubbers of less than 90% efficiency were assumed to have scrubbers with 90% efficiency. Likewise for B2 in 2040 the same units were controlled with scrubbers of 95% efficiency and for B3 they were all controlled to 98% efficiency. Power plants built in 2040 are assumed to be powered in three different ways at the following ratio - 20% pulverized coal, 40%combined cycle natural gas and 40% gasified coal. In the B2 and B3 strategy it has been assumed that none of these new units would be pulverized coal and that the units would be split equally among the other two types. This assumption lowers the composite SO2 rate from 0.025 lbs./MMBtu to 0.0116 lbs./MMBtu.

For NOx emissions the assumptions of fuel mixture for new units also applies. For existing units the following controls apply: In 2010 and 2040 B1 it is assumed that the controls that are in place for the NOx SIP call would be run year-round instead of just during the ozone season. All units that are controlled would be controlled to either the emissions achieved for the SIP call or 0.15 lbs./MMBtu, whichever is less. Likewise the B2 strategy would be the same except the maximum emission rate would be 0.10 lbs./MMBtu. In the B3 scenario the emission rate of 0.07 lbs./MMBtu year-round was used for 2010 and 0.05 lbs./MMBtu for 2040.

Industrial Sector

Similar strategies were applied for the industrial sectors. In general, greater and greater level of controls were added to more and more units as the strategies became more stringent. See Appendix A for greater detail of the industrial sector. In general the methods and levels of NOx and SO2 reductions for the utility and industrial sectors were deemed achievable in the timeframes considered by the industrial and utility representatives to the SAMI process.

Highway Vehicle

Additional emission reductions from highway vehicles were achieved for each strategy by continually more aggressive implementation of several strategies. First in developing the B strategies from the A2 strategy it was assumed that fleet turnover would occur at a faster than natural pace and that a greater percentage of the fleet would achieve the 2004 Tier II controls in the year 2010. It was also assumed that a percentage of the fleet would convert to zero emission vehicles - in the 2040 B3 case 100% of the light duty vehicles are assumed to be ZEV's. The other control assumed is reduction in the growth rate of vehicle miles traveled. Similarly, heavy-duty vehicles, which would be predominately trucks and exclusively diesel-powered vehicles, are assumed to increase fleet turnover resulting in greater percentages of the fleet meeting the 2007 emission guidelines in 2010. In 2040 there are significant portions of the fleet that are assumed to have converted to ZEV and there is the assumption that some of the vehicle miles traveled con be converted to rail traffic. There are also increasing stringent reductions in the amount of sulfur in diesel.

Non-road Engine

The non-road engine sector includes the variety of motors and engines used for all other activities besides passenger cars and trucks, such as airport service equipment, gasoline powered lawn and garden equipment and recreational vehicles, all diesel engines except trucks including boats and trains, and construction equipment and aircraft engines. The different strategies involved increased reliance on ZEVs in many of these categories. Strategies also included decreasing the level of sulfur in diesel
Fuel, and increased penetration rates for the 2007 diesel engine standards and the clean aircraft rules.

Deleted: ed

Deleted: the

In both the non-road and highway vehicle sector it is unclear whether it will be technically feasible to reach the levels of ZEV usage or other fleet turnover options. Likewise the feasibility of VMT reductions are uncertain because SAMI has projected unprecedented levels of VMT reduction.

Area Sources

The area source sector is considered by pollutant type. Thus there are five categories of pollutants for which there are area sources and then specific sources that generate each of those pollutants. There is significant overlap in the sources that generate SO2 and NOx, with all of these sources being some type of combustion. There are also sources for PM10, PM2.5, Ammonia, and VOCs. Instead of discussing specific types of controls as was done for the other source sectors, for the area source it was just determined what level of reduction would be assigned to each source in each strategy. See the appendix/table for the specific percentages. Again, at the B3 level and in some cases at the B2 level it is not clear that the reductions included in the strategy are technically achievable. This is true, for example, in the area of ammonia reduction.

Results: Application of Emission Reduction Strategies

This chapter will emphasize the emission inventory results of the three pollutants that are most significant to the SAMI analysis, remembering that the goal of SAMI was to analyze the levels of and affects of ozone, acid deposition and fine particle haze on the Southern Appalachia's Class I wilderness area. Those pollutants are NOx, SO2 and NH3. Graphics in this section will compare the 1990 baseline to the A2 reference strategy and to either the B1 and B3 strategies or all of the B strategies. VOCs are a significant contributor to the chemistry of ozone formation. However, it has been determined that in the southern Appalachian mountains, naturally occurring VOCs are much more prevalent than man-made VOCs. SAMI's analysis only discusses man-made VOCs. The pattern of VOC emissions over the study years and under various strategies can be seen in (Figure 3.6), VOCs and primary particles will be discussed briefly. Other pollutants including carbon monoxide can be examined in the annual inventory but are not discussed in the text.

Deleted: is

Deleted: that

[INSERT FIGURE 3.6: ANNUAL STRATEGY EMISSIONS] (Figure name differently)

SO2

Total reductions from each B-group strategy compared to A-2 is (Figure 3.7):

- In 2010, B1 - 34%, B2 - 44%, B3 - 81%
- 2040 A-2 strategy is 51% 2010 A-2
- In 2040, B1 - 48%, B-2 - 60%, B3 - 79% (relative to 2040A2)

[INSERT FIGURE 3.7: ANNUAL SO2 EMISSIONS]

The A2 reference case, as discussed previously, would reduce SO2 levels from the 1990 baseline by 23% in 2010 and by 61% in 2040. The utility sector contributes most to SO2 emissions. This sector also experiences the greatest emission reductions, through increasingly tight controls on more and more units and on switching from pulverized coal to other fuel sources. In the utility sector in 2010, the B1 and B2 strategies require scrubbers of 90% and 95% efficiency respectively on 50% of the capacity that still did not have scrubbers. The B3 strategy required scrubbers of 98% efficiency on 100% of the unscrubbed capacity.

Deleted: t

The 2040 strategies for the existing utility facilities were similar. There was also the recognition that by 2040 there would be new plants to meet increasing demand and many utility plants would be retired (an active life of 65 years was assumed for power generating facilities). These new and re-powered facilities were assumed to use the following combination of fuel types: 20% pulverized coal, 40% Integrated gasification combined cycle and 40% natural gas combined cycle in the A2 reference case and the B1 strategy. In the B2 and B3 strategies the percentage of pulverized coal was dropped to 0% and the other two were each raised to 50%. These are the strategies by which utility sector reductions of SO2 were assumed to be accomplished.

In addition to the significant reductions in the utility sector, there are small reductions in the area and non-road vehicle sectors through fuel switching. There is very little SO2 emission reduction from the industrial source sector because there are so many small sources that none of the strategies assumed the depth of controls that would significantly change this sector. It is noteworthy, that the B1 and B2 strategies implemented in the year 2010 would accelerate annual

Deleted: of note

emissions reductions that would be achieved through the reference strategy alone by 2040. The 2010 B3 strategy would create emission reductions greater than the reference strategy in the year 2040.

Confidence in the SO2 inventory is the highest of all the pollutants in the analysis.

Deleted: of

NOx

The largest sources of NOx are the Utility and Highway Vehicle sectors and the greatest reductions are also in these sectors (Figure 3.8). NOx reductions in the utility sector are created by placing tighter controls in each subsequent strategy. NOx control on utility boilers is achieved by use of selective catalytic reduction (SCR). New units and replacement units are also assumed to have even tighter controls. In the Highway vehicle sector the strategies presume increasing penetration of the TIER II rules which take effect in 2007 and greater conversion to zero emission vehicles. It was assumed that ZEV's did not cause an increase in electricity demand.

[INSERT FIGURE 3.8: ANNUAL NOX EMISSIONS]

Total reductions from each B-group strategy compared to A-2 is:(Figure 3.8)

- In 2010, B1 - 27%, B2 - 45%, B3 - 63%.
- 2040 A2 is 83% of 2010 A2.
- In 2040, B1 - 39%, B2 - 57%, B3 - 76%.

The 2010 A2 strategy requires NOx reductions in the summer months only, since NOx is a precursor to ozone formation and ozone is a summertime pollution problem because both sunshine and warm temperature promote the chemical reactions that generate and accumulate ozone. All of the B-group strategies require the same level of control year round. However state policy makers continue to be interested in the summer inventories so these inventories were prepared by SAMI to assist in deciding what controls might be best suited to alleviating the ozone problem (Figure 3.9)

[INSERT FIGURE 3.9: SUMMER DAY NOX EMISSIONS]

NH3

Ammonia emissions are almost exclusively from agricultural sources coming from animal waste products and fertilizer production and application. In the reference strategy emissions increase with activity as there are no significant controls foreseen in the area of ammonia emission controls. As greater controls are envisioned in the different strategy reductions are accomplished but it is not until the B3 strategy that emission levels are significantly less than 1990 levels. (Figure 3.10). Ammonia emissions are more significant in the area of fine particulate development and acid deposition than was recognized at the beginning of this analysis. The level of confidence in the baseline NH3 inventory is very low because it is more difficult to assess emissions from area sources. Estimating agricultural emissions from animal operations requires estimating the emissions from each animal and then estimating the level of activity. The development of reference strategies required assessing the growth in the number of animals. This inventory was developed using economic growth of the agricultural sector as a surrogate for the number of animals. While these assumptions make it clear that there is a high level of uncertainty in this inventory - it is not clear if the inventory under predicts or over predicts the ammonia production from these sources. The B strategies were designed to specific reductions in ammonia emissions - it is highly uncertain that reductions of emissions from livestock of greater than 30 or 40% could ever be achieved.

Deleted: even

[INSERT FIGURE 3.10: ANNUAL NH3 EMISSIONS]

Ammonia is significant in the development of fine particulate, it is also a significant contributor to overall nitrogen deposition. To begin to understand this contribution SAMI assessed the total nitrogen emissions as Nitrogen from both the NOx sources and the NH3 sources (Figure 3.11).

Deleted: the

[INSERT FIGURE 3.11: ANNUAL NITROGEN EMISSIONS]

OTHER POLLUTANTS:

VOC emissions come from three source sectors; area sources, highway vehicle sources, and industrial sources. In the A2 strategy there are reductions from the highway vehicles sector that cause VOC emissions to be less in 2010 than in 1990. These reductions are more than overwhelmed by the growth in activity in several sectors including the industrial sector by 2040. In the B-group strategies the most significant reductions are seen in the highway vehicle sector as the strategies call for lower emission vehicles in 2010 and more ZEVs in 2040. Also the B3 strategy calls for significant reduction in VOC emissions from area sources.

Deleted: ,

Deleted: the

Emissions of primary PM2.5 come mostly from area sources including combustion sources (uncontrolled burning like agricultural burning, residential heating and forest fires) and unpaved road dust. These sources actually contribute little to the visibility problem, which is predominately the result of secondary fine particles that form in the atmosphere from SO2, NOx and ammonia emissions. The reference method A2 offers no controls for primary fine particulate and so the emissions increase with the increase in activity from 1990 to 2010 and then 2040. Only the B3 strategy requires controls that would significantly reduce the levels of primary fine pollutants.

CONCLUSION

The SAMI emission inventory quantifies emissions for a 1990 base case, a 2010 and 2040 reference case, and a series of hypothetical cases for the years 2010 and 2040. These inventories are used in the SAMI air quality and effects model to determine what the effect on the Class 1 wilderness areas in the eight state SAMI region could be. While baseline inventories were developed for the eastern two-thirds of the United States the hypothetical, B-group strategies, were inventoried for the SAMI states only.

The inventory provides the foundation for the SAMI analysis. There is very high confidence in the point source inventories (utility and industrial sectors). There is moderate confidence in the highway vehicle sector. Emission Inventory tools are still being developed and there are now models for estimating highway vehicle emissions that are better than those available when this inventory was completed. One of the clear needs of emission inventory development in the future is improvements in NH3 inventories.

Deleted: ,

Deleted: the

The results of the inventory in terms of emission reductions have been discussed in this chapter and can be found in tabular form in [REFERENCE TBD]. However, further conclusions can not be drawn from these emissions. It is through the process of the integrated assessment that further conclusion and ultimately decision -making is possible.

Air Quality and
Geographic Sensitivity Analysis

[SECTION UNDER DEVELOPMENT, WILL BE SENT OUT IN BATCH 2 ON MAY 31, 2002.]

Fine Particles and Visibility

SAMI VISIBILITY ASSESSMENT OBJECTIVES

- Summarize visibility and fine particle trends for SAMI Class I areas based on IMPROVE data
- Assess methods used to calculate light scattering from measured or modeled fine particle mass
- Use SAMI air quality model results to project future fine particle levels and visibility in response to SAMI strategies
- Provide visibility estimates to support SAMI socioeconomic analyses
- Provide electronic software tools to archive and display SAMI visibility results
- Relate SAMI assessment to EPA guidance for the regional haze rule

[INSERT GRAPHIC 5.1: LOOK ROCK VISIBILITY]

WHAT IS VISIBILITY?

Visibility is a term that refers to human perception of a scenic vista. The term addresses our ability to distinguish the color, contrast, and outline of objects viewed in a landscape. Fine particles and gases in the atmosphere scatter or absorb light and reduce the clarity of the view and the distance that can be discerned by the human eye. As visibility is reduced, colors appear washed out and less vivid, and landscape features become less clear, or may disappear altogether.

Light energy is transmitted through the atmosphere as electromagnetic waves called photons (Malm, 1999). The passage of light photons in the atmosphere can be altered in three ways:

- Light is scatttered out of the sight path between the viewer and the image. Particles in the size range closest to the wavelengths of visible light (particles between 0.3 and 0.7 microns) are the most efficient in scattering photons.

- Light is absorbed out of the sight path by fine particles and gases.

- Light is scattered into the sight path from sunlight or from light reflected off the ground or other objects in a landscape.

Visibility is also affected by the angle of the sun. When the sun is overhead, photons encounter few particles in the vertical sight path to our eye and little light is scattered. We perceive the sun as white. When the sun is nearer the horizon, the sight path to our eye is longer and more likely to be distorted by particles and gases in the atmosphere. At sunrise or sunset, blue light is scattered out of the sight path and we perceive the sun and sky as red.

[INSERT GRAPHIC 5.2: SAMI RELEVANCE TO REGIONAL HAZE]

WHAT CAUSES HAZE?

Particles and gases in the atmosphere scatter or absorb light and impair visibility. **Fine particles** are those less than 2.5 microns, while **coarse particles** are those particles between 2.5 and 10 microns. Most fine particles are secondary byproducts formed in the atmosphere from emissions of gases and organic compounds.

Fine particles include sulfate, nitrate, organic, and soil particles. Organic particles in rural areas are primarily emitted by vegetation. Organic particles reflect blue photons and cause a bluish haze. The Great Smoky Mountains and Blue Ridge Mountains were named for the bluish haze and misty clouds common to these mountains.

Sulfate particles are formed from sulfur dioxide emissions, primarily from coal combustion. As illustrated in Figure Visibility 1, sulfate particles occur in the atmosphere as sulfuric acid (one sulfate molecule associated with two hydrogen ions), as ammonium bisulfate (one sulfate molecule associated with one hydrogen ion and one ammonium ion), or as ammonium sulfate (one sulfate molecule associated with two ammonium ions). Sulfate particles scatter photons of all colors and cause a whitish or gray haze. Ammonia gas is emitted primarily from livestock and fertilizer applications. Ammonia gas causes a smelly haze.

[INSERT FIGURE 5.1: ILLUSTRATION OF MOLECULES OF SO4 WITH H AND NH4, NO3 GAS WITH NH4 TO FORM NH4NO3 PARTICLE]

Nitrate particles are formed from nitric acid gas and ammonia gas. Nitric acid gas is formed from nitrogen oxide emissions from combustion of fossil fuels (coal, natural gas, gasoline, and diesel). Ammonia gas reacts with nitric acid gas to form ammonium nitrate particles. Because ammonia gas preferentially binds with sulfate, ammonium nitrate particles will not be formed until all sulfate particles are fully neutralized (ratio of ammonium to sulfate ions of 2.0). For most of the year in the southeastern United States, sulfate particles are not fully neutralized by ammonium, and nitrate particles concentrations are low (IMPROVE).

Fine soil particles are primarily from construction, agricultural, and road sources. Fine soil particles scatter less light than sulfate, nitrate, and organic particles.

Elemental carbon is emitted from forest fires and other combustion sources. Elemental carbon absorbs photons and removes light from the sight path. Nitrogen dioxide gas (NO2) absorbs blue light and thus we perceive a reddish brown haze. This is particularly notable above urban areas with high densities of N02 emissions.

HOW IS VISIBILITY MEASURED?

Visibility is measured using visual observations, optical instruments, or calculated from fine particle mass.

Visual range is a common measure of visibility that describes the distance that can be viewed and is reported in miles or kilometers (Figure 5.2). Visual range is not a good measure of the clarity of an image. Visual range can be measured using photographs or observations of objects at fixed distances from an observation point. Visual range can also be calculated from light extinction.

[INSERT FIGURE 5.2: MEASUREMENT SCALES FOR VISUAL RANGE, EXTINCTION, AND DECIVIEW; INSERT SCALE FROM MALM, 1999, PAGE 35]

Light extinction is an optical measure of both the absorption and scattering of light in a sight path and is reported as inverse megameters. The higher the extinction value, the poorer the visibility. Light extinction measures atmospheric conditions but does not address how people perceive visibility. Light extinction is measured using optical instruments (called transmissometers or nephalometers) or calculated based on measured mass of fine particle components.

Deciview is a measure of visibility that is based on the same concept as decibels, which measure hearing. A deciview measures an equivalent incremental change in visibility whether the atmosphere is clear or hazy. Most people can discern a 1 deciview change in visibility. Deciview is calculated from light extinction using a logrithmic scale. The higher the deciview value the poorer the visibility.

Photographic images are commonly used to illustrate visibility. In recording a view, cameras function similarly to the human eye. The aperture of a camera controls the amount of light entering the camera in much the same manner that the iris of the eye controls the light reaching the retina. The retina of the eye detects the relative differences in brightness and contrast between objects and the background. Photographs capture the clarity, contrast, and colors of objects in an image. Because photographs cannot record as much detail as the human eye, they are imperfect images of how we perceive a vista.

Photographs of clear vistas in the SAMI Class I areas have been recorded as computer images using a computer software tool called WINHAZE (*reference* ARS,). These images represent visibility on the 3% (*check*) best visibility days at these sites. The computer images can be adjusted to visualize how a view changes in response to changes in light extinction. These photographs of Shining Rock Wilderness Area, NC, illustrate the range of visibility from clear to hazy days.

[*Illustrate range of visibility conditions in Shining Rock Wilderness Area, NC using either WINHAZE photos here or inserting photos of actual modeled days after text describing episode selection and just reference those photos here.]*

CALCULATING LIGHT EXTINCTION

Light extinction can be calculated using assumptions about particle mass, extinction efficiency, and the amount of water vapor in the air, or relative humidity. SAMI used the equation below to calcuate light extinction from measured particle mass and changes in light extinction in response to changes in particle mass under SAMI strategies. For simplicity this equation ignores the effects of different particle sizes and shapes on light extinction and assumes that particles behave the same way in mixtures as they do when all particles are the same chemical component.

$$\Delta \text{ bext} = E_{idry} \text{ x } f_i \text{ (RH) x } \Delta C_i$$

Where: Δ bext = change in light extinction
E_{idry} = dry extinction efficiency of fine particle species i
f_i (RH) = effect of relative humidity on extinction efficiency of fine particle species i
ΔC_I = change in concentration of fine particle species i

Fine particles are more efficient in scattering light than coarse particles and play a greater role in visibility impairment. Organic particles scatter light more efficiently than sulfate and nitrate particles, and all three components scatter more efficiently than soil and coarse particles. Elemental carbon absorbs light. To calculate light extinction, a factor to account for the efficiency of light scattering or light absorption is assigned to each fine particle species and to coarse particles. This efficiency factor is multiplied by the measured mass of each species, as defined in the equation below.

$$\begin{aligned} b_{ext} = & \ 3.0 \text{ x } f(RH) \text{ x } [\text{Ammonium Sulfate}] \\ & + 3.0 \text{ x } f(RH) \text{ x } [\text{Ammonium Nitrate}] \\ & + 4.0 \text{ x } [\text{organics}] \\ & + 1.0 \text{ x } [\text{soil}] \\ & + 10.0 \text{ x } [\text{Elemental Carbon}] \\ & + 0.6 \text{ x } [\text{Coarse Mass}] \\ & + 10 \ [\text{light scattering in clear air}] \end{aligned}$$

The calculation of light extinction includes a term that accounts for relative humidity. Sulfate and nitrate particles, and to a lesser extent, organic particles absorb water vapor. With added water vapor, sulfate particles grow to larger particle sizes (0.6 microns) that are more efficient at scattering light. Acidic sulfate particles absorb more water vapor and scatter more light than ammoniated sulfate particles. At higher relative humidity (greater than 75%) sulfate and nitrate particles can scatter (*what factor*?) as much light as at lower relative humidity (35% or below) (reference)

WHAT IS NATURAL VISIBILITY?

In the absence of human emissions, natural background visibility is effected only by scattering by air molecules, by water vapor, and by organic particles from vegetation. Natural background visibility in the eastern United States is estimated as 93 miles plus or minus 30 miles (Trijones, et. al. 1990). Natural visibility is lower in the summer than in the winter in the southeastern US, because both relative humidity and natural production of organic particles are higher in the summer than in the winter.

VISIBILITY AND FINE PARTICLE MONITORING IN SAMI CLASS I AREAS

The Interagency Monitoring of Protected Visual Environments (IMPROVE) network has measured fine and coarse particles at national parks and wilderness areas beginning in the late 1980s. By 2002, the network includes ____ sites nationally, and 8 sites in the SAMI region (Figure 5.3). Great Smoky Mountains and Shenandoah National Parks have the most complete IMPROVE data sets in the SAMI region (Table 5.1).

[INSERT FIGURE 5.3: MAP OF SAMI REGION AND LOCATIONS OF IMPROVE MONITORS IN SAMI CLASS I AREAS.]

METHODS

The IMPROVE network collects particles on teflon or quartz filters (*check*, add reference) over a 24-hour period, for two days per week (prior to 2000, every Wednesday and Saturday, since 2000, every 3rd day). [Description of IMPROVE mass may need to move to air quality modeling section with discussion of model performance.] Average daily particle mass is measured directly for sulfate, nitrate, soil, and elemental carbon. Ammonium mass is not routinely measured by IMPROVE. Sulfate mass is reported as the mass of ammonium sulfate assuming that sulfate is fully neutralized (ratio of ammonium to sulfate ions is 2.0). Nitrate is reported as the mass of ammonium nitrate.

Only a fraction of the total organic particles are captured on the filter. To account for the unmeasured organic mass, IMPROVE multiplies the measured organic mass by a factor of 1.4 to report total organic mass.

Total measured PM2.5 mass is often larger than the sum of the measured individual species: sulfate, nitrate, organics, soils, and elemental carbon. The composition of the unmeasured mass is unknown but commonly attributed to water vapor associated with the fine particles.

Light extinction and relative humidity are currently measured by IMPROVE at Great Smoky Mountains, TN; James River Face, VA; and Shenandoah, VA; Light extinction and relative humidity were measured at Dolly Sods, WV, from 1991 to   and at Shining Rock, NC, from 1993 to ____ . These measurements have been discontinued (Table 5.1).

Table 5.1. IMPROVE monitoring at Class I areas in SAMI region.

Class I area	Date IMPROVE particle monitoring	source of particle data for SAMI analyses (1991-1995)	Date Relative Humidity Initiated and RH Source for	

	initiated		SAMI analyses	
Sipsey Wilderness Area, AL,	1991	Borrow July 1991 episode from Great Smoky Mtns.	None, use modeled RH for episodes	
Cohutta Wilderness Area, GA,	2000	Borrow 1991-1995 episodes from Great Smoky Mtns	2002, use modeled RH for episodes	
Great Smoky Mountains National Park, TN	1988	Use Great Smoky Mtns. data	1991 – current, use measured hourly RH	
Joyce Kilmer-Slickrock Wilderness Area, NC	None, IMPROVEuses Great Smoky Mtns.	Use Great Smoky Mtns. data	None, use Great Smoky Mtns. RH	
Shining Rock Wilderness Area, NC	1993	Borrow data for 4 episodes 1991-1993 from Great Smoky Mtns, use on-site data for 5 episodes.	1993-check, use modeled RH for episodes with on-site measured RH	
Linville Gorge Wilderness Area, NC	2000	Borrow data for 1991-93 episodes from Great Smoky Mtns. and 1994-1995 episodes from Shining Rock	None, use modeled RH	
James River Face Wilderness Area, VA	1993	Borrow data for 1991-1993 episodes from Shenandoah; use on-site data for 5 episodes	2000?, use modeled RH for episodes	
Shenandoah National Park, VA	1988	Use Shenandoah data	1991 to current, use measured hourly RH	
Dolly Sods Wilderness Area, WV	1991	Borrow July 1991 episode from Shenandoah; use on site data for 8 episodes	1991- , use modeled RH for July 1991 episode, measured hourly RH for episodes	
Otter Creek Wilderness Area, WV	None IMPROVE uses Dolly	Use Dolly Sods data	Use same RH data as Dolly Sods	

	Sods			

TRENDS

Based on the IMPROVE data, there has been no clear trend in annual median visual range (Figure 5.4) over the past decade at SAMI Class I areas (IMPROVE, 2002). There are greater differences in annual median visibility between Class I areas than between years at any one site. Summer days tend to be hazier than the annual average. Compared to natural background of 93 miles, current annual median visibility at Shenandoah National Park is **____** miles and at Great Smoky Mountains is _____ miles.

[INSERT FIGURE 5.4: VISUAL RANGE AT SAMI CLASS I AREA BASED ON IMPROVE DATA]

For annual average conditions at SAMI Class I areas, sulfate particles are the largest contributors to fine particle mass and visibility impairment.. Organic particles are the second largest contributors to fine particle mass. Nitrate particles contribute more to light extinction than to fine particle mass. Nitrate particles have lower mass than organic particles at all sites (5 to 10 % of fine particle mass on annual average) but similar or slightly larger contributions to light extinction than organic particles (Adlhoch, 2002). On most days elemental carbon and soils are minor contributors to fine particle mass and visibility impairment . On the 20% haziest days, sulfate particles contribute greater than 70% (*check*) of total light extinction. On the 20% clearest days, sulfate contributes roughly 50% (*check*) of light extinction and organics, nitrate, soils, and elemental carbon have larger contributions to light extinction than on hazier days (IMPROVE, 2002).

LINKING SAMI AIR QUALITY MODEL AND VISIBILITY EFFECTS ASSESSMENT

IMPROVE fine particle and relative humidity data from 1991 to 1995 at Look Rock, TN, in Great Smoky Mountains National Park and at Big Meadows, VA, in Shenandoah National Park was used to select episode days for air quality modeling (SAI, 1998, Timin, 2002). All IMPROVE days were assigned to one of five classes based on the combined fine particle mass of sulfate, nitrate, organics, and soil (Table 5.2). Class 1 days are the days with the lowest 20% of fine particle mass. Class 4 plus Class 5 days together represent the 20% highest mass days in the 1991-1995 record. Class 5 alone address the days with 3% highest mass.

Table 5.2. Adapt from SAI Episode Selection Report (include columns for summer vs winter?)

Visbility Class	Combined Fine Particle Mass (SO4, NO3, organics, and soils, µg/m3)	Frequency of Days	Number of modeled days with IMPROVE data- Great Smoky Mtns.	Number of modeled days with IMPROVE data- Shenandoah
1	0 - 5.0	0 -20%		
2	5.1 - 9.1	21-50%		
3	9.1 – 15.8	51-80%		
4	15.8 – 24.9	81-97%		
5	24.9 – 41.5	98-100%		

Sixty-nine days in nine episodes in 1991-1995 were selected to represent annual average fine particles, annual average wet deposition, and growing season ozone. Air quality on these 69 days was modeled using the Urban to Regional Multiscale (URM) model. URM is an integrated, one-atmosphere model for fine particles, ozone, and acid deposition (see Chapter ___ Air Quality Modeling). URM was first run using emissions specific to the 69 days in 1991-1995. SAMI emissions inventories for 2010 and 2040 (see Chapter ____ Emissions Inventory) were then used to project future air quality on the modeled days.

The 69 modeled days include 22 days when IMPROVE monitoring data are available for model performance evaluation (Figure 5.5). Weights are assigned to each of these 22 days to account for the frequency of occurrence during 1991-1995 of meteorology similar to that on the modeled days. These weights are used to reconstruct fine particle mass and visibility for annual average, summer average, and class average conditions.

[INSERT FIGURE 5.5: FINE PARTICLE MASS AT GREAT SMOKY MOUNTAINS FOR EXAMPLE MODELED DAYS IN EACH OF 5 VISIBILITY CLASSES (FROM IMPROVE ON LEFT AND URM MODELED ON RIGHT)]

IMPROVE monitoring data was used as the basis for projecting future changes in visibility in response to SAMI strategies. The modeled percentage change in fine particle mass from the 1991-1995 reference year to 2010 or 2040 was used to adjust the monitored fine particle mass. The modeled percentage change is called the relative reduction factor. If modeled mass of a chemical component varied from measured mass on a modeled day by more than a factor of two, then the relative reduction factor was not accepted. Instead the relative reduction factor was substituted from days with good model performance.

Where IMPROVE monitoring data was not available, data was borrowed from nearest IMPROVE site (see Table 5.1; Adlhoch, 2002). If relative humidity was not measured at the sites for the modeled days, then modeled hourly RH was used for visibility calculations.

EVALUATING ASSUMPTIONS FOR CALCULATING LIGHT EXTINCTION

SAMI investigated the sensitivity of light extinction calculations to the assumptions used in the extinction equation. SAMI tested the effects of the following assumptions on calculated light extinction:

- increase the multiplier used with measured organic mass to calculate total organic mass from 1.4 (value assumed by IMPROVE) to 1.7 or 2.0.
- assume that 15% of total organic mass asborbs water vapor (IMPROVE assumes organics do not absorb water)
- combine the effect of two assumptions above (increase multiplier and assume 15% of increased mass absorbs water
- vary the acidity of sulfate fine particles ratio of ammonium to sulfate ions from 0.5 to 2.0 (value assumed by IMPROVE).
- vary the scattering efficiency of coarse mass from 0.4, 0.6 (value assumed by IMPROVE), 0.8, to 1.5 (upper limit)
- vary the data source for relative humidity (using measured hourly, modeled hourly, or monthly average relative humidity)

In all cases, the standard IMPROVE assumptions gave lower light extinction values than the alternatives tested. The acidity of sulfate particles and the source of relative humidity data were the two assumptions that had the greatest effect of calculated light extinction. All other assumptions showed negligible or small increases in extinction and were not considered in SAMI's strategy analyses.

IMPROVE does not routinely measure ammonium but assumes that measured sulfate particles are fully neutralized (ratio of ammonium to sulfate ions of 2.0). Since 1997, ammonium has been measured from the filters at three IMPROVE sites in the SAMI region: Great Smoky Mountains National Park in eastern Tennessee, Shenandoah National Park in Virginia, and Dolly Sods Wilderness Area in West Virginia (reference IMPROVE). These ammonium measurements and those from other studies (Saxena, SEARCH) indicate that on many days sulfate particles are not fully neutralized. On a daily basis, that ratio may be below 1.0, especially in the summertime. At ammonium to sulfate ratios below 1.0, sulfate is more efficient at scattering light than when the ratio is in the range 1.5 – 2.0. These ammonium measurements suggest that, at least in the southeastern US, light extinction by sulfate may be underestimated on some days. SAMI chose to use the monthly average measured ratio of ammonium to sulfate (Figure 5.6) to calculate light extinction in 1991-1995 and in 2010 and 2040 in response to SAMI strategies.

[INSERT FIGURE 5.6: MONTHLY AVERAGE RATIO OF AMMONIUM TO SULFATE IONS MEASURED AT IMPROVE MONITORING SITES AT GREAT SMOKY MOUNTAINS, SHENANDOAH, AND DOLLY SODS FROM 1997 TO 1999.]

The selection of data source for relative humidity had the greatest effect on calculated light extinction. Because relative humidity effects how much light is scattered by fine particles, days with the lowest particle mass are not necessarily the days with the clearest visibility. Across the seasons, relative humidity is generally higher in the summer than in the winter. The highest relative humidity generally occurs in the hours before and after dawn and the lowest relative humidity at mid-day.

The Environmental Protection Agency recommends using monthly average relative humidity data for the purpose of evaluating visibility trends over time (reference Regional Haze guidance). For air quality modeling, SAMI used the same relative humidity data to model current and future emissions. SAMI used relative humidity measured at the same site as fine particle mass as the most accurate representation of visibility on the modeled days. If measured hourly relative humidity data was not available, modeled hourly relative humidity data were used (Table Visibility 1).

IMPROVE assumes that the multiplier for measured organic mass to calculate total organic mass is 1.4. More recent measurements (Turpin, et. al.,) suggest that in the southeastern US, a multiplier for measured mass of 1.6 to 2.2 might be more appropriate. Increasing the multiplier to 2.0 changed visibility by more than 1 deciview on less than 6% of all days in 1991-1995 at Great Smoky Mountains and Shenandoah. The response to changes in the assumed multiplier for organic mass might be larger at sites where organic compounds have a larger contribution to visibility than is the case at the SAMI Class I areas.

VISIBILITY RESPONSES TO SAMI STRATEGIES

Annual average SO2 and NOx emissions in 2010 and 2040 will be reduced under SAMI emissions strategies. Ammonia gas emissions are projected to increase in the A2 and B1 strategies and decrease in the B3 strategy (assuming 75% reductions in NH3 emissions from livestock). Changes in emissions of volatile Organic Compounds (VOCs?), elemental carbon, and soils are small (Figure 5.7, Chapter___, Emissions Inventory).

INSERT FIGURE 5.7: ANNUAL EMISSIONS IN 8 SAMI STATES (ALSO IN EI CHAPTER]

KEY FINDINGS

Fine particle responses to SAMI strategies are illustrated in Figures 5.8 and 5.9 for Great Smoky Mountains and Shenandoah National Parks. These trends are representative of those at the other SAMI Class I areas. In 1991-1995 at Great Smoky Mountains, sulfate particles account for 68 % of annual average reconstructed fine particle mass and 72 % of annual average light extinction. In 2010, annual average SO4 fine particles are projected to decrease by 12, 26, and 50% under SAMI's A2, B1, and B3 strategies, respectively, compared to 1991-1995. Annual average visibility at Great Smoky Mountains is projected to increase from 23 miles in 1991-1995 to 24, 27, and 36 miles in 2010 under the SAMI A2, B1, and B3 strategies.

[INSERT FIGURE 5.8: ANNUAL AVERAGE FINE PARTICLE MASS AT GREAT SMOKY MOUNTAINS AND SHENANDOAH NATIONAL PARKS IN 1991-1995 AND IN 2010 AND 2040 IN RESPONSE TO SAMI STRATEGIES.]

[INSERT FIGURE 5.9: ANNUAL AVERAGE LIGHT EXTINCTION AT GREAT SMOKY MOUNTAINS AND SHENANDOAH NATIONAL PARKS IN 1991-1995 AND IN 2010 AND 2040 IN RESPONSE TO SAMI STRATEGIES.]

The largest improvements in visibility are projected to occur in response to SO2 reductions. Sulfate contributions to fine particle mass and light extinction are projected to decrease under all SAMI strategies. The URM model projects little change in visibility in the SAMI Class I areas in response to changes in human-made organic compounds.

On some days, nitrate particles are projected to increase in response to SAMI strategies. On these days, sulfate particles are reduced while ammonia gas increases. When all sulfate particles are fully neutralized, nitrate particles are formed. The increases in nitrate particles are much smaller than the decreases in sulfate particles projected on these days, so visibility is still projected to improve, but less than would be expected based solely on sulfate reductions.

The largest improvements in visibility in response to SAMI emissions strategies are projected to occur on days with the highest fine particle mass (Figure 5.10 a and b).

[INSERT FIGURES 5.10 A AND B: CHANGES IN VISIBILITY IN 2010 IN RESPONSE TO SAMI STRATEGIES FOR MODELED DAYS IN FIVE CLASSES BASED ON FINE PARTICLE MASS AT (A) GREAT SMOKY MOUNTAINS AND (B) SHENANDOAH]

Annual average visual range in 1991-1995 varied from 10-25 miles across the 10 SAMI Class I areas (Figure 5.11). The poorest annual visibility occurred at Dolly Sods in WV and Sipsey in northern AL. The best annual visibility occurred at Great Smoky Mountains in eastern TN. Across the 10 SAMI Class I areas, annual average visual range in 2010 is projected to increase by less than 2 miles under the A2 strategy, by 1-6 miles under the B1 strategy, and by 4-15 miles under the B3 strategies.

[INSERT FIGURE 5.11: CHANGES IN ANNUAL AVERAGE VISIBILITY BETWEEN 1991-1995 AND 2010 AT 10 CLASS I AREAS IN RESPONSE TO SAMI STRATEGIES]

The greatest improvements in annual average visibility are projected for those Class I areas that are mostly influenced by emissions from the SAMI states: Cohutta, GA; Great Smoky Mountains, TN; Joyce Kilmer, NC; Shining Rock, NC; and Linville Gorge, NC (see Chapter ___, Air Quality Modeling, also Boylan, et. al., 2002). Sipsey Wilderness Area in north AL, and the Class I areas in WV and VA receive greater contributions from states outside the SAMI region. Because emissions for sources in the non-SAMI states were held at the same levels in the B1 and B3 strategies as the A2 strategy, annual average visibility at these Class I areas did not improve as much as for the Class I areas in GA, TN, and NC.

Visibility improved more for the summer average days than the annual average visibility. At most sites, visibility for the 20% highest mass days also improved more than annual average visibility (Adloch). Visibility improved more on the 20% highest mass modeled days than on the 20% lowest mass

Under the regional haze rules, states are to set reasonable progress goals for the rate of improvement in visibility, using deciview as the unit of measure. For the 20% highest mass days in the SAMI analyses, the rate of improvement in the 15 years between 1991-1995 and 2010 for the A2 strategy varied across the SAMI Class I areas from ___to ____deciviews (Figure 5.12). This is equivalent to _ to ___deciviews per decade by 2010 for the A2 strategy. The rate of improvement between 1991-1995 and 2010 would be ___ to ____ deciviews per decade for the B1 and ____ to _____ deciviews per decade for the B3 strategy. Between 2010 and 2040 the rate of improvement on the 20% highest mass days would be ___ to ____ deciviews per decade for the A2 strategy, ___to____ for the B1 strategy, and ___ to ___ for the B3 strategy.

[INSERT FIGURE 5.12: CHANGES IN VISIBILITY BETWEEN 1991-1995 AND 2010 FOR THE 20% HIGHEST MASS DAYS AT 10 CLASS I AREAS IN RESPONSE TO SAMI STRATEGIES]

LINK TO SOCIOECONOMIC ANALYSES

[SECTION UNDER DEVELOPMENT]

UNCERTAINTIES

[SECTION UNDER DEVELOPMENT, DRAFT ITEMS BELOW]

- Cumulative results carried from emissions inventory and atmospheric model contribute largest uncertaintyConfidence is highest for SO4 aerosols, intermediate for organics, soil, and EC, and lowest for NH4 and NO3 Other, smaller, sources of error from:
- Using modeled days to represent all other days
- Using relative reduction method to calculate change in response to SAMI strategies
- Assumptions used to calculate visibility
- Borrowing IMPROVE monitoring data for sites without monitors
- Uncertainties in IMPROVE monitoring methods

LESSONS LEARNED

[SECTION UNDER DEVELOPMENT]

CONCLUSIONS

[SECTION UNDER DEVELOPMENT]

Ozone and Forest Effects

[THIS SECTION IS BROKEN OUT INTO A SEPARATE MS WORD FILE DUE TO ITS SIZE (GRAPHICS ARE INCLUDED IN FILE): summary_Ozone_05282002.doc]

Acid Deposition and the Effects on Streams and Forests

SAMI ACID DEPOSITION ASSESSMENT OBJECTIVES

Deleted: SAMI

- Characterize current acid sensitivity of streams and forests in SAMI region
- Use URM atmospheric model to project future changes to deposition in response to SAMI strategies
- Use MAGIC and NuCM watershed models to project stream and forest responses to future deposition under SAMI strategies
- Provide estimated changes in streams suitable for supporting brook trout to socioeconomic analyses of fishing impacts

[INSERT GRAPHIC 7.1: SPRUCE FIR FOREST FROM BLUE RIDGE PARKWAY]

WHAT IS ACID RAIN?

Acidic deposition refers to the delivery of strong acids ions (sulfate and nitrate) and acid-forming ions (ammonia) from the atmosphere to the surface of the Earth. Deposition occurs in several ways. Precipitation, in the form of rain, snow, or hail, is collectively called wet deposition. Fine particles and gases in the atmosphere are dry deposited onto surfaces. At most low elevation sites in the eastern United States, wet and dry deposition have similar contributions to total annual deposition[1]. Cloud water interception is an additional source of acid deposition in many mountainous forests. In the SAMI region, cloud water interception increases with increasing elevation, beginning around 3500 ft in elevation. Above 5500 ft elevation in the Great Smoky Mountains, forests may be immersed in clouds for 30-50% of the year[2]. At elevations below 3500 feet, fog may be an additional but minor (usually <10% of the total) source of deposition. These elevational limits for cloud interception are lower for mountains farther north in Virginia and West Virginia.

Deleted: via

Deleted: path

The predominant chemical components of wet and cloud water deposition are sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), and base cations, such as calcium (Ca) and magnesium (Mg). In dry deposition, both sulfate (SO_4) particles and sulfur dioxide (SO_2) gas are important. Nitric acid gas (HNO_3) and ammonia gas (NH_3) are the predominant nitrogen species in dry deposition. Base cations, occur on fine soil particles in the atmosphere and are dry deposited fairly near to the sources of emissions.

DEPOSITION TRENDS

Sulfate deposition has been reduced at most Class I areas in the SAMI region since 1990 in response to sulfur dioxide emissions controls under the acid rain rules of the 1990 Clean Air Act

Amendments. Nitrogen dioxide emissions from utilities and industries have decreased since 1990, while emissions from highway vehicles have increased. As a result, nitrate deposition is little changed since 1990. Ammonia emissions and ammonium deposition have increased since 1990. Base cation deposition has decreased significantly since the 1980s[3]. Similar trends are observed for dry deposition [4]. Wet and dry deposition at Shenandoah National Park from ____ to ______ are illustrated in Figure Acid 1 as an example of deposition trends at SAMI Class I areas.

[INSERT FIGURE 7.1: (SIMPLIFY: FROM GRAPHICS IN ACIDDEP_CHAPTER.PPT) NIKI NICHOLAS AND JIM RENFRO WORKING ON THIS GRAPHIC)]

In general the highest wet deposition of sulfur and nitrogen occurs in West Virginia and Virginia and in high elevation areas in eastern Tennessee and western North Carolina.

CURRENT SENSITIVITY OF STREAMS AND FORESTS AND IN SAMI REGION TO ACID DEPOSITION

Acidic deposition has adversely impacted some streams and forested watersheds in the Southern Appalachian Mountains[5] (references) By lowering stream pH, acid neutralizing capacity, and base cation concentrations, acid deposition has impacted the ability of certain aquatic biota, including native brook trout and other fish, to survive or maintain stable populations.

Watershed acidification occurs when deposited acids exceed the buffering capacity of the geology, soils, forests, and streams of a watershed. In the southesastern United States, the resources most sensitive to acid deposition generally occur in the Southern Appalachian Mountain region[5]. Within the SAMI region the spruce fir forest ecosystem is the forest type most sensitive to acidification**.** The streams that are most sensitive to acid deposition are those in upland and mountainous areas in the Appalachian Plateau region of WV, the Ridge and Valley region of VA, and higher elevations in eastern Tennessee and western North Carolina.

Stream Acid Neutralizing Capacity (ANC) is an indicator of the suitability of a stream to support fish. Stream acid neutralizing capacity reflects the combined impact of the concentrations of sulfate and nitrate anions, organic acids, base cations, aluminum, and hydrogen ions in stream water. Streams for which the annual average acid neutralizing capacity is less than 0 μeq/l year round are considered **chronically acidic**. Streams for which the annual average acid neutralizing capacity is below 20 μeq/l are likely to experience storm events with acid neutralizing capacity below 0 μeq/l. These streams are considered to be **episodically acidic**. Stream acid neutralizing capacity levels can be used to define streams that are suitable to support brook trout (Table Acid 1) and can also be used to predict the numbers of fish species that might be present in streams. Brook trout are more tolerant of acid stream conditions than other fish species. Factors other than stream acid neutralizing capacity (for example, stream flow rates, stream bottom substrate) also influence fish habitat and not all streams with suitable acid neutralizing capacity will be suitable for brook trout.

Table 7.1: Stream Acid Neutralizing Capacity (ANC) as an indicator of stream suitability to support brook trout

Stream ANC Class	Biological Response
ANC $\leq$ 0 μeq/l	Acidic, unsuitable for brook trout
ANC > 0 to $\leq$ 20 μeq/l	Highly sensitive to chronic and episodic acidification; marginal benefit for brook trout
ANC >20 to $\leq$ 50 μeq/l	Potentially sensitive to chronic and episodic acidification; brook trout status indeterminate, site specific factors influence suitability for brook trout
ANC >50 to $\leq$ 150 μeq/l	May be sensitive to episodic acidification in future; suitable for brook trout but still poor habitat for other aquatic life

(Reference for Socioeconomics?)

Several factors influence the sensitivity of forests and streams to acidic deposition. These factors include:

- **Bedrock geology** determines the ability of a watershed to neutralize acids. Base cations in rocks and minerals are slowly weatherized and released to the soils. Limestone is a rich source of base cations and watersheds underlain by limestone have low risk of acidic soils and streams. In contrast, sandstone has a low supply of base cations. More watersheds on the Appalachian Plateau region of West Virginia are underlain by sandstone, and this region has more acidic streams than other parts of the SAMI region.
- **Soil base cation supply** and soil retention of sulfate anions are two important factors that control soil acidity. In acidic soils, aluminum can be released into soil solutions at levels that are toxic to plants and fish. Many of the soils on the Appalachian Plateau in West Virginia are acidic with low base supply and low ability to retain sulfate. In contrast, soils on the Blue Ridge province in western North Carolina and northern Georgia have historically had higher ability to retain sulfate and higher base cation supplies. Fewer soils and streams in the Blue Ridge province are acidic.
- At **watershed elevations** above 900 meters (3000 feet), watersheds are smaller and steeper, deposition is higher and streams are more likely to be chronically or episodically acidic.
- **Forest type** is an indicator of the acidity of soils and streams. The spruce-fir forest ecosystem is the most sensitive to acidic deposition with naturally acidic soils and high deposition levels. Nitrogen deposition to these slow growing forests is likely to exceed nitrogen uptake by vegetation and micro-organisms in the soil. Nitrate as well as sulfate anions acidify the soils, and streams draining spruce-fir forests are likely to be acidic.
- **Previous land use or disturbance** (e.g. forest harvesting, fire, or insect or disease outbreak) can also acidify soils.

WHERE DO SENSITIVE ECOSYSTEMS OCCUR?

SAMI's landscape analyses[6]determined that underlying bedrock geology dominated by sandstone or elevations greater than 900 meters (3000 feet) could be used to identify areas of the SAMI region most likely to have acidic streams. Ninty five percent (95%) of the streams with acid neutralizing capacity less than 0 μeq/l and 88% of the streams with acid neutralizing capacity less than 20 μeq/l occur in the area highlighted in green in Figure 7.2. Streams with acid neutralizing capacity greater than 20 μeq/l occur throughout the SAMI region.

[INSERT FIGURE 7.2: AREA IN SAMI REGION MOST LIKELY TO HAVE STREAMS WITH LOW ACID NEUTRALIZING CAPACITY (ANC)] (SEE SE FISHING MAP)

Spruce-fir forests in the Southern Appalachian Mountains occur at elevations greater than 1400 meters (4600 feet) and cover approximately 29,000 acres (Figure 7.3). Seventy four percent of the spruce fir ecosystem in the Southern Appalachian Mountains occurs within Great Smoky Mountains National Park.

[INSERT FIGURE 7.3: CLOSE UP MAP OF SPRUCE-FIR ECOSYSTEM FROM SAA]

FUTURE CHANGES IN ACID DEPOSITION DUE TO SAMI STRATEGIES

METHODS

SAMI's assessment is unique in using air quality model results to project changes in acid deposition in the stream and forest effects modeling. Previous modeling efforts have relied on changes in emissions to estimate change in deposition and effects. Deposition monitoring data were adjusted by changes in deposition projected by the atmospheric model in response to SAMI strategies.

Wet deposition monitoring data from the National Atmospheric Deposition Program (NADP) for the period 1991-1995 were used to calculate annual average total deposition in the reference year and in future years. Wet deposition data from 16 sites were spatially extrapolated using elevation and distance[7] for 170 stream and forest sites in the SAMI region. Because dry deposition measurements are infrequent and influenced by local conditions, ASTRAP, a general atmospheric transport model, was used with 1990 emissions data to project wet, dry, and fog/cloud deposition at 33 sites in and around the SAMI region[9]. The ratios of wet to dry deposition and wet to cloud deposition from the ASTRAP model were used with calculated wet deposition to estimate dry, cloud, and total deposition at each of the 170 stream and forest sites. In SAMI's analyses, the total annual average deposition for 1991-1995 is referred to as the 1995 Reference. The only exception was for high-elevation sites in Great Smoky Mountains National Park where site-specific monitoring data for wet, dry, and cloudwater deposition[2] was used in place of ASTRAP model results to calculate total deposition.

To project future deposition under SAMI strategies, the percentage changes in wet and dry deposition were calculated from the URM atmospheric model results (see Chapter ___, Air Quality Modeling. These percentage changes were used to adjust the wet, dry, and cloud deposition in the 1995 Reference deposition for each stream and forest site.

DEPOSITION RESPONSE TO SAMI STRATEGIES

The highest wet deposition of sulfur and nitrogen in both 1991-1995 and in response to SAMI strategies occur in WV and at high elevations sites in eastern TN and western North Carolina.

Sulfur Deposition

Under all SAMI strategies, sulfur deposition is projected to decrease at all modeled sites in 2010 and in 2040. The changes in total annual average sulfur deposition in 2010 at 5 example modeling sites in SAMI Class I areas are illustrated in Figure 7.4. These sites are examples that represent the geographic range from Sipsey Wilderness in northwestern AL to Dolly Sods in northern WV and a range from low elevation (Sipsey) to high elevation (Noland Divide in Great Smoky Mountains National Park) sites. Across all modeled sites, total sulfur deposition is projected to decrease from 15 to 70% (mean 57%) for the A2 reference strategy in 2010 compared to 1990.

The largest reductions in total sulfur deposition are predicted for sites in WV and VA. This finding is consistent with emissions trends. The largest reductions in sulfur dioxide emissions in the A2 strategy were projected to occur in the midwestern states because many of these electric utility units were required to reduce sulfur dioxide emissions by January 1, 1995, under Phase I of Title IV of the 1990 Clean Air Act Amendments. SAMI's source contribution analyses indicate that the WV and VA sites are heavily influenced by emissions in the midwestern states (Boylan, et. al. 2002 a). Sulfur deposition at sites in eastern TN and western NC showed less response to the A2 strategy, and greater response to the B1 and B3 strategies, than at sites in WV and VA. The TN and NC sites are more influenced by emissions in the SAMI states (Boylan et al 2002 a) and deposition responded to emissions trends in these states. (text here or reference air quality modeling chapter?)

[INSERT FIGURE 7.4: TOTAL ANNUAL AVERAGE SULFUR DEPOSITION IN 1991-1995 AND IN 2010 UNDER SAMI STRATEGIES FOR 5 EXAMPLE SITES IN SAMI CLASS I AREAS.]

Nitrogen Deposition

In contrast to sulfur deposition, SAMI's atmospheric model results indicate that total nitrogen deposition is little changed in 2010 and 2040 in response to SAMI strategies (Figure 7.5). Deposition of oxidized nitrogen species, including nitrogen oxides, nitric acid vapor, and nitrate particles, is projected to decrease in 2010 and 2040 under all strategies. Deposition of reduced nitrogen (ammmonia and ammonium) is projected to increase in the A2 and B1 strategies and decrease in the B3 strategy. These deposition trends are consistent with projected emissions trends. Nitrogen oxide emissions from utilities, industries, highway vehicles and non-road engines are projected to decrease in all strategies. Ammonia emissions are projected to increase in the A2 and B1 strategies (see Chapter , Emissions Inventory). SAMI's B3 strategy assumes that ammonia emissions from livestock and fertilizer applications could be reduced by 30% and 75% in 2010 and 2040, respectively. The net result is little change in total nitrogen deposition in response to SAMI strategies.

[INSERT FIGURE 7.5. TOTAL ANNUAL AVERAGE NITROGEN DEPOSITION IN 1991-1995 AND IN 2010 UNDER SAMI STRATEGIES FOR 5 EXAMPLE SITES IN CLASS I AREAS]

Nitrogen deposition trends from SAMI inventory projections to 2010 and 2040 are more uncertain than S deposition trends. Ammonia emissions factors and future growth rates for the SAMI states are likely overestimated in the SAMI inventory. *[clarify why here or in air quality chapter?]*. The URM model projected that dry deposition of oxidized nitrogen (e.g. nitric acid vapor) would be more responsive to nitrogen oxide emissions reductions than wet deposition of nitrate. The URM model may have underestimated the response of wet nitrate deposition to nitrogen oxide emissions reductions. *[clarify why here or in air quality chapter?]*. It is likely that actual reductions in nitrogen deposition in response to NOx emissions reductions would be larger than those modeled by URM.

Base cation deposition

Base cation deposition is projected to show small changes in future years in response to SAMI strategies[7]. Base cation emissions are primarily emitted as fine particles from construction sources. These sources are projected to increase in future years, however these fine particles are deposited fairly close to the sources of emissions and regional deposition patterns are expected to be little changed.

SAMI STREAM ASSESSMENT

APPROACH

The Model of Acidification of Groundwater in Catchments (MAGIC) was used to project current and future stream water chemistry in response to SAMI strategies. MAGIC is a watershed model that integrates the combined impacts of physiographic features, geology, soils, and forest cover to project stream water quality.

SAMI used the 1985-86 National Stream Survey database [8] as the statistical basis to define the regional distribution of stream acid neutralizing capacity in the SAMI region. This database is the most complete survey of streams in the Southern Appalachian Mountains. Based on the 1985-86 National Stream Survey, only 3% of the total stream lengths in the SAMI region have stream acid neutralizing capacity less than 20 μeq/l (Figure 7.6). These streams are most likely to occur in headwater systems. They are of concern to SAMI because many of the SAMI Class I areas include headwater systems. These systems are habitat for cold-water fish such as brook trout. Increasing acid neutralizing capacity in these streams would improve habitat for brook trout and other aquatic species. More streams with acid neutralizing capacity less than 50 μeq/l were modeled in the SAMI assessment than occur in the regional population because these are the streams that are at greatest risk of acidifying.

Deleted: Headwater

[INSERT FIGURE 7.6: PERCENTAGE OF STREAM LENGTHS IN SAMI REGION IN EACH OF FOUR ANC CLASSES, BASED ON NATIONAL STREAM SURVEY. *(HERE OR EARLIER IN TEXT?)*]

Streams in the national database were classified in one of twelve categories based on four acid neutralizing capacity classes and three physiographic provinces (Table Acid 2). Streams that are obviously impacted by other factors (e.g. acid mine drainage, insect defoliation) were excluded from the analyses. Within each category streams were selected to represent the range of geographic coverage and stream chemistry. A total of 130 streams were selected to statistically represent all other streams in the SAMI region. Responses of modeled streams were used to represent responses of all streams in the same acid neutralizing capacity class and geographic province.

Table 7.2: Numbers of streams modeled in each acid neutralizing class in each of three physiogeographic provinces (used for the regional assessment) and additional special interest streams in Class I areas *(check with Tim, Class I streams add to 27 not 34)*

Stream Acid Neutralizing Capacity (ANC)	Numbers of Modeled Streams			
	Appalachian Plateau	Ridge and Valley	Blue Ridge	Class I special interest streams
< 0 μeq/l	25	6	3	10
0 – 20 μeq/l	8	14	12	3
21 – 50 μeq/l	9	12	17	5
50 – 150 μeq/l	11	11	36	9

In addition to this regional analysis, 34 additional streams in Class I areas were modeled to provide a qualitative, site-specific, analysis for the Class I areas. Acidic streams (acid neutralizing capacity less than 0 μeq/l) were most prevalent in the Dolly Sods and Otter Creek Wilderness areas on the Appalachian Plateau in West Virginia. Many streams in Shenandoah and Great Smoky Mountains National Parks and James River Face Wilderness area have stream acid neutralizing capacity less than 20 μeq/l. Streams in Class I areas in the southern portion of the SAMI region have higher acid neutralizing capacity.

STREAM RESPONSES TO SAMI STRATEGIES

Stream water acid neutralizing capacity is determined by the combined effect of sulfate, nitrate, and base cation concentrations. Under SAMI's A2 strategy, stream acid neutralizing capacity is projected to decrease slightly at most modeled streams in the SAMI region. The numbers of streams in the acid neutralizing capacity classes less than 0 μeq/l and 0-20 μeq/l are projected to increase slightly under the A2 strategy (Table Acid 3). For most sites, ANC changes (positive or negative) were less than 20 μeq/l between 1995 and 2040 and few streams changed risk based on acid neutralizing capacity class. The exception is acidic streams in West Virginia where increases in ANC under the A2 strategy are projected to be sufficient to improve fish habitat.

Table 7.3. Stream Acid Neutralizing Capacity for 130 modeled streams in response to SAMI strategies *(need to complete, use barchart (#) or piecharts (%) instead?)*

Stream Acid Neutralizng Capacity Class (μeq/l)	1991-95	2040 CC (deposition continues at 1991-95 levels)	2040 A2	2040 B1	2040 B3
	# of modeled streams				
< 0	19				
0 - 20	30				
21-50	32				
51 - 150	49				

??

If deposition continued at 1995 reference levels (constant conditions, CC), additional streams with low acid neutralizing capacity are projected to acidify than under the A2 strategy. Thus the primary benefit of the 1990 acid rain controls, as represented by the A2 strategy, is to prevent further acidification of streams in the SAMI region. Under SAMI's B1 and B3 strategies, stream acid neutralizing capacity will increase at more streams. Few streams will change acid neutralizing capacity class (Figure 7.7). The small changes in stream acid neutralizing capacity in response to large reductions in sulfate deposition can be attributed to the slow recovery of watershed processes for sulfate retention in soils and base cation supplies. Because these processes will require decades to recover, improvements in stream acid neutralizing capacity are projected to continue beyond 2040, especially for the most acidic streams.

[INSERT FIGURE 7.7. AVERAGE STREAM ACID NEUTRALIZING CAPACITY (ANC) IN SAMI REGION IN RESPONSE TO SAMI STRATEGIES]

In response to reduced sulfate deposition under SAMI's A2 strategy, sulfate levels are projected to decrease by 2040 for some streams (mostly in WV and VA) and to increase at most streams (VA, TN, NC, GA, AL). The largest reductions in stream water sulfate (> 20 μeq/l) are projected for streams in West Virginia. In these watersheds, soils are retaining little of the deposited sulfate and reductions in sulfate deposition are projected to result in reduced stream water sulfate. At most sites other than those in West Virginia, stream water sulfate is projected to increase (< 10 μeq/l) under the A2 strategy, despite decreased sulfate deposition. Soils at these sites are currently retaining a high percentage of the deposited sulfur and are expected to exhibit gradual decreases in the ability to retain sulfur adsorption in future years. Thus even as sulfate deposition is projected to decrease, stream sulfate levels are projected to increase. In response to the B1 and B3 strategies, more streams are projected to show decreased sulfate stream water concentrations (add range).

Stream water nitrate concentrations are elevated in those streams that drain watersheds where total nitrogen deposition exceeds nitrogen uptake. These streams are scattered throughout the SAMI region but occur primarily in West Virginia and higher elevations in eastern Tennessee and western North Carolina. Stream water nitrate concentrations respond to changes in total nitrogen deposition, with both increases and decreases in response to the A2 strategy. The largest nitrate reductions are projected for those streams with the highest nitrate concentrations in 1995. Stream nitrate levels are projected to decrease at most streams under the B1 strategy and at all streams under the B3 strategy.

At most modeled sites, base cation levels in stream water are projected to decrease under SAMI strategies. This is in response to reduced leaching of base cations from soils to stream water. By 2040 reduced base cations in stream water offset the benefits of reduced sulfate deposition, particularly in West Virginia streams, and thus changes in stream ANC are smaller than might be expected given the magnitude of sulfate reductions.

Extrapolating from modeled stream results to the population of streams in the SAMI region, by 2040, the percentages of streams in each acid neutralizing capacity class are little changed in response to SAMI strategies (Figure 7.8). Average acid neutralizing capacity within a class increases for acidic streams and decreases for streams with acid neutralizing capacity greater than 20 μeq/l (Table 7.4).

[INSERT FIGURE 7.8: STREAM ACID NEUTRALIZING CAPACITY (ANC) FOR UPPER NODE STREAM IN SAMI REGION IN 2040 UNDER SAMI STRATEGIES]

[INSERT TABLE 7.4. CLASS AVERAGE ANC]

Stream results in Class I areas followed the same pattern as for the region. Dolly Sods, Otter Creek, and James River Face wilderness areas and in Great Smoky Mountains and Shenandoah National Parks have higher percentages of acidic streams than the region as a whole. Acid neutralizing capacity is projected to increase for acidic streams and decrease for most streams with acid neutralizing capacity greater than 20 μeq/l.

LINK TO SOCIOECONOMIC ANALYSES

The percentages of streams in each acid neutralizing capacity class by 2040 are little changed in response to SAMI strategies. There is little projected increase in numbers of streams suitable for brook trout. The exception is seven counties in West Virginia where increases in stream acid neutralizing capacity would decrease the risk of aluminum toxicity to fish and improve stream suitability for brook trout. The changes in stream acid neutralizing capacity in these counties were used in SAMI's socio-economic analyses of fishing impacts in response to SAMI strategies.

Deleted: Because t

Deleted: Therefore t

FOREST RESPONSE TO SAMI STRATEGIES

APPROACH

The Nutrient Cycling Model was used to project forest responses to changes in deposition due to SAMI strategies. The Nutrient Cycling Model represents the effects of acid deposition on the chemistry of foliage, soils, and soil solutions. The model is not able to project how forest growth or species composition will respond to those chemical changes.

Fourteen forested sites in three forest types (spruce-fir, northern hardwood, and mixed hardwood) were selected for modeling with NuCM (Figure 7.9). The analyses rely on available monitoring data and were preferentially selected to represent Class I areas. The spruce-fir forest ecosystem is the forest type most sensitive to acidification and the most likely to receive high levels of acid deposition. Soils in these forests are typically shallow and highly weathered, with low levels of base cations and high levels of nitrate, inorganic aluminum, and organic acidity. Northern hardwood forests occur at elevations below spruce-fir and are less at risk. Elevated levels of nitrate have been observed in streams in some northern hardwood forests, indicating potential risk of acidification in future decades. Because mixed hardwood forest generally have larger supplies of soil base cations, these forests are not likely to be adversely impacted by acid deposition in the near future. The exception would be forests that have experienced significant disturbance that has depleted soil nitrogen or base supplies (e.g fire, insect defoliation, extensive harvesting).

[INSERT FIGURE 7.9. MAP OF FOREST DISTRIBUTION AND SITE LOCATIONS FOR MODELED SITES]

RESPONSE TO SAMI STRATEGIES *(still needs work, 5/24)*

Soil acidification is projected to continue at almost all sites. Base saturation is projected to decrease at all sites between 1995 and 2040 under the A2 strategy, and to decrease as well at most of the sites under the B1 and B3 strategies. Soil solution chemistry responded to changes in sulfate and nitrate deposition, but at most sites the differences in response across all the SAMI strategies were small. Improvements in forest health will likely be delayed until soil base supply? reaches greater than 10%.

The Nutrient Cycling Model also suggests that the ratio of calcium-to-aluminum ions in soil solutions would decrease at most sites under all strategies. Previous studies have indicated that when calcium-to-aluminum ratios fall below a threshold of 1, an ecosystem might be entering a zone of increased stress (Cronan and Grigal 1995). The model results suggest a future deterioration of soil conditions for forest growth and health, especially in the spruce-fir forests. These forests generally exhibited calcium-to-aluminum ratios in soil solution near or below 1.0 in the reference year. Continued decreases in calcium to aluminum ratios indicate increased stress to these forests.

The spruce-fir forest is the most sensitive to N deposition levels and changes in N deposition under SAMI strategies were small. Based on previous studies in the United States and Europe, forests with N deposition levels below 10 kg/ha/yr are expected to have low risk for N saturation.

Spruce-fir forests in the SAMI region are currently receiving significantly greater N deposition than 10 kg/ha/yr. N deposition measured at Noland Divide in Great Smoky Mountains was 32 kg/ha/year. Federal Land Managers have defined that N deposition levels of 3-5 kg/ha/yr may be required to protect the most sensitive forests and streams.

It is not clear to what extent the chemistry of soils and soil solutions currently or in the future are impacting forest growth and health. Mortality of red spruce trees in the Southern Appalachian Mountains is not abnormally high when compared to historical rates. Fraser fir stands that were killed by the balsam wooly adelgid in the 1980s and early 1990s are largely being replaced by vigorous re-growth of young stands of that species. To what extent spruce or fir mortality will be replaced with a species mix similar to that existing prior to the mortality remains to be seen.

[INSERT FIGURE 7.10: SIMPLIFIED SUMMARY OF FORESTS RESULTS; SAMPLE GRAPHIC IS PRELIMINARY]

UNCERTAINTIES

The major uncertainties in the stream assessment include:

- Changes in future deposition projected for SAMI strategies (cumulative uncertainty from emissions inventory and atmospheric model assumptions)
- Quality of watershed data available to calibrate MAGIC model
- MAGIC model validity and accuracy in projecting watershed processes and responses to deposition changes
- Seasonal variability in stream water chemistry and biological response
- Errors associated with spatial extrapolation from modeled streams to regional population of streams
- Changes in N deposition as function of emissions reductions may be larger than those projected by URM for SAMI strategies.

These errors are difficult to quantify but are not additive.

SAMI did not model a strategy that included emissions reductions in non-SAMI states beyond the A2 strategy. Further improvements in stream ANC would be expected if future emissions are also reduced outside the SAMI states.

Too few forest sites were modeled to make general statements for regional forest response to SAMI strategies. The Nutrient Cycling Model does not define how forest growth will respond to changes in soil chemistry in response to SAMI strategies. SAMI results combined with other NuCM applications in the SAMI region allow general statements about risk for different forest types. There is a lot of uncertainty in the prediction of forest responses based on soil chemical indicators such as Ca:Al ratios.

KEY FINDINGS *(still needs work 5/24)*

- SO_4 deposition decreases in response to SAMI strategies, changes in deposition of N and base cations are projected to be small
- Geology (sandstone) and elevation (above 1200? m) are good indicators where these low ANC streams will occur
- Under all strategies, largest improvements in ANC are projected in low ANC streams, but few streams change ANC class in any of the three major scenarios tested. Add CC scenario?}
- More low ANC (< 20 μeq/l) streams are found in WV and VA, where most improvements are projected.
- Stream lengths with ANC > 20 μeq/l occur throughout SAMI region
- Under all strategies, ANC decreases in many streams with ANC > 20 μeq/l, but few decreases are sufficient to shift streams to lower ANC class.
- Under scenarios _______, stream suitability for trout projected to increase for some streams in WV and a few streams in VA, TN, NC
- Changes in soil chemistry over time are likely to be negative in most cases across all SAMI strategies
- Spruce-fir forests are the most at risk from acid deposition. Soil chemical indicators of forest health (such as Ca:Al ratios) are likely show no improvement or to become more negative in most spruce-fir ecosystems, regardless of the strategy adopted. There is a lot of uncertainty in the prediction of forest responses based on soil chemical indicators such as Ca:Al ratios.

Socioeconomics and Direct Costs

SOCIOECONOMIC ASSESSMENT

The objective of the socioeconomic assessment is to estimate the social and economic implications of the SAMI strategies. This was a two-phase process. Phase I produced a list of topics with estimated costs, and potential relative magnitude of impacts, the ability to develop credible estimates of the impacts, and the costs associated with varying levels of analysis. This report enabled the workgroup to choose the final 6 topics maintaining balance across the selected topics in terms of the types of values considered and the stakeholders affected. The workgroup was primarily made up of representatives of the federal land managers, utilities, EPA and states.

Phase I also described methods for quantitatively assessing each of the selected topics. The report suggested a "benefits transfer "approach which relies on information from existing studies in which the subjects and the environmental quality improvements are as close as possible to those under consideration. It is used for fishing and visibility to estimate participants' willingness to pay (WTP). Another method used for recreational visibility valuation was the Contingent Valuation Method (CV) which used surveys of park users all over the country to estimate WTP.

In the Phase II report, the SAMI workgroup selected topic areas to examine a small sample of the social and economic implications of the SAMI emission reduction strategies. This was not a comprehensive assessment but provided information for the topic areas in the SAMI region for three emissions management strategies A2, B1 and B3 in millions of year 2000 dollars. The socioeconomic assessment is missing key benefit categories including particulate matter (PM), health and ecosystem effects, and effects from additional pollutants. Initially six indicators were chosen. Two of those, mortality and competitiveness, were not finalized. The contractors fulfilled their obligations, but it was felt that the scope of the draft reports on those topics was not comprehensive enough to form conclusions and therefore these topics did not become finished reports. The four remaining topic areas and their scope are:

Fishing: The extent to which reductions in air pollution may reduce acidification of fishable waters in the SAMI region leads to a variety of measurable chemical or biological changes. The SEWG looked at how these changes affect the demand for fishing. As the density of the fish population increases so does the probability of catching fish which provides a value to those who fish. This change in the value brought about by a selected control strategy is then quantified.

Visibility while hiking and enjoying scenery: In an area such as the Southern Appalachian Mountains, improved visibility is one of the most noticible results of improving air quality. When the view is obscured aesthetic and economic consequences potentially occur. Many visitors to National parks and wilderness (class I) areas are currently unable to see the spectacular views as well as they expect because, at times, a veil of white or brown haze obscures them. Because poor visibility reduces a person's enjoyment of the views (recreational visibility), it may reduce the likelihood of a return visit. There also is evidence that people value visibility at National Parks even when they are at home, whether they visit those areas or not. People at home have also shown that they value good visibility (residential visibility) within the area they live. Although hard to estimate, people's desire for improved visibility, be it in a recreational area or where they live, seems genuine.

Sense of Place/Stewardship (SOP/S): Environmental regulations provide both benefits and costs to society. Some of the benefits can be associated with a direct use by individuals of an environmental resource (e.g., consumption of agricultural products) or linked to activities sensitive to environmental quality (e.g., recreation activities). These benefits involve values based on use of the environment. Individuals may also have intrinsic values for environmental resources and environmental quality that do not involve a use value. Stewardship and community sense of place are examples of such non-use values that may play a substantial role in the case of SAMI concerns.

Stewardship refers to the notion that there is a fundamental ethical responsibility for humans to tend to nature and to pass on to succeeding generations a world that reflects a sustainable pattern of consumption of nature's resources. Stewardship values are reflected in individual preferences but do not overlap with any present or future use value held by an individual. They are distinct values, often associated with unique, irreplaceable environmental assets, for which an individual has a willingness to pay to maintain positive supply now and in the future. Stewardship values can have local, regional and global dimensions.

Community sense of place refers to values that reflect the mixture of quality-of-life attributes associated with living in a specific area. In the context of the environment, sight attributes, including viewscape are especially important to community values. Another aspect of sense of place may be closer to the idea of preservation of a particular complex set of quality of life attributes. SOP explores community values, beliefs and behaviors as they relate to life and the surrounding natural environment. It explores the relationship in the Appalachian Mountains between air pollution and what makes residents identify with the place they live.

Lifestyles: The effects of implementing the SAMI strategies on the well being of residents in the SAMI region. The focus is on how restrictions on both consumer and producer activities in industries with large emissions affect individuals' lifestyles. This is a qualitative examination of "hidden cost" impacts such as the time consumers invest due to environmental regulations such as waiting on vehicle inspection lines and constraints on consumer choices that are altered by control strategies due to higher costs or fewer options.

Fishing

Objective

This study assessed the extent to which reductions in acid deposition in streams in the SAMI region result in economic gains. The indicator was the effect on recreational fishing for native brown trout. A stream's acid neutralizing capacity (ANC) is affected by acid rain resulting from nitrogen and sulfur emissions. SAMI's emissions management strategies are designed to reduce these emissions, which should in turn increase ANC (refer to the section on acid deposition for more detail). The benefits that result from improvements in a stream's ANC, lead to an increase in the populations of various recreational fish species, in this case native brook trout. The main assumption is that anglers will spend more money if they can catch more fish.

Methods:
The Model of Acidification of Groundwater in Catchments (MAGIC) provided by SAMI's effects contractor estimates changes in ANC for A2, B1 and B3. The estimated changes in water quality chemistry were used to analyze changes in fishing opportunities to recreational anglers due to increased fish populations. These changes include both increases in the number of fishing sites available and improvements in the quality of existing sites. A benefits transfer method was used to estimate an angler's willingness to pay (WTP) for projected changes in the number and quality of trout fishing sites in the SAMI region

This study applies only to native brook trout because they favor higher elevation streams that are more likely to be affected by acid rain. Changes in fish biomass (the amount of fish) from improved ANC are estimated using a computer model which links ANC and fish biomass. The model looked at changes from one ANC classification to another, not changes within an ANC class. The Five ANC Classes are:

ANC< 0	Unsuitable-Lethal to Brook Trout
ANC 0 – 20	Marginal-Sub-lethal
ANC 20-50	Indeterminate-Extremely sensitive to acidification
ANC 50-150	Suitable- Brook trout will reproduce
ANC >150	Sustainable- Brook trout will reproduce

Exhibit 3.2 shows the estimated brook trout biomass for streams in each of the five ANC classes. Because effects of the emissions management strategies on stream ANC take the form of categories or class specified by ranges of ANC rather than by specific point estimates. Low, mid and high ANC estimates were used to estimate a range of brook trout biomass for each ANC class. The first estimate of brook trout biomass was in kilograms per 0.1 hectare, and then a conversion factor was used to express fish biomass in pounds/acre. The latter metric is used to place a monetary value on the benefit to anglers.

Exhibit 3.2 Conversion of Stream ANC to Brook Trout Biomass

ANC Class	ANC Range (µeq/L)	ANC (µeq/L)			Biomass (kg/.1ha)			Biomass (lbs/acre)		
		Low	Midpoint	High	Low	Midpoint	High	Low	Midpoint	High
1. Chronically acidic	Less than 0	0	0	0	0.7	0.7	0.7	1.3	1.3	1.3
2. Episodically acidic	0 to 20	0	10	20	0.7	1.0	1.3	1.3	1.8	2.3
3. Indeterminate	20 to 50	20	35	50	1.3	1.6	1.9	2.3	3.0	3.6
4. Not acidic-1	50 to 150	50	100	150	1.9	2.7	2.9	3.6	4.9	5.4
5. Not acidic-2	Greater than 150	150	150	150	2.9	2.9	2.9	5.4	5.4	5.4

The resulting estimates for the average that anglers are WTP per trip per amount of fish available to catch (low, medium, high) are given below for the three SAMI scenarios A2, B1, B3 in the years 2010 and 2040:

Average Willingness To Pay per Trip per Angler for Levels of Biomass (Millions, 2000$) *

Year	Baseline Average WTP under A2 Biomass			Change in Average WTP under B1 Biomass			Change in Average WTP under B3 Biomass		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
2010	$ 56.47	$ 56.77	$ 56.89	$ 0.08	$ 0.08	$ 0.08	$ 0.18	$ 0.18	$ 0.18
2040	$ 58.82	$ 59.05	$ 59.14	$ 0.15	$ 0.15	$ 0.15	$ 0.54	$ 0.54	$ 0.55

The above information combined the estimated angler's WTP for trout fishery improvements in the SAMI region with the estimated level of angler participation in trout fishing in the SAMI region to estimate the total economic value of trout fishing improvements. Angler participation for years 2010 and 2040 was adjusted to reflect changes in demographics in the SAMI region, but not for changes in income.

Estimated Total Willingness To Pay for Water Quality Improvements in the Eight-County Region of the Northern Plateau (Millions, 2000$) *

ear	Strategy (B1) (Biomass Level)			Strategy (B3) (Biomass Level)		
	Low	Medium	High	Low	Medium	High
2010	$ 0.5	$ 0.5	$ 0.5	$ 1.2	$ 1.2	$ 1.2
2040	$1.2	$ 1.2	$ 1.2	$ 4.4	$ 4.4	$ 4.4

* WTP does not account for income growth in 2010 and 2040.

Results

Using this methodology, it was found that the quantified recreational fishing benefits from changes in acid deposition are substantially lower than other benefits (i.e., benefits from visibility improvements). Under strategy B1, the resulting gain in an angler's welfare is estimated at $0.08 and $0.15 (measured in millions, 2000$) per trip in 2010 and 2040, respectively. The corresponding value of improvement in enjoyment is $0.5 and $1.2 million (2000$) for 2010 and 2040, respectively. Under scenario B3, the estimated gain in an angler's welfare is $0.18 and $0.54 (millions, 2000$) per trip in 2010 and 2040, respectively. The estimated economic value of fishery improvement in the SAMI region under strategy B3 is $1.2 and $4.4 million (2000$) annually for 2010 and 2040, respectively.

Limitations and Uncertainties

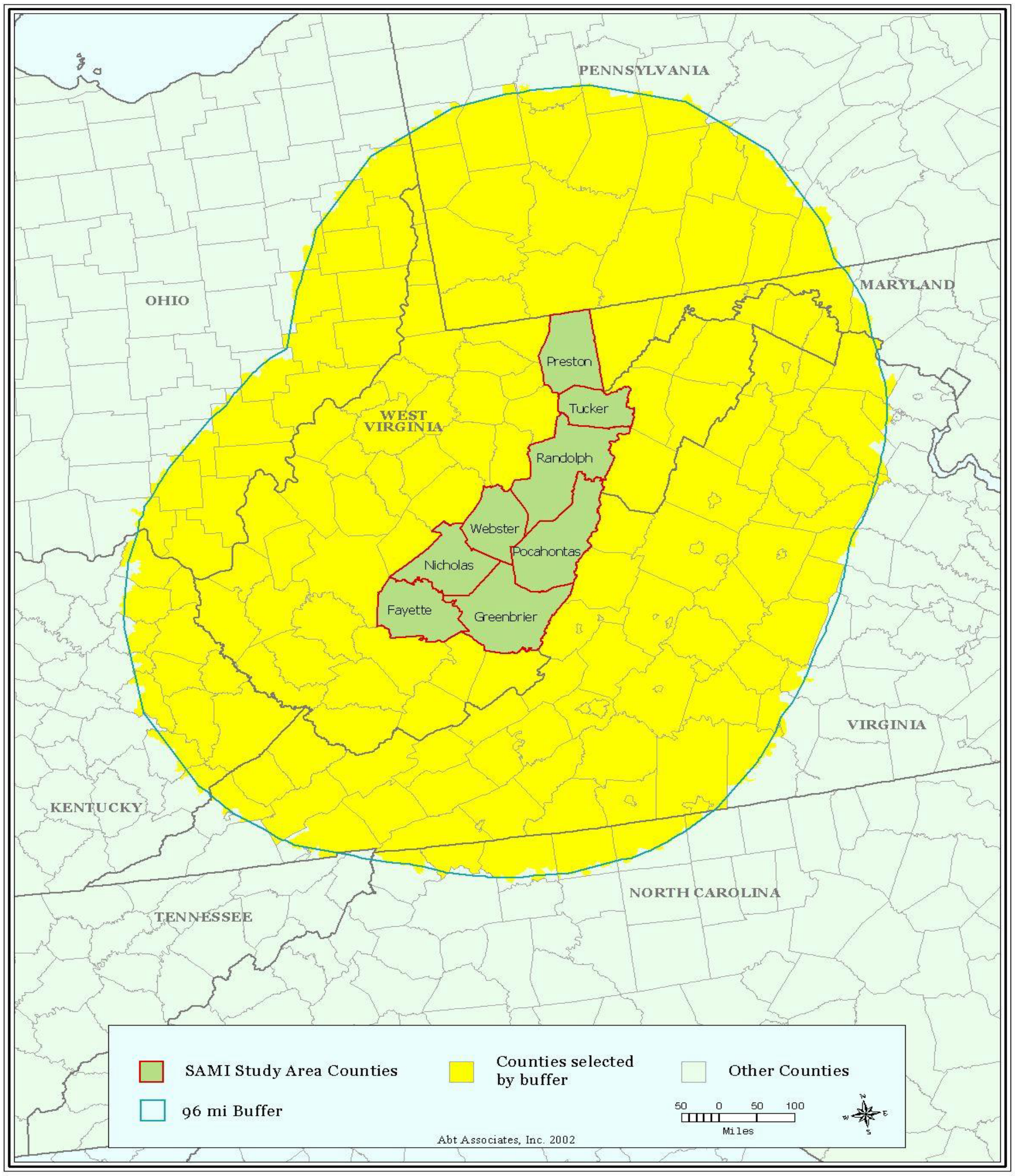
Limitations of this fishing study include: (1) the lack of data on water chemistry changes within each ANC class; (2) the focus on only one species—brook trout; and (3) the consideration of only one benefit category - recreational trout fishing. (4) the lack of projections of fisheries to 2100. (5) the focus on a small geographic area, the Northern Plato region, seven counties in West Virginia. (see following map) where streams were estimated to have larger changes in

ANC, resulting in shifts into higher ANC classes.[1] (6) the focus on a short period of time (from 1995 to 2040), which may not be enough to adequately capture the benefits of water chemistry improvements because acidification and recovery operate over much longer time periods. (7) the location of actual benefiting streams and anglers is not known. Benefit estimates are sensitive to stream length (8) This analysis makes no adjustments to the WTP estimates to reflect the growth in real income in 2010 and 2040, (9) the changes within ANC classes are not considered.

Most of the above factors are likely to result in an underestimation of the total benefits from improvements in ANC. A potential over-estimate of benefits relating to distances anglers are willing to travel is also possible if the improving streams are farther to angler's residence than average travel distance benefits based on assumed ANC changes for affected streams will be too

[1] Recreational anglers frequently target brown and rainbow trout, including wild trout and those stocked from a hatchery. The value of stocked fishable size rainbow trout can reach tens of thousands of dollars per stream mile. Constant or sporadic stream acidification may therefore result in significant losses to the rainbow and brown trout.

high.



Area of fishing Study

The majority of the streams that improve their ANC under the SAMI strategies, as determined by the effects work group, are located in the following eight counties in West Virginia: Fayette, Preston, Greenbriar, Nicolas, Pocahontas, Tucker, Randolph and Webster. The analysis of economic benefits resulting from improved brook trout fishing is limited to the geographic area comprised of these eight counties shown in the previous figure.

Observations

Using the results of the study submitted by the contractor, the SAMI Socioeconomic workgroup (SEWG) observed that:
The Benefits Analysis focused on the Small Geographic Area where only larger ANC changes occurred.

- The results showed: small increases in total WTP across all Strategies
- The estimated economic value of fishery improvement in the SAMI region under strategy B1 is $1.2 million in 2040. (These would be larger benefits if shifts within ANC classes were measured). B1 increases are less than half the increase in the value per trip under B3.
- The estimated economic value of fishery improvement in the SAMI region under strategy B3 is $4.4 million in 2040. The trend is toward increased fishing benefits as air quality improves.

Conclusions

Brook Trout improvements provide a small incremental benefit to the total value of SAMI policies compared to other socioeconomic topic areas. WTP for water quality improvements in the eight-county region of West Virginia ranges from a low of $500,00 in 2010 to a high of $4.4 million in 2040.

Visibility

Objectives

The SAMI strategies generally show visibility improvements throughout most of the SAMI region. The object of the SAMI visibility indicator is to evaluate the socioeconomic impacts of visibility improvements from SAMI emissions reduction strategies, in and around the Class I areas. This may be measured in visual range (how far you can see) or by Extinction or Deciview (the optical property of air). It puts a monetary value on people's desire for clear views (WTP) using emission reductions from the SAMI strategies. Visibility includes recreational visibility (WTP for visibility improvements in Class I areas) which assumes people everywhere in the country want good visibility in the National parks in the southeast whether they plan to visit them or not. A more limited analysis was done for residential visibility (people's WTP for good visibility where they live.)

Methods

SAMI's atmospheric modeling contractor prepared visual air quality profiles for A2, B1 and B3. emissions reduction strategies, in and around the Class I areas. The socioeconomic report estimates a general relationship between the amount of visibility improvement and the average value households are willing to pay for that improvement using benefits transfer methodology.

Benefit Transfer Studies

Though there have been a number of visibility valuation studies, only two gave monetary estimates of the visibility changes in the Southeast. One is a study on residential visibility conducted in 1990 (McClelland et al., 1991) and the other is a 1988 survey on recreational visibility value (Chestnut and Rowe, 1990). Chestnut and Rowe (C&R) was chosen to serve as the basis for the recreational estimate of visibility benefits in the SAMI analysis. It is the only study to estimate the value of visibility improvements at parks in the Southeast. The McClelland et al. visibility study was chosen as the basis for the estimate of SAMI residential visibility benefits. Valuation tries to place a dollar value on people's desire for improved visual air quality by asking them what they are willing to pay for improved views. It must separate this desire from other effects of emission changes. Both studies chosen for this indicator use the contingent valuation (CV) method, which uses surveys to ask specific questions about WTP for visibility improvements. McClelland et al. (1991) conducted a CV study of residential visibility in Atlanta. Chestnut and Rowe (1990) included a CV study of visibility at National Parks in the Southeast with particular emphasis on Shenandoah National Park.

Benefit Transfer Function

In order to estimate the value of the different visibility improvements projected to occur under each of the SAMI strategies, a general relationship between the amount of improvement in visibility and the average value households place on that improvement, observed in both the C&R and McClelland et al. studies was used. Separate recreational values were estimated for residents of the Southeast, the rest of country and each of 10 Class I Areas (requiring apportionment of benefits among the Class I areas and the wilderness areas in the SAMI region). Residential visibility has a separate estimate. Using the benefit transfer function, the C&R- and McClelland-based WTP parameters, the projected visual air quality for A2 B1, and B3 and the corresponding future year population are used to estimate each household's WTP for visibility improvements. The sum of household WTP for recreational visibility improvements equaled the total estimate of recreational visibility benefits. Similarly, the sum of household WTP for residential visibility improvements equals the estimate of total residential visibility benefits.

Primary Estimate of Total Recreational Visibility Benefits in Class I Areas Only

Year	Control Scenario	Benefits ($million)
2010	A2 to B1	$796
	A2 to B3	$2502
2040	A2 to B1	$1474

(Last column of table below should read Benefits (in $millions)

Class I Visibility Results

Year	Scenario	Region	Benefits
2010	A2 to B1	National	$796
		SAMI 8 State Region	$155
		Non-SAMI Region	$641
	A2 to B3	National	$2,502
		SAMI 8 State Region	$482
		Non-SAMI Region	$2,021
2040	A2 to B1	National	$1,474
		SAMI 8 State Region	$301
		Non-SAMI Region	$1,173
	A2 to B3	National	$2,705
		SAMI 8 State Region	$555
		Non-SAMI Region	$2,150
Benefits in Millions of year 2000 $			

****Totals do not reflect adjustments for income growth, which would increase benefits in 2010 up to 27% and in 2040 up to 82% using EPA's methods.*** 10

Results

Visibility Benefits by Class I Area

Class I Area	2010		2040	
	A2 to B1	A2 to B3	A2 to B1	A2 to B3
Great Smoky Mountains	$561	$1,810	$952	$1,724
Shenandoah	$229	$673	$511	$961
Cohutta	$3.0	$9.3	$5.4	$9.9
Dolly Sods	$0.4	$1.1	$0.6	$1.4
James River Face	$0.1	$0.4	$0.3	$0.5
Joyce Kilmer-Slickrock	$1.3	$3.5	$1.9	$3.4
Linville Gorge	$0.5	$1.3	$0.7	$1.3
Otter Creek	$0.2	$0.5	$0.3	$0.7
Shining Rock	$0.7	$2.3	$1.1	$2.0
Sipsey	$0.3	$1.1	$0.7	$1.1
Benefits in Millions of year 2000 $				

Totals do not reflect adjustments for income growth, which would increase benefits in 2010 up to 27% and in 2040 up to 82% using EPA's methods. 11

The above table shows the national benefits for each control scenario in 2010 and 2040 as well as the portion of national benefits attributed to residents both within and outside of the SAMI region. Recreational visibility benefits are based on the change in visibility at each of the Class I areas and therefore apply to each park itself.

Recreational visibility improvements are the primary estimate of SAMI-related visibility benefits. Under scenario B1, the value of recreational visibility improvements is $796 and $1,474 million (2000$) for 2010 and 2040, respectively.[2] Under scenario B3, the value of recreational visibility improvements is $2,502 and $2,705 million (2000$) for 2010 and 2040, respectively.

Supplemental Estimate of Residential Visibility Benefits

Year	Control Scenario	Benefits ($million)
2010	A2 to B1	$224
	A2 to B3	$1022
2040	A2 to B1	$791

[2] Benefits in 2010 would be up to 27% higher if an adjustment for income growth were applied. Likewise, in 2040 the total benefits would be up to 82% higher. These values were calculated by EPA for the Heavy Duty Diesel regulatory impact analysis. EPA's Science Advisory Board has concurred with the methodology for the calculation in its review of EPA's health-related analyses, but has been silent regarding the acceptability of these specific values used for assessing visibility benefits. While the concept of an income growth adjustment is reasonable, there are significant uncertainties concerning its value.

	A2 to B3	1463

This analysis considers the value of residential visibility improvements to be a supplemental estimate of SAMI-related visibility.[3] Under scenario B1, the value of residential visibility improvements is $224 and $791 million (2000$) for 2010 and 2040, respectively.4 Under scenario B3, the value of residential visibility improvements is $1,022 and $1,463 for 2010 and 2040, respectively.

Limitations and Uncertainties

The estimates of recreational and residential visibility valuation are uncertain and controversial. There are many potential sources of information that could shift the results up or down. Assumptions were made using available data to estimate visibility valuation (using techniques from prior federal visibility assessments) associated with improved visual air quality at Class I areas in the SAMI region under SAMI's strategies.

Observations and Conclusions

The above table: Class I Visibility Results, shows that 80% of the benefits for visibility improvement are for non-residents who live outside the SAMI region. The per park recreational visibility benefits show that across the scenarios, the Great Smokey Mountain National Park and Shenandoah receive the bulk of the benefits based on visibility improvements and how these benefits are apportioned.

Sense of Place /Stewardship
Objectives

This indicator, Sense of Place/Stewardship (SOP/S), of the SAMI assessment addresses the quality of life associated with living in a specific area. Its objective is to expand the impact analysis of air pollution policies beyond traditional "endpoints", to explore relationships in the Appalachian mountains between air pollution and "What makes this place this place?" to local residents.

SOP

The US Environmental Protection Agency developed a broad definition of SOP in the Community Social and Cultural Profiling Guide (1997): "[the] local values, beliefs, and behaviors as they relate to community life and the surrounding natural environment." These include: community capacity and activism; community interaction and information flow; demographic information; economic conditions and employment; education; environmental awareness and values; geographic and administrative boundaries; governance; infrastructure and public services; local arts, history, and tradition; local identity; local leisure and recreation; natural resources and landscape; property ownership, management, and planning; public safety and health; and religious and spiritual practices.

---

[3] The analysis creates a distinction between primary and supplemental benefits to highlight the uncertainty present within each estimate. Primary benefits, though uncertain, are a better estimate of the magnitude of recreational visibility benefits. Supplemental estimates of the value of improvements in residential visibility are more uncertain than the primary benefits.
[4] See footnote 1.

Stewardship

Stewardship is a set of distinct values often associated with unique, irreplaceable, environmental assets for which there is a desire to maintain the essence of a place for future generations. It further involves accepting or assigning continuing responsibility for preserving what residents' value about the place they live.

SOP is oriented towards past and present while stewardship is aimed at preservation for future generations. Both SOP/S share common components such as personal experiences and opinions, a combination of facts and myths and variations among individuals. Many elements are intertwined such as: peoples sense of family and community and history. The environment is just one aspect. The economy (types of employment, income levels, cost of living and architecture) is another variable.

Methods

Information on residents' feelings about SOP/S was gathered through 6 focus groups held at three locations. Since every town or city in the southern Appalachians has unique characteristics that would lead to a different SOP for each location and it was impossible to study every location, three places were chosen. These were:

- Traditional Appalachian economy, Madison, West Virginia, a small coal mining town in Boone County, located 35 miles southwest of Charleston, WV.

- Tourist and recreation destination, Asheville, North Carolina, a rapidly growing city that is an important tourism and recreation center in the Carolina mountains. Asheville is also a growing retirement destination.

- Growing metropolitan area, Knoxville, Tennessee, the largest city in the immediate mountain area. Knoxville has a diverse economy, with tourism (as a major gateway to the Smoky Mountain recreational destinations), a high tech sector (through the University of Tennessee, Oak Ridge National Laboratory, and the Tennessee Valley Authority), and traditional Appalachian manufacturing.

Two focus groups were held in each location. Participants were recruited via random telephone solicitation in Madison and newspaper advertisements in Asheville and Knoxville. A topic guide was developed and followed in the discussion process. It was divided into 4 key sections: "What makes (this place) (this place)?, where do you see this place heading in a generation?, what are the essential aspects of the (this place economy), and what about the environment makes (this place), (this place)? Participants were instructed not to try to agree, but to express their own thoughts. As with all focus group research, the small sample size (3 locations, 48 people) does not represent the full population, but is an illustrative sample. The focus group sessions were recorded and transcribed.

Results

Focus group participants seemed to understand the concepts of way of life and environmental stewardship. They spoke about responsibility, preservation, and conservation of both the environment and way of life. Madison focus group participants, talked about stewardship in terms of "putting things right" with respect to the environment and "restoration" with respect to their way of life, leaving jobs for the future, zoning and planning. They wanted to make sure that coal-mining companies that altered the land left it in usable condition (not necessarily its *original* condition) after they were through with it. This implied a kind of social contract between area residents and these industries: companies that left the land with no restoration after completing their mining were the objects of contempt. Most of all, Madison participants wanted to retain their way of social life as a close knit, caring community. They were concerned about attracting young people to stay in their community and deeply pessimistic, even fearful about the future of their town. They were doubtful that new jobs would be created. They wanted coal mining to continue as mining wages, low as they are, are higher than other wages. Few non-mining "good jobs" exist in Madison.

Asheville participants talked about stewardship issues in terms of the conflict between individual rights and the good of the community in land-use zoning. They saw zoning as a "hugely contentious issue," with large consequences for preservation of Asheville residents' way of life. The dominant view was that land use zoning in what participants perceived to be the public interest was a good thing, in order to prevent Asheville from turning into a "giant trailer park," or a little Atlanta, "where you have convenience store, grocery store, house, house, house." Asheville participants also spoke about effective planning on the local level: how this had already paid off in an aesthetically pleasing urban area, and how it would continue to work to preserve Asheville residents' quality of life. A number of participants talked about gardening, and even a "gardening mentality," which cultivates now for benefits in the future.

Focus group participants' sense of Knoxville revolved around (1) the Smoky Mountains and other mountains in the area, (2) the University of Tennessee, and (3) a feeling of division, or dualism, that splits the city in various ways. Throughout the discussions, participants expressed an understanding that the environment, economy, and culture are all interrelated.

In particular, the influence of the mountains can be seen in "the independence of the people – they're stubborn." In addition, the people are "neighborly ... and there's a lot of good in that," "very caring," "hospitable [and] friendly." Participants perceived other regional traits: "When you need somebody to do something and you need a volunteer to step forward, this part of the world is there." And: "the people seem to have more of a sense of self in this area … knowing where they came from. The history … you have a big comfort and a sense of where you belong and where you're going."

Though there are individual differences, the six focus groups' discussion of stewardship were similar in the following views:

- Not all area residents would agree on all the elements that would make up a desirable future. Second, participants felt that the probable way their area's environment or way of life or both would be preserved were political. All six focus groups had a significant political content, (*although politics was not included in the topic guide).* The Knoxville discussions were a good example. Participants perceived a lack of effective future city planning. Poor communication between government and citizens and fighting between city and county contributed to Knoxville residents' lack of confidence in planning for the future. As one person said, "You've got those two separate entities that are fighting when what they should [do] is come together for the better of the community."

- If the environment is going to be properly stewarded, it will be "government" that will have to do the job. There were differences regarding which level of government – city, county, state, regional, national – ought to be the responsible party. Then whether government stewardship of the environment would be successful, or even necessary. In Knoxville, University of Tennessee educational programs were also anticipated to influence the future.

- Not personally responsible for environmental and social problems, others were. In Madison, these "others" were industry and government. In Knoxville, the "others" were tourists, whose cars bring pollution; Oak Ridge; power plants in other states; and developers. In Asheville, the city of Charlotte, N.C.; out-of-state power plants; and anti-zoning residents were the primary culprits. Focus group participants did accept that their own automobiles helped cause pollution, to some extent.

- Concerned about economic matters like jobs, more than the environment, but generally they would prefer to have both.

Observations

The SEWG agreed upon the following observations:

- SOP/S reflects citizens' views of an externality caused by air pollution - The air we breathe and the mountains we view are considered free and an integral part of the environment we live in". With this free good, everyone believes that someone else is responsible for polluting or damaging it (no ownership of the problem), and that someone else will be responsible for cleaning it up.
- The mountain environment is an integral part of the citizen sense of place - what makes their community special
  - In lower income areas, such as Madison, the environmental resource is viewed as the key to economic survival, jobs, and family livelihood. Because employment and income are essential to them, environmental resources used by them (and the industries in their area) are perceived to be necessary to sustain their way-of-life (for them and their children).
  - In communities with higher incomes, jobs are not as directly linked to an environmental resource, but they view the environment (i.e., the mountain view) as a key element of what makes their community special. They use the environment as a recreational resource and/or tie it to the economy

through tourism and/or real estate.

- Planning for the future is important to citizens.
  - Many feel “small voices” are not heard when decisions are made that impact the future of their economy.
  - Many feel city, county, State, or Federal government will provide what is needed to sustain the community’s well being. Perceptions are that government will either provide jobs or supplemental income, or plan for smart growth decisions, or maintain the environment in the way they are accustomed to (i.e., the government will maintain the mountain view that makes the area special, or citizens hope that coal or other environmental resources will continue to provide for their economic well-being).

Conclusions

SOP/S has implications for SAMI region air policies. The region is very diverse, and residents differ deeply in their opinions. The environment is a strong element in their SOP. The outdoors, especially the mountains, hold a special place in people’s sense of what makes their place special, Air quality is seen as critical for tourism and recreation. Cost of living and job losses are major concerns. Lower income participants are worried that they may be forced to leave. There is a uniform awareness of local, state and federal government’s role in protecting the quality of life.

Lifestyles

Objective

Lifestyles is a qualitative assessment of the potential impacts of SAMI strategies on individual household (not the effect of cleaner air on household well being and health) lifestyle changes associated with air emissions regulation. Improving air quality requires restrictions on emission generating activities of both consumers and producers. Restricting consumer activities affects household well being directly because individuals must seek alternatives to activities (including the consumption of goods and services) that are affected by emission reduction strategies. Restricting the activities of producers affects households’ well being indirectly through effects on prices and employment.

Methods

Lifestyles is a qualitative and not comprehensive study that was developed from reviewing the SAMI strategies and developing types of effects:

- Direct effects are elements of strategies affecting consumer goods or activities generating emissions.
- Indirect effects are elements of strategies affecting producers of goods and services generating emissions.

SAMI strategies were used in order to characterize the qualitative effects on consumer lifestyles.

The focus is on how restrictions on both consumer and producer activities affect lifestyles. Case study industries were chosen that must make large emission reductions. Air quality improvements resulting from implementing the SAMI strategies are also likely to have positive affects such as potential improvements in health, visibility, and opportunities for recreation.

Some of these benefits have been estimated and described in other components of SAMI's integrated assessment and are not described further in this lifestyles assessment.

Direct Impacts on Consumers

The SAMI strategies affect consumers directly through emission reduction for vehicles and residential fuel combustion. Reduced vehicle emissions are to be achieved by more stringent emission controls for onroad vehicles, the gradual market penetration of onroad zero emission vehicles (ZEVs), reductions in the growth of onroad vehicle miles traveled (VMTs), and substituting ZEVs for nonroad gasoline lawn, garden, and recreational vehicles. Plans for reducing emissions from residential fuel combustion include efficiency improvements for residential natural gas combustion, and substituting natural gas for residential wood and coal combustion. Each of these measures will affect household well being by requiring changes in consumer behavior.

Consumers will incur additional costs associated with higher emission standards for onroad vehicles and replacing conventional vehicles with ZEVs. Given the current state of technology, the performance of ZEVs is inferior to that of conventional vehicles. There are also safety concerns about ZEVs.

From the perspective of consumers, there are both potential advantages and disadvantages associated with strategies to reduce VMT growth rates. Advantages include the amenities and lower expense of telecommuting, ridesharing and public transportation, and the convenience of high occupancy vehicle lanes. Reducing VMT growth rates will also reduce highway congestion. Potential disadvantages include possible loss in worker productivity, loss of workplace amenities, the inconvenience of ridesharing and public transportation, and the tax burden of subsidies to public transportation. Nonroad ZEVs have lower operating costs than gasoline vehicles. However, the up front cost of ZEVs is higher, and ZEVs may, in some cases, have inferior performance relative to gasoline vehicles.

There are also potential advantages and disadvantages associated with strategies to reduce emissions from residential fuel combustion (fireplaces, wood stoves etc.). The potential advantages include cleanliness, convenience, reliability, and efficiency improvements. Potential disadvantages include the costs of switching to natural gas and loss of aesthetics and aromatics. Localized unavailability of natural gas supplies is another potential problem.

Indirect Impacts: Price and Employment Impacts

The analysis of potential price and employment impacts focuses on ten "case study" industries. These include electric utilities, textiles, paper and paperboard, chemicals, primary metals, natural gas transmission, coal mining, liquid fuel providers, and railroads. Each of these industries is expected to be affected by the SAMI strategies.

The SAMI strategies have the potential for causing price increases in the following industries: electric utilities, textiles, paper and paperboard, chemicals, primary metals, and natural gas transmission. Each of these industries is expected to have higher production costs and may attempt to pass on some of these costs through price hikes. We emphasize, however, that their ability to do so will be limited by the availability of substitutes and by competition from producers outside the SAMI region.

Coal prices are more likely to decrease than increase under the SAMI strategies. The demand for coal is likely to fall because the SAMI strategies call for switching away from coal combustion to fuels with lower emissions, particularly natural gas. The exception is if scrubbers can clean local coal and it is more advantageous to use due to lower transportation costs.

Price effects for railroads, trucking and liquid fuel providers are uncertain. The demand for rail services is likely to increase because of converting truck traffic to rail. However, this effect will be offset, at least partially, by lower demand for coal traffic. The trucking industry is expected to incur increased operating costs because of higher emission standards and conversion to heavy duty ZEVs. These higher costs will tend to increase prices in the industry. In contrast, converting truck traffic to rail will decrease demand for trucking services, and tend to depress prices. The demand for liquid fuel will likely fall because of market penetration of ZEVs and reductions in VMT growth rate. However, the reduction in demand, especially under strategy B3, is substantial enough to change the structure of the industry, reduce spatial competition, and possibly increase distribution costs. The effects of the strategies on liquid fuel prices are uncertain at this point in time.

Employment losses resulting from the SAMI strategies could occur in the following industries: electric utilities, textiles, paper and paperboard, chemicals, and primary metals since each of these industries is expected to incur higher production costs as a result of the strategies. Higher prices could reduce the demand for their products, causing firms to reduce output and employment. Also, some firms in these industries could become unprofitable and close down operations.

Employment losses in the coal mining, liquid fuel provider, and trucking industries are also possible because of reduced demand. The trucking industry is also expected to experience higher operating costs as a result of the strategies.

The employment impacts on the natural gas transmission and railroad industries are uncertain. As noted earlier, the natural gas transmission industry is expected to incur higher operating costs. However, the demand for transmission services is likely to increase as a result of fuel switching strategies. Railroads will pick up new traffic diverted from trucking, but are likely to lose coal traffic.

Of the ten case study industries, projected baseline employment for the SAMI region is largest in the trucking industry. However, employment in the coal mining industry is concentrated largely in two states, Kentucky, and especially West Virginia. This raises the potential for adverse impacts on local economies.

While this analysis focuses on employment losses, we note that the SAMI strategies are also likely to generate positive employment impacts. Examples include potential employment gains in the tourist industry (due to improved air quality) and increases in employment associated with manufacturing, installing, operating, and maintaining emission controls.

Observations

Across all sources, strategy B3 calls for larger emission reductions than B1. As a result B3 will have larger impacts on households in 2010 and 2040. Restrictions on consumer activities and price impacts tend to be smaller in the long run. Over time, consumers have better opportunities to adapt and to find substitutes for higher priced goods and services. Employment effects also tend to be small in the long run. While length of unemployment spells are likely to vary considerably depending on individuals' circumstances, the economy tends to absorb available labor resources in the long run though not always with equivalent employment. An example would be with mining towns or manufacturing towns where the industries have shut down.

While these factors tend to mitigate impacts in the long run, other factors may worsen impacts. Both strategies B1 and B3 call for progressively larger emission reductions over time, suggesting larger impacts on households. Also, employment impacts may be increased in the long run if producers outside the SAMI region, both domestic and abroad, increase capacity in industries affected by the strategies.

Uncertainty

Uncertain technological advances could mitigate some of the impacts of the strategies by providing more environmentally friendly consumer goods and more efficient low-emission production technologies. The rate at which agencies outside the SAMI region adopt strategies for emissions generated by producers is also uncertain. International competition adds uncertainty. The employment impacts of the SAMI strategies will be mitigated if producers outside the region face similar emission controls. Long-run expansion of capacity outside the SAMI region might mitigate price impacts, but have negative employment impacts.

Summary

SAMI decided early in its design of the SE analysis to focus on a few topic areas of the dozens of areas where socioeconomic effects are likely to be felt in response to air quality management actions. As a result of that decision, the SAMI analysis cannot be considered a comprehensive cost- benefit analysis and costs cannot be compared to benefits. Even with in the six topics that SAMI selected, two topics – human health and competitiveness –were not taken to completion in the context of SAMI's tradition of consensus decision making. The four topics that were taken to completion may be useful to policy makers in evaluating the implications of their decisions on society and on our economies. Since the inception of SAMI different rules and regulations have been promulgated such as the Heavy-Duty Diesel rule and the No_x Sip call. As other programs are implemented, the results of the socioeconomic analyses will be lowered: costs, benefits and lifestyle impacts will be less.

The results of the socioeconomic analysis may also be useful as SAMI and the SAMI States disseminate the results of the Integrated Assessment. As the SE analysis suggests both positive and negative effects are likely to be seen in communities throughout the SAMI region. Low-income communities are particularly sensitive about jobs. All communities feel a connectedness to the mountains and many feel that “government” should do something about a perceived deterioration in the environmental quality of the mountains. As with any major environmental management action, positive and negative societal effects are likely. Sharing the results of the SAMI analysis broadly is likely to improve understanding of the possible effects as States implement the SAMI recommendations.

Lessons Learned /General observations:

- Many communities in the SAMI 8-State region will be affected by the selected strategy either negatively and/or positively, thus, communication with the citizens affected is important.
- The early sections of the final SAMI report and/or outreach efforts for SAMI should be sensitive to the differences in views across communities.
  - Low-income areas that may lose jobs due to SAMI strategy implementation need to have an explanation of why SAMI is taking action. SAMI could communicate with them and help them understand the need for controls. SAMI’s communication efforts can remove the feeling that “big brother is making decisions that will hurt them. Some may need to realize that if their area is already in transition to a different way of life, that this transition will continue if SAMI strategies will impact their environmental resource (i.e., coal). Express that SAMI does not intend to change their sense of place, but that preserving the environment for the future is needed.
  - For higher income areas, communication through the report or outreach should focus on the expectation that we will have clearer mountain views by 2040. Make the citizens aware of SAMI and communicate responsibly with them.
  - The SAMI report should speak to the changes that occur over time regardless of the impact of SAMI. In some areas, they are advancing from manufacturing jobs to more high-tech jobs. In other areas, one environmental resource is phasing out and another is transitioning in (i.e., coal to lumber). Their sense of place will evolve with these changes, but SAMI’s influence on the air and views in the mountain region will help to maintain their current “Appalachian feel of the area.

DIRECT COST

[SECTION CURRENTLY UNDER DEVELOPMENT]

Incentive Programs

[SECTION CURRENTLY UNDER DEVELOPMENT, TEXT WILL BE SENT OUT ON MAY 31 IN BATCH 2]

Conclusions and Recomendations

CONCLUSIONS

1. SUMMARY CONCLUSIONS - Sulfur dioxide reductions are needed to improve visibility.
2. Ammonia reductions will become more important as sulfur emissions are reduced.
3. Sulfur reductions are also needed to reduce acid deposition in the central and northern part of the SAMI region.
4. For limited areas in the SAMI region, nitrogen oxide and ammonia reductions are needed to reduce acid deposition both for stream and forest ecosystems.
5. Nitrogen oxide reductions are not needed to protect overall forest productivity in the SAMI region. Some tree species are at a competitive disadvantage with higher ozone and may be reduced in number or size without expanded ozone controls.
6. Reduced emissions inside and outside the SAMI region will be needed to accomplish the SAMI mission.
7. REGION-WIDE CONCLUSIONS -Sulfur dioxide emission reductions are the highest priority.
8. Ammonia controls will be increasingly important as sulfur is reduced because of its role in contributing to haze.
9. In winter weather, nitrogen oxide reductions may improve visibility by reducing the formation of ammonium nitrate which contributes to haze.
10. Volatile organics, elemental carbon, and soil contribute to haze under certain circumstance but they are less important than the emissions discussed above.
11. Streams in the central and northern part of the SAMI region that run over geology that imparts poor buffering capacity are at risk from acid deposition.
12. Sulfur dioxide emission reductions will generate benefits for aquatic resources in West Virginia, Virginia, and high elevation areas along the Tennessee and North Carolina border. Nitrogen oxide and ammonia reductions will benefit certain streams in these same areas.
13. Most forests in the SAMI region are not at risk from acid deposition. High elevation, slow-growing forests growing in soils with low buffering capacity are at risk in limited areas of the central and northern parts of the SAMI region. Sulfur dioxide, nitrogen oxide, and ammonia reductions are needed to reduce the impacts to sensitive forests in these areas. The high elevation spruce-fir forests in these areas are the most sensitive to the deposition of nitrogen compounds.
14. **OZONE –** SAMI modeling indicates that forest basal area does not greatly change in response to changes in ozone exposures. Some species show a competitive advantage as ozone exposures change and some species are at a disadvantage. These changes in competitiveness did not produce any change in forest type over the range of conditions tested by the SAMI strategies. In specific areas within the Class I areas the strategies tested by SAMI did not reduce exposures to approach natural conditions. A change in abundance of certain species in Class I areas remains a concern to some SAMI

stakeholders. Nitrogen oxide emissions reductions will be required if ozone exposures are to be reduced.

15. **EMISSIONS CHANGES FROM SAMI STRATEGIES –** Visibility will improve immediately when emission reductions take place. Reductions beyond the A2 strategy (description in chapter __) will be required to significantly improve annual visibility. (Figure 10.1). Strategy B1 improves visibility on hazy days from one deciview (dv) to 2.3 dv. Strategy B3 improves hazy days to 5.5 dv (Figure 10.2)

[INSERT FIGURE 10.1: ANNUAL AVERAGE VISIBILITY]
[INSERT FIGURE 10.2: CLASS AVERAGE DECIVIEW]

16. Stream response to changes in emissions that produce acid deposition occur over decades and results in small changes in the number of streams that are at risk from acid deposition. Streams with very low ability to neutralize the acid in acid deposition will benefit the most from the changes projected by the SAMI modeling.
17. **MAGNITUDE AND TIMING OF RESPONSES TO SAMI STRATEGIES –** The response to the ozone changes produced by the SAMI strategies is small and occurs in the context of other species composition changes that occur naturally over time. The ozone changes modeled by SAMI did not significantly alter forest basal area or forest type. (Figure 10.3)

[INSERT FIGURE 10.3: KEY FINDINGS: OZONE FOREST EFFECTS]

18. **COST OF STRATEGIES –** The total cost of the strategies for sulfur dioxide reductions modeled by SAMI ranged form $1 billion to approximately $6.5 billion per year. The range of costs over all sectors was $908/ton to $2,592 dollars per ton. Mobile sources and ammonia sources costs are particularly uncertain.
19. **SE**
20. **SOURCE ATTRIBUTION**
21. **INCENTIVES**
22. **RECOMMENDATIONS**

RECOMMENDATIONS

(adopted by consensus action of the SAMI Governing Body on April 18, 2002)

The SAMI states support and will promote strong national multi-pollutant legislation for electric utility plants to assure significant sulfur dioxide and nitrogen oxides reductions both in and outside the SAMI region. This national multi-pollutant legislation should result in no less than the reductions for sulfur dioxide and for nitrogen oxides represented by the Administration's Clear Skies Initiative. Reductions from other source categories should also be considered in national legislation, and such national legislation should contain sufficient measures to protect Class I areas. Should the national legislation fail to materialize, the states that participated in SAMI will work together to consider regulatory alternatives and to encourage non-SAMI states to participate. Leadership by states ahead of national legislation is encouraged.

Each SAMI State should seek ways to reduce ammonia emissions from animal feeding operations. Also support should be given in future work such as VISTAS to improve the understanding of the sources of ammonia, to develop better inventories, and to seek more effective control approaches.

Where States have control strategy option choices in their eight hour ozone and fine particle State Implementation Plans, that also have co-benefit for the environmentally sensitive Class I areas, they should choose them. Ambient ozone monitoring should be conducted near all Class I areas in the future.

Each SAMI state should encourage energy efficiency, conservation, and use of renewable energy to reduce the emissions from stationary and mobile sources.

[INSERT FIGURE 10.4 EASTERN US RPO MAP; FIGURE STILL UNDER DEVELOPMENT]

Implementation and Reporting

In mid-2002 SAMI will close its doors having provided a strong technical basis for fulfilling the SAMI Mission. Implementation of the SAMI recommendations and other programs on which improved air quality depends will take years. Recovery of damaged ecosystems will take decades. SAMI recommends the following actions to track progress toward fulfilling the SAMI work.

1. VISTAS will assume responsibility for haze modeling and will recommend any additional measures needed to meet the requirements of the Regional Haze rule. Fulfilling the reasonable progress requirements of that rule is equivalent to making reasonable progress in fulfilling the SAMI Mission with regard to haze.

2. SESARM in collaboration with Virginia and West Virginia will annually evaluate and report on progress toward the first SAMI recommendation. If national multipollutant legislation does not materialize in 2003, SESARM will recommend actions by the SAMI states to fill this gap. EPA and the SAMI states will encourage states in other regions to assist.

3. The U.S. Forest Service and the National Park Service will issue an annual report on the progress toward protecting the air quality related values in the SAMI Class I areas. They will also evaluate the adequacy of the monitoring network to allow this progress to be measured.

4. The Southern Air Principles States (SOAPS) will issue an annual report on their progress toward meeting their objectives in the areas of transportation and energy efficiency.

5. The environmental organizations that issued the report entitled Blueprint for Breathing Easier – Southeast Energy Strategy for Clean Air will issue an annual report on progress toward energy efficiency and other recommendations in their report.

6. (Need a volunteer state – SC??) will host the next Governors Air Summit in the spring of 2005. At that event VISTAS will report on progress in involving the agricultural community in managing agricultural ammonia emissions including recommended best management practices and the likely effect of those practices on haze and nitrogen deposition. The Environmental Protection Agency will report on progress toward ozone attainment in Southeastern urban areas and the likely implications for the SAMI Class I areas. The EPA will also report on their progress in encouraging the states outside the SAMI region to assist in protecting air quality in the SAMI Class I areas. SAMI envisions a similar Summit on alternate years following 2005.

7. SAMAB will manage the SAMI archives and provide access to all data and reports developed by SAMI.

Lessons Learned from the SAMI Experience

1. Consensus decisions by a stakeholder group are possible for high stakes, highly complex environmental decisions but participants should be prepared for the process to take two to three times as long. If that time is not available, do not involve stakeholders or do not rely on consensus decisions. SAMI's cultural norm of making all decisions by consensus slows progress in many cases but hopefully that approach has lead to long-term ownership of the results.

2. Group decisions always take longer than individual decisions, large groups take longer and large stakeholder groups take longer yet. Assuming that a "fast track" Integrated Assessment would take two years if done by a small team within one organization, five years with a large stakeholder group making consensus decisions is probably as good as can be reasonably expected, based on the SAMI experience.

3. Several reasons other than consensus decisions led to slow progress over the SAMI decade. When new groups assemble, a certain amount of milling about and getting to know how much to trust each-other typically occurs. For SAMI, that process took about five years. Hopefully that process will not need to be repeated in the SAMI states as long as the stakeholders stay in touch with each other. Once the Integrated Assessment was under way, the development of new science – particularly with regard to the atmospheric "one atmosphere" model took another year although work was proceeding in others areas. If rapid progress is a concern in the future, "off-the-shelf" scientific approaches should be emphasized. Fund-raising was another distraction that took valuable time from SAMI leadership. The absence of complete funding in the SAMI middle years made more work for staff and committees in negotiating contracts and made many SAMI decisions seem tentative during that period. Competition from OTAG for participant time and meeting dates was another distraction that accounts for part of the SAMI decade

4. Lawsuits are generally avoided by using consensus decisions with full stakeholder participation. Many lawsuits were filed and most were resolved over the SAMI decade but they were not specifically about SAMI's work. The SAMI approach appears to keep technical debates in the scientific realm and out of the courtroom. Some may say that approach leads to better environmental decisions.

5. Free flow of information increases trust and promotes open dialog. All stakeholders had access to all information as SAMI proceeded. All meetings were open. All e-mail lists were open to all. While stakeholder caucus at breaks and between meetings were common, SAMI discussions were direct and fairly efficient in part because all participants shared a common base of information.

6. High level state and federal gatherings such as the Air Summits are effective at gradually informing public policy as new technical information is developed. Throughout the SAMI decade, policy makers were aware of the questions that SAMI was addressing, the progress

being made as new information was developed and when the final answers were expected. A number of new regulatory initiatives occurred during this period but the initiating organizations were aware of the unfolding new SAMI information when the regulations were announced.

7. Virtual organizations can be effective. SAMI participants developed the ability to identify hundreds of other participants by voice alone. Conference calls plus simultaneous access to contractor results on websites proved very effective in moving through and approving large bodies of technical information. Policy discussions seemed to be more effective face-to-face.

8. The participants involved shape the nature of the recommendations. Regulators tend to think in terms of regulations. Legislators tend to think in terms of legislation. SAMI discussions were dominated by people involved somehow in the regulatory process since few others understand air quality issues at fairly sophisticated level of designing and running an integrated assessment. Not surprisingly, most of the SAMI recommendations involve traditional regulatory approaches. Most participants recognized that patterns of growth, modes of transportation, energy efficiency and emerging new technologies will affect our long term air quality. Work like that by the Southern Air Principles States which involves energy, transportation and air agencies may suggest an approach to developing more specific recommendations outside the realm of traditional command and control approaches.

Appendix A

[Section currently under development]

Appendix B

[Section currently under development]

List of Figures

[TO BE COMPLETED AFTER FINAL DRAFT]

List of Tables

References

[TO BE COMPLETED AFTER FINAL DRAFT]

Glossary

[SECTION UNDER CONSIDERATION]