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U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards

Air Quality Strategies
and Standards Division
Innovative Strategies
and Economics Group (MD-15)
Research Triangle Park, NC 27711

Number of pages to follow: 21

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LOCATION: OMB / CEA

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DATE: 11/25/98

COMMENTS:

Bill Harnett passed the message to me that you never received the attached fax with our changes in response to your comments on Volume II of the NO_x SIP Call RIA. I believe we have adequately addressed your comments. Please review by 12/4/98. Thank you.

United States Environmental Protection Agency
Office of Air Quality Planning and Standards • Air Quality Strategies and Standards Division
(MD-15) • Research Triangle Park, North Carolina 27711

Facsimile Transmission Cover Sheet

Please deliver the following pages to:

Name: Art Fraas, OMB
Steve Polasky, CEA

Organization:

Facsimile No: OMB--202-395-7285
CEA--202-395-6870

Date: November 4, 1998

Total Number of Pages (including this cover sheet): ~~20~~ 21

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From: **Scott Mathias**
Phone No: **(919) 541-5310**
Facsimile No: **(919) 541-0839**

Message:
Attached are EPA's revisions to Volume 2 of the NOx SIP Call RIA (Health and Welfare Benefits) based on comments received from you on October 23, 1998. The revisions are indicated using the redline-strikeout convention. The redline text, which indicates additions or corrections, may not be readable on the fax copy. If this is a problem, perhaps we can email the wordperfect files to you or manually highlight the text. We have attempted to address all of your comments and concerns. Please review the material and let us know if you continue to have concerns.

cc: Ron Evans
Bill Harnett
Bryan Hubbell

Table ES-5
Comparison of Annual Costs and Monetized Benefits in 2007 Associated with the NOx SIP Call
(millions of 1990 dollars)

Benefits Case	Total Annual Costs	Annual Monetized Benefits*	Annual Net Benefits
"Low" Assumption Set	$1,660	$1,100	($560)
"High" Assumption Set	$1,660	$4,170	$2,510

*There are many benefits of the NOx SIP call that EPA was not able to quantify or monetize.

Limitations

Comparing the benefits and the costs provides one framework for policy makers and the public to assess policy alternatives. Not all the potential costs and benefits can be captured in any analysis. However, EPA is generally able to estimate reasonably well the costs of pollution controls based on today's control technology and assess the important impacts when it has sufficient information for its analysis. EPA compiled through the OTAG process and from many other sources sufficient information for this rulemaking. There are, however, important limitations in the RIA analysis:

- EPA is increasingly able to estimate benefits from pollution controls, but EPA believes that there are many important benefits that it can not quantify or monetize that are associated with the NOx SIP call, including many health and welfare effects. There are also potential disbenefits that are not quantified, including passive nitrogen fertilization and UV-B screening.

- EPA must employ different pollutant models to characterize the effects of alternative policies on relevant pollutants. Not all atmospheric models have been widely validated against actual ambient data. The Agency has chosen the best available models for its application needs in this RIA and tried to make the most reasonable assumptions possible in using them for predicting air quality changes.

- There are some data limitations in some aspects of the RIA, despite the Agency's extensive efforts to compile information for this rulemaking. While they exist, EPA believes that it has used the models and assumptions that are made to conduct its analysis in a reasonable way based on the available evidence, but this should be kept in mind when reviewing various aspects of the RIA's results.

- Another factor that adds to the uncertainty of the results is the potential for pollution control innovations that can occur over time It is impossible to estimate how much of an impact, if any, new technologies that are just now emerging may have in lowering the compliance costs for the NOx SIP call, which goes into effect in 2003. We can only recognize their possible influence.

1.5 Statement of Need for the NOx SIP Call

The following sections discuss the statutory authority and legislative requirements of the NOx SIP call, health and welfare effects of NOx emissions, and the basis for the regulatory actions of the NOx SIP call.

1.5.1 Statutory Authority and Legislative Requirements

Section 110(a)(2)(D) provides that a SIP must contain provisions preventing its sources from contributing significantly to nonattainment or interfering with maintenance of the NAAQS in a downwind State. This section applies to all pollutants covered by NAAQS and all areas regardless of their attainment designation. Section 110(k)(5) authorizes EPA to find that a SIP is substantially inadequate to meet any CAA requirement, as well as being inadequate to mitigate interstate transport as described in Sections 184 and 176A. Such a finding would require States to submit a SIP revision to correct the inadequacy within a specified period of time.

1.5.2 Health and Welfare Effects of NOx Emissions[16]

NOx emissions contribute to the formation of ozone during the summer season. Ozone is a major component of smog and is harmful to both human health and the environment. Research has shown the following health effects of ozone:

- Exposure to ambient ozone concentrations has been linked to increased hospital admissions for respiratory ailments, such as asthma. Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation, and can aggravate preexisting respiratory diseases.

- Children are at risk for the effects of ozone because they are active outside during the summer months when ozone levels are at their highest. Adults who are outdoors and moderately active during the summer months are also at risk. These individuals can experience a reduction in lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during periods of moderate exertion.

- Long-term exposures to ozone can cause repeated inflammation of the lung, impairment of lung defense mechanisms, and irreversible changes in lung structure, which could lead to premature aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis.

- ~~Twenty-one~~Several peer reviewed epidemiology studies recently published suggest a possible association between ozone exposure and mortality.

Ozone has also been shown to adversely affect vegetation, including reductions in agricultural and commercial forest yields, reduced growth and decreased survivability of tree seedlings, and increased tree and plant susceptibility to disease, pests and other environmental stresses.

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[16] A comprehensive discussion of health and environmental issues related to NOx appears in EPA, 1997d.

requirements to solicit and consider flexible regulatory options that minimize adverse economic impacts on small entities. The RFA's analytical and procedural requirements were strengthened by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996.

For reasons explained more fully in the Federal Register notice for the final NOx SIP call, it is EPA's position that the RFA as amended by SBREFA does not apply to the final NOx SIP call, because the rule does not impose direct requirements on emissions sources. States will ultimately decide what emissions limits are imposed for specific sources. However, the EPA has determined that the RFA as amended by SBREFA does apply to both the proposed FIP and section 126 actions. Therefore, EPA has examined the potential for small entity impacts to provide policy makers and States with additional decision information.

The RFA and SBREFA require use of definitions of "small entities", including small businesses, governments and non-profits, published by the Small Business Administration (SBA).[17] Screening analyses of economic impacts presented in Volume 1 of the RIA examine potential impacts on small entities.

1.6.3 Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act (UMRA) of 1995 (PL 104-4) was enacted to focus attention on federal mandates that require other governments and private parties to expend resources without federal funding, to ensure that Congress considers those costs before imposing mandates, and to encourage federal financial assistance for intergovernmental mandates. The Act establishes a number of procedural requirements. The Congressional Budget Office is required to inform Congressional committees about the presence of federal mandates in legislation, and must estimate the total direct costs of mandates in a bill in any of the first five years of a mandate, if the total exceeds $50 million for intergovernmental mandates and $100 million for private-sector mandates.

Section 202 of UMRA directs agencies to provide a qualitative and quantitative assessment of the anticipated costs and benefits of a Federal mandate that results in annual expenditures of $100 million or more. The assessment should include costs and benefits to State, local, and tribal governments and the private sector, and identify any disproportionate budgetary impacts. Section 205 of the Act requires agencies to identify and consider alternatives, including the least costly, most cost-effective, or least burdensome alternative that achieves the objectives of the rule.

~~For reasons explained more fully in the Federal Register notice for the NOx SIP call, it is EPA's position that section 202 of UMRA does~~EPA has not ~~apply to the~~reached a final ~~NOx SIP call, because the annual estimated costs of possible SIP submittals by States is less than $100 million and no Federal or private sector mandates are directly imposed~~conclusion as to the applicability of the requirements of UMRA to the NOx SIP call rule. ~~However,~~ EPA has determined that UMRA does affirmatively apply to both the proposed FIP and proposed section 126 rules. Volume 1of this RIA presents a summary of analyses of the potential impacts of the NOx SIP call on State and local governments, to support compliance with ~~Section~~section 202 of UMRA. This analysis includes administrative requirements of State and local governments associated with revising SIPs and collecting and reporting data to EPA. It also includes the

[17] Where appropriate, agencies can propose and justify alternative definitions of "small entity." This RIA relies on the SBA definitions.

compliance and administrative costs to emissions sources owned by government entities. In addition, EPA has prepared a more detailed written statement consistent with the requirements of section 202 and section 205of the UMRA and placed that statement in the docket for this rulemaking.

1.6.4 Paperwork Reduction Act

The Paperwork Reduction Act of 1995 (PRA) requires Federal agencies to be responsible and publicly accountable for reducing the burden of Federal paperwork on the public. EPA has submitted an Information Collection Request (ICR) to the Office of Management and Budget (OMB) in compliance with the PRA. The ICR explains the need for additional information collection requirements and provides respondent burden estimates for additional paperwork requirements to State and local governments associated with the NOx SIP call.

1.6.5 Executive Order 12898

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," requires federal agencies to consider the impact of programs, policies, and activities on minority populations and low-income populations. Disproportionate adverse impacts on these populations should be avoided. According to EPA guidance, agencies are to assess whether minority or low-income populations face risk or a rate of exposure to hazards that is significant (as defined by the National Environmental Policy Act) and that "appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group." (EPA, 1996b) This guidance outlines EPA's Environmental Justice Strategy and discusses environmental justice issues, concerns, and goals identified by EPA and environmental justice advocates in relation to regulatory actions.

The NOx SIP call is expected to provide health and welfare benefits to eastern U.S. populations, regardless of race or income. Chapter 3 of this RIA presents information on the changes in potential ozone and PM exposure for white and non-white populations and low income populations, and compares these relative changes to the general populations.

1.6.6 Health Risks for Children

Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks," directs Federal agencies developing health and safety standards to include an evaluation of the health and safety effects of the regulations on children. Regulatory actions covered under the Executive Order include rulemakings that are economically significant under Executive Order 12866, and that concern an environmental health risk or safety risk that the agency has reason to believe may disproportionately affect children. EPA has developed internal guidelines for implementing the E.O. 13045. (EPA, 1998b)

The NOx SIP call is a "significant economic action," because the annual costs are expected to exceed $100 million. Both NOx and ozone formed by NOx are known to affect the health of children and other sensitive populations, which were addressed in the development of the new ozone NAAQS. However, the NOx SIP call is not expected to have a disproportionate impact on children. Chapter 3 of this RIA presents information on the changes in potential ozone and PM exposure for persons under the age of 18.

Chapter 4. BENEFITS OF REGIONAL NOx REDUCTIONS

The changes in ozone and PM ambient concentrations described in Chapter 3 will result in changes in the physical damages associated with elevated ambient concentrations of these pollutants. The damages include changes in both human health and welfare effects categories.

This chapter presents the methods used to estimate the physical and monetary benefits of the modeled NOx and SO_2 emissions changes from implementing the revised SIPs, the estimates of the avoided physical damages (e.g., incidence reductions), and the results of the benefits analysis for a range of regulatory alternatives considered for the SIP call. EPA decided to analyze the benefits of the most significant alternatives that it considered for determining state NOx budgets for the electric power industry and other stationary sources. The five alternatives are described in Table 2-3 in Chapter 2 of Volume 2 of the RIA. Regionality 2 is not analyzed because on an air quality basis, Regionality 1 appeared to be ~~a~~ superior ~~alternative~~to Regionality 2.

The remainder of this chapter is laid out as follows. Section 4.1 provides an overview of the benefits methodology. Section 4.2 discusses issues in estimating health effects. Sections 4.3 discusses methods and provides estimated values for avoided incidences and monetary benefits for ozone and PM related health effects. Section 4.4 discusses methods and provides estimated values for ozone and PM related welfare effects. Section 4.5 provides estimates of total health and welfare benefits associated with alternative NOx emission limit policies. Finally, Section 4.6 discusses potential benefit categories that are not quantified due to data and/or methodological limitations, and provides a list of analytical uncertainties, limitations, and biases.

4.1 Overview of Benefits Estimation

Most of the specific methods and information used in this benefit analysis are similar to those used in the §812 Retrospective of the Benefits and Costs of the Clean Air Act and forthcoming §812 Prospective EPA Reports to Congress, which were reviewed by EPA's Science Advisory Board (EPA, 1997c),as well as the approach used by EPA in support of revising the ozone and PM NAAQS in 1997 (EPA, 1997a and 1997b).

Prior to describing the details of the approach for the benefits analysis, it is useful to provide an overview of the approach. The overview is intended to help the reader better identify the role of each issue described later in this chapter.

The general term "benefits" refers to any and all outcomes of the regulation that are considered positive; that is, that contribute to an enhanced level of social welfare. The economist's meaning of "benefits" refers to the dollar value associated with all the expected positive impacts of the regulation; that is, all regulatory outcomes that lead to higher social welfare. If the benefits are associated with market goods and services, the monetary value of the benefits is approximated by the sum of the predicted changes in "consumer (and producer) surplus." These "surplus" measures are standard and widely accepted measures in the field of applied welfare economics, and reflect the degree of well being enjoyed by people given different levels of goods and prices. If the benefits are non-market benefits (such as the risk reductions associated with environmental quality improvements), however, other methods of measuring benefits must be used. In contrast to market goods, non-market goods such as environmental quality improvements are public goods, whose benefits are shared by many people. The total value of such a good is the sum of the dollar amounts that all those who benefit are willing to pay.

In addition to benefits, regulatory actions may also lead to potential disbenefits, i.e. outcomes that have a negative impact on social welfare. In general these disbenefits will be incidental to the stated goals of the regulation, otherwise (in an efficient regulatory environment) the regulation would not have been promulgated. In order to fully quantify the benefits and costs of a regulatory action, both the benefits and disbenefits should be calculated, so that net benefits (equal to benefits minus disbenefits minus costs) will not be biased upwards. In many cases, however, disbenefits are difficult to quantify, as it is often unclear where and how disbenefits will occur.-

Benefits may also be difficult to quantify, since many benefits are not measurable using market based measures.

This conceptual economic foundation raises several relevant issues and potential limitations for the benefits analysis of the regulation. First, the standard economic approach to estimating environmental benefits is anthropocentric -- all benefits values arise from how environmental changes are perceived and valued by people in present-day values. Thus, all near-term as well as temporally distant future physical outcomes associated with reduced pollutant loadings need to be predicted and then translated into the framework of present-day human activities and concerns. Second, as noted below, it is not possible to quantify or to value all of the benefits resulting from environmental quality improvements.

Conducting a benefits analysis for anticipated changes in air emissions is a challenging exercise. Assessing the benefits of a regulatory action requires a chain of events to be specified and understood. As shown in Figure 4-1, illustrating the causality for air quality related benefits, the estimation of benefits requires information about: (1) institutional relationships and policy-making; (2) the technical feasibility of pollution abatement; (3) the physical-chemical properties of air pollutants and their consequent linkages to biological or ecological responses in the environment, and (4) human responses and values associated with these changes.

The first two steps of Figure 4-1 reflect the institutional and technical aspects of implementing the NOx SIP call regulation (the improved process changes or pollutant abatement). The estimated changes in ambient PM or ozone concentrations are directly linked to the estimated changes in precursor pollutant emission reductions through the use of air quality modeling, as described in Chapter 10.

relationships for urban ornamentals and values associated with specific types of injuries and mitigation) currently prevents quantification of this benefits category.

It is also difficult to identify all the types of benefits that might result from environmental regulation and to value those benefits that are identified. A cost analysis is expected to provide a more comprehensive estimate of the cost of an environmental regulation because technical information is available for identifying the technologies that would be necessary to achieve the desired pollution reduction. In addition, market or economic information is available for the many components of a cost analysis (e.g., energy prices, pollution control equipment, etc.). A similar situation typically does not exist for estimating the benefits of environmental regulation. This problem is due to the non-market nature of many benefits categories. Since many pollution effects (e.g., adverse health or ecological effects) traditionally have not been traded as market commodities, economists and analysts cannot look to changes in market prices and quantities to estimate the value of these effects. This lack of observable markets may lead to the omission of significant benefits categories from an environmental benefits analysis. Likewise, difficulties in measuring disbenefits may lead to a positive bias in net benefits. The net result of underestimating benefits and disbenefits will depend on how completely each category is measured.

Because of the inability to quantify many of the benefits categories listed in Table 4-1, as well as the omission of unknown but relevant environmental benefits categories, the quantified benefits presented in this report may underestimate total benefits. It is not possible to quantify the magnitude of this underestimation. The more important of these omitted effect categories are shown in Table 4-2. Underestimation of total benefits may be mitigated to some extent if there are also relevant disbenefit categories that are omitted or unquantified.

Within each effect category, there may be several possible estimates of health and welfare effects or monetary benefit values. Each of these possibilities represents a health or welfare "endpoint." The basic structure of the method used to conduct the benefits analysis is to create a set of benefit estimates reflecting different key assumptions concerning environmental conditions and the responsiveness of human health and the environment to changes in air quality. Total benefits are presented as a plausible range representing the sensitivity of benefits over the set of maintained assumptions. The upper and lower ends of the plausible range of total benefits are constructed using estimates of non-overlapping endpoints for each effect category, selected to avoid double counting. Double counting occurs when two endpoints contain values for the same thing. For example, an endpoint measuring avoided incidences of all hospital admissions would incorporate avoided incidences of hospital admissions just for heart disease. Thus including values for avoiding both types of hospital admissions would double count the value of avoided hospital admissions for heart disease. The upper and lower ends of the plausible range do not necessarily represent the sum of the highest values for each endpoint. Instead, they represent the points associated with the combinations of assumptions that are expected to generate the lowest and highest benefit estimates for the majority of regulatory alternatives. The plausible range does not provide information on the likelihood of any set of assumptions being the correct one. Thus, while the plausible range indicates the sensitivity of benefits to the various assumptions, it requires a subjective determination of which assumption set most closely represents reality. ~~EPA has assessed the available scientific information and has determined that the most probable scenario includes health effects occurring down to the lowest observed levels in the epidemiological studies and a reasonable likelihood that elevated ozone concentrations are associated with premature mortality.~~

epidemiological studies. Where no lowest observed level was reported, the functions will be applied down to the "anthropogenic background" level. Theoretically, C-R functions should be reestimated when a threshold is assumed to insure consistency with the observed correlation between mortality incidences and the pollutant. If no threshold is assumed in the epidemiological study, then the slope of the C-R function will be flatter than for a function with a threshold. This reflects the fact that all of the observed changes in mortality would have to be associated with changes above the threshold, rather than being associated with changes along the full spectrum of pollutant concentrations. Unadjusted C-R functions are used in this benefits analysis due to a lack of availability of the underlying data used to estimate the C-R functions. These data are necessary to develop threshold adjusted C-R functions. Use of an unadjusted C-R function will result in an underestimate of total avoided incidences.

Because the issue of possible thresholds can have a major effect on the benefits estimation, estimates for individual benefit endpoints will be generated using alternative assumptions of thresholds for PM. Following advice from EPA's Science Advisory Board, both high and low threshold assumptions will be used to generate benefits estimates. The low threshold assumption will assume a threshold equal to anthropogenic background concentrations and the high threshold assumption will assume a threshold equal to the PM standard of 15 $\mu g/m^3$.

4.3 Ozone and PM Health-Related Benefits

While a broad range of adverse health effects have been associated with exposure to elevated ozone and PM levels, only subsets of health effects are selected for inclusion in the quantified benefit analysis. Effects are excluded from the current analysis (1) in order to prevent double counting (such as hospital admissions for specific respiratory diseases); (2) due to uncertainties in applying effect relationships based on clinical studies (where human subjects are exposed to various levels of air pollution in a carefully controlled and monitored laboratory situation) to the NOx SIP call affected population; or (3) due to a lack of an established concentration-response relationship.

The general format for the following sections detailing benefits for each endpoint is to begin with a discussion of the method and studies used for economic valuation, then present the studies used to obtain the concentration-response function for estimation of avoided incidences. Following these discussions, tables of avoided incidences and associated monetary benefits for ozone-related effects and PM-related effects are presented. Benefits estimates are presented for a subset of the regulatory alternatives presented in chapters 6, 7 and 9. Air quality changes used to generate the benefits estimates are not based on the final NOx SIP call control requirements. For additional information on air quality modeling scenarios for the benefits analysis, see Section 10.1.5. Numbers presented in the tables represent changes in the number of incidences and associated monetary benefits given the illustrative implementation of particular NOx control strategies relative to the 2007 baseline air quality. For endpoints which are affected by both ozone and PM, ozone-related benefits are presented first, followed by PM-related benefits.

A preliminary explanatory note on the calculation of the point estimates presented in the tables below is warranted. Each point estimate of ~~avoided incidences presented~~monetary benefits in the tables below is the mean of a ~~Latin Hypercube approximation of a~~ distribution of ~~avoided incidences reflecting the uncertainty in~~

~~the pollutant coefficient in the C-R function~~monetary benefits derived through a Monte Carlo procedure[2]. ~~The Latin Hypercube method selects 100 percentile points (in this case, the (n-0.5)th percentile points of the distribution, for n = 1, 2, ..., 100) to represent the distribution. Each point estimate of monetary benefits in the tables below is the mean of a distribution of monetary benefits derived through a Monte Carlo procedure, using a distribution of unit dollar values and the Latin Hypercube distribution of avoided incidences.~~ The estimate derived by this method approaches the simple product of the mean of the unit dollar distribution and the mean of the incidence change distribution, but for a finite number of iterations may be slightly off. For an illustrative example of the procedure and for further details, see Appendix A and the technical support document for this RIA (Abt Associates, 1998a).

For ozone, three health effects are selected for inclusion: mortality associated with short-term exposure, hospital admissions for all respiratory diseases, and acute respiratory symptoms. One other human health-related effect, decreased worker productivity, is included as a welfare effect rather than a health effect (see Section 4.3.4). The ozone-related effect categories that are included in the NOx SIP call analysis are shown in Table 4-5. Premature mortality is the only ozone-related endpoint for which a range of benefits is presented.

Although the primary environmental purpose of the NOx SIP call is to help achieve attainment of the ozone NAAQS in the eastern United States, significant monetary benefits will also be associated with changes in ambient levels of PM. Several PM health endpoints are included in the quantified benefits estimation. The PM-related effect categories that are included in this analysis are shown in Table 4-6. For all of the PM-related endpoints, benefits are estimated using both the RADM-RPM and S-R Matrix generated PM concentrations. In addition, for health endpoints, benefits are estimated under both a background threshold assumption and an assumed threshold of 15 $\mu g/m^3$.

Table 4-5
Quantified Ozone-Related Health Effects Included in the Benefits Analysis

Health Effect	Affected Population	Study
Mortality		
Ozone-related short-term exposure mortality	all ages	pooled analysis of 4 U.S. studies
Hospital Admissions		
"All Respiratory"	all ages	Thurston et al., 1992
Respiratory Symptoms/Illnesses Not Requiring Hospitalization		
Acute respiratory symptoms (any of 19)	ages 18-65	Krupnick et al., 1990

[2] Each point estimate of avoided incidences presented in the tables below is the mean of a Latin Hypercube approximation of a distribution of avoided incidences reflecting the uncertainty in the pollutant coefficient in the C-R function. In the Latin Hypercube method 100 percentile points (in this case, the (n-0.5)th percentile points of the distribution, for n = 1, 2, ..., 100) are selected to represent the distribution. This reduces the computational burden associated with preserving the full distribution.

solicit WTP information from subjects; the rest are wage-risk studies, which base WTP estimates on estimates of the additional compensation demanded in the labor market for riskier jobs. The 26 studies used to form the distribution of the value of a statistical life are listed in Table 4-7.

There are two types of exposure to elevated levels of air polluation that may result in premature mortality. Acute (short-term) exposure (e.g., exposure on a given day) to peak pollutant concentrations may result in excess mortality on the same day or within a few days of the elevated exposure. Chronic (long-term) exposure (e.g., exposure over a period of a year or more) to levels of pollution that are generally higher may result in mortality in excess of what it would be if pollution levels were generally lower. The excess mortality that occurs will not necessarily be associated with any particular episode of elevated air pollution levels. Both types of effects are biologically plausible, and there is an increasing body of consistent corroborating evidence from animal toxicity studies indicating that both types of effects exist.

There are, similarly, two basic types of epidemiological studies of the relationship between mortality and exposure to pollutants. Long-term studies (e.g., Pope et al., 1995) estimate the association between long-term (chronic) exposure to air pollution and the survival of members of a large study population over an extended period of time. Such studies examine the health endpoint of concern in relation to the general long-term level of the pollutant of concern -- for example, relating annual mortality to some measure of annual pollutant level. Daily peak concentrations would impact the results only insofar as they affect the measure of long-term (e.g., annual) pollutant concentration. In contrast, short-term studies relate daily levels of the pollutant to daily mortality. By their basic design, daily studies can detect acute effects but cannot detect the effects of long-term exposures. A chronic exposure study design (a prospective cohort study, such as the Pope study) is best able to identify the long-term exposure effects, and will likely detect some of the short-term exposure effects as well. Because a long-term exposure study may detect some of the same short-term exposure effects detected by short-term studies, including both types of study in a benefit analysis would likely result in some degree of double counting of benefits.

Another major advantage of the long-term study design concerns the issue of the degree of prematurity of mortality associated with air pollution. It is possible that the short-term studies are detecting an association between air pollution and mortality that is primarily occurring among terminally ill people. Critics of the use of short-term studies for policy analysis purposes correctly point out that an added risk factor that results in a terminally ill person dying a few days or weeks earlier than they otherwise would have (known as "short-term harvesting") is potentially included in the measured air pollutant mortality "signal" detected in such a study. As the short-term study design does not examine individual people (it examines daily mortality rates in large populations, typically a large city population), it is impossible to know anything about the overall health status of the specific population that is detected as dying early. While some of the detected excess deaths may have resulted in a substantial loss of life (measuring loss of life in terms of lost years of remaining life), others may have lost a relatively short amount of lifespan.

While the long-term study design is preferred, these types of studies are expensive to conduct and consequently there are relatively few well designed long-term studies. For PM, there has only been one high quality study accepted by the Science Advisory Board, and for ozone, no acceptable long-term studies have been published. For this reason, short-term ozone mortality is used as the basis for determining ozone-related mortality benefits for the NOx SIP call.

~~balanced~~An alternative approach ~~may be~~is to ~~provide a high estimate based on~~conduct a meta-analysis which ~~assumes that~~includes only studies which find a statistically significant relationship between ozone concentrations and premature mortality ~~should be used in constructing an estimate of avoided ozone-related mortality incidences~~. This approach is based on the idea that if the existence of an ozone-mortality relationship is accepted, then the goal is to find the appropriate concentration-response function, given that a positive relationship exists. This may be a preferred approach when there is strong clinical data suggesting a relationship, but, due to data and statistical limitations, epidemiological stuides have had difficulty isolating an effect. The practical implication of this assumption is that one of the four studies used in the meta-analysis is dropped from the analysis. Table 4-9 presents the estimated avoided incidences and monetary benefits using the significant study only meta-analysis. Estimated monetary benefits are between 45 and 47 percent higher than those obtained using the full meta-analysis, dependent on the regulatory alternative.

Table 4-9

Sensitivity Analysis: Avoided Ozone-related Mortality Incidences and Monetary Benefits Associated with the NOx SIP Call -- Significant Studies Only[a]

Regulatory Alternative	Avoided Incidences (cases/year)	Monetary Benefits (millions 1990$)
0.12 Trading	460	$2,195
0.15 Trading	408	$1,947
Regionality 1	365	$1,725
0.20 Trading	341	$1,627
0.25 Trading	254	$1,211

[a] Annual baseline incidence for non-accidental deaths in the general population for all ages is 803/100,000. Total annual baseline incidence for the NOx SIP call region is 1,768,014 non-accidental deaths.

PM-related Mortality

PM-associated mortality in the benefits analysis is estimated using the $PM_{2.5}$ relationship from Pope et al., 1995. This decision reflects the Science Advisory Board's explicit recommendation for modeling the mortality effects of PM in both the completed §812 Retrospective Report to Congress and the ongoing §812 Prospective Study. The Pope study estimates the association between long-term (chronic) exposure to $PM_{2.5}$ and the survival of members of a large study population. This relationship is selected for use in the benefits analysis instead of short-term (daily pollution) studies for a number of reasons.

The Pope long-term study is selected as providing the best available estimate of the relationship between PM and mortality. ~~There are two types of exposure to elevated levels of PM that may result in premature mortality. Acute (short-term) exposure (e.g., exposure on a given day) to peak PM concentrations may result in excess mortality on the same day or within a few days of the elevated PM exposure. Chronic (long-term) exposure (e.g., exposure over a period of a year or more) to levels of PM that are generally higher may result in mortality in excess of what it would be if PM levels were generally lower. The excess mortality that occurs will not necessarily be associated with any particular episode of elevated air pollution levels.~~

~~Both types of effects are biologically plausible, and there is an increasing body of consistent corroborating evidence from animal toxicity studies indicating that both types of effects exist.~~

~~There are, similarly, two basic types of epidemiological studies of the relationship between mortality and exposure to PM. Long-term studies (e.g., Pope et al., 1995) estimate the association between long-term (chronic) exposure to PM and the survival of members of a large study population over an extended period of time. Such studies examine the health endpoint of concern in relation to the general long-term level of the pollutant of concern -- for example, relating annual mortality to some measure of annual pollutant level. Daily peak concentrations would impact the results only insofar as they affect the measure of long-term (e.g., annual) pollutant concentration. In contrast, short-term studies relate daily levels of the pollutant to daily mortality. By their basic design, daily studies can detect acute effects but cannot detect the effects of long-term exposures. A chronic exposure study design (a prospective cohort study, such as the Pope study) is best able to identify the long-term exposure effects, and will likely detect some of the short-term exposure effects as well. Because a long-term exposure study may detect some of the same short-term exposure effects detected by short-term studies, including both types of study in a benefit analysis would likely result in some degree of double counting of benefits.~~

~~Another major advantage of the long-term study design concerns the issue of the degree of prematurity of mortality associated with PM. It is possible that the short-term studies are detecting an association between PM and mortality that is primarily occurring among terminally ill people. Critics of the use of short-term studies for policy analysis purposes correctly point out that an added risk factor that results in a terminally ill person dying a few days or weeks earlier than they otherwise would have (known as "short-term harvesting") is potentially included in the measured PM mortality "signal" detected in such a study. As the short-term study design does not examine individual people (it examines daily mortality rates in large populations, typically a large city population), it is impossible to know anything about the overall health status of the specific population that is detected as dying early. While some of the detected excess deaths may have resulted in a substantial loss of life (measuring loss of life in terms of lost years of remaining life), others may have lost a relatively short amount of lifespan.~~

~~It is much less likely that the excess mortality reported by Pope et al., 1995, whose study is based on a prospective cohort design, contains any significant amount of this short-term harvesting.~~ It is used alone, rather than considering the total effect to be the sum of estimated short-term and long-term effects, because summing creates the possibility of double-counting a portion of total mortality. The Pope study is selected in preference to other available long-term studies because it uses the best methods (i.e., a prospective cohort method with a Cox proportional hazard model), and has a much larger cohort population, the longest exposure interval, and more locations (51 cities) in the United States, than other studies. It is unlikely that the Pope study contains any significant amount of short-term harvesting. First, the health status of each individual tracked in the study is known at the beginning of the study period. Persons with known pre-existing serious illnesses were excluded from the study population. Second, the Cox proportional hazard statistical model used in the Pope study examines the question of survivability throughout the study period (10 years). Deaths that are premature by only a few days or weeks within the 10-year study period (for example, the deaths of terminally ill patients, triggered by a short duration PM episode) are likely to have little impact on the calculation of the average probability of surviving the entire 10 year interval.

~~The Pope long-term study is selected as providing the best available estimate of the relationship between PM and mortality. It is used alone, rather than considering the total effect to be the sum of estimated short-term and long-term effects, because summing creates the possibility of double-counting a portion of total mortality. The Pope study is selected in preference to other available long-term studies because it uses the best methods (i.e., a prospective cohort method with a Cox proportional hazard model), and has a much larger cohort population, the longest exposure interval, and more locations (51 cities) in the United States, than other studies.~~ In relation to the other prospective cohort study (Dockery, et al., 1992, the "Six-cities" cohort study), the Pope study found a smaller increase in excess mortality for a given PM air quality change.

Table 4-10 presents point estimates of avoided incidences of long-term PM-related mortality and monetary benefits associated with the five regulatory alternatives for the NOx SIP call. As noted earlier, non-linearities inherent in the RADM-RPM air quality model lead to an inconsistent ranking of results between the RADM-RPM and S-R Matrix results. With the exception of the 0.12 trading alternative, estimated premature mortality incidences are higher for S-R Matrix generated PM changes than for RADM-RPM generated PM changes.

Table 4-10
Avoided Long Term PM-related Mortality Incidences and Monetary Benefits Associated with the NOx SIP call[a]

Regulatory Alternative	Avoided Incidences (cases/year)				Monetary Benefits (millions 1990$)			
	RADM-RPM		S-R Matrix		RADM-RPM		S-R Matrix	
	15 $\mu g/m^3$	Back ground	15 $\mu g/m^3$	Back ground	15 $\mu g/m^3$	Back ground	15 $\mu g/m^3$	Back ground
0.12 Trading	310	657	306	561	$1,468	$3,173	$1,459	$2,672
0.15 Trading	53	101	231	370	$251	$482	$1,099	$1,763
Regionality 1	67	94	190	278	$317	$459	$904	$1,326
0.20 Trading	78	149	216	315	$370	$715	$1,028	$1,499
0.25 Trading	44	75	202	294	$208	$358	$962	$1,400

[a] Annual baseline incidence for non-accidental deaths in the general population aged over 30 is 759/100,000. Total annual baseline incidence for the NOx SIP call region is 929,557 non-accidental deaths.

The estimates of excess mortality from the short-term studies are presented as an important sensitivity analysis. Because there is only one short-term study (presenting results from 6 separate U.S. cities) that uses $PM_{2.5}$ as the metric of PM (Schwartz et al., 1996), an estimate based on the pooled city-specific, short-term $PM_{2.5}$ results will be presented.

Table 4-11 presents the results of a sensitivity analysis using mortality associated with short-term exposure to $PM_{2.5}$. In some cases, the avoided incidences of mortality (and corresponding monetary benefits) predicted using the short-term function are higher than those predicted using the long-term function, and in other cases the reverse is true. For the RADM-RPM background threshold results, the magnitude of the difference between the value of avoided incidences of short- and long-term mortality ranges from $-1,539 million for the 0.12 trading alternative to $207 million for the Regionality 1 alternative. For the S-R Matrix background threshold results, the magnitude of the difference ranges from $-1,703 million for the 0.12 trading alternative to $-709 million for the Regionality 1 alternative. As with long-term mortality, the relationship between the RADM-RPM and S-R Matrix generated results is not consistent across alternatives, due to the differences in air chemistry modeling between the two models. In addition, the rank ordering across threshold levels is not consistent across alternatives.

Table 4-11
Sensitivity Analysis: Premature Mortality Benefits
Using Avoided Short Term PM-related Mortality Incidences[a]

Regulatory Alternative	Avoided Incidences (cases/year)				Monetary Benefits (millions 1990$)			
	RADM-RPM		S-R Matrix		RADM-RPM		S-R Matrix	
	15 μg/m³	Back ground	15 μg/m³	Back ground	15 μg/m³	Back ground	15 μg/m³	Back ground
0.12 Trading	293	339	136	203	$1,393	$1,634	$649	$969
0.15 Trading	130	128	110	152	$619	$615	$523	$726
Regionality 1	129	136	99	129	$614	$666	$473	$617
0.20 Trading	113	129	103	138	$536	$619	$493	$658
0.25 Trading	76	91	99	132	$360	$434	$473	$630

[a] Annual baseline incidence for non-accidental deaths in the general population is 803/100,000. Total annual baseline incidence for the NOx SIP call region is 1,768,014 non-accidental deaths for the population aged over 30.

A new study (Woodruff et al, 1997) finds a significant association between annual PM_{10} levels and post-neonatal (infants aged 28 - 51 weeks) mortality. Conceptually any additional mortality from this function would be additive to the Pope results (because the Pope function covers only the population over 30 years old), although not additive to the daily mortality studies (which cover all ages). The SAB recently advised the §812 Prospective project to not include this in the §812 primary analysis at this time, primarily because the study is of a new endpoint and the results have not been replicated in other studies in the U.S. The coherence and consistency arguments which support the use of the Pope study are not present with this study at this time. For the SIP call analysis, this endpoint will be presented as a sensitivity analysis. $PM_{2.5}$ changes associated with the NOx SIP call are used with this PM_{10} C-R function. This will produce a conservative estimate of infant mortality for two reasons. First, there may be some reductions in the coarse fraction (PM between 2.5 and 10 microns in diameter) that result from the NOx reductions which will be omitted from the analysis. Perhaps more importantly, estimating infant mortality using the estimated change in $PM_{2.5}$ levels in a PM_{10} function implicitly assumes that the fine fraction of PM is no more toxic than the coarse fraction. EPA's decision in 1997 to set an additional NAAQS using $PM_{2.5}$ in addition to a PM_{10} standard, is based in part on a growing scientific consensus that the fine fraction of the total PM_{10} mass is likely to be most associated with adverse health effects. If in fact the toxicity of $PM_{2.5}$ is greater than the toxicity of PM_{10}, then using changes in $PM_{2.5}$ in a C-R function based on PM_{10} will underestimate the total effect on infant mortality.

Table 4-12 presents a sensitivity analysis using neo-natal mortality. Monetary benefits associated with the avoided incidences are not presented due to a lack of information about the value of avoided neo-natal mortality. It is likely that avoided infant mortalities will be valued higher than mortalities for adults. However, at present, no studies have been conducted to determine this value. For this reason, only avoided incidences of neo-natal mortality are presented in Table 4-12.

Table 4-12

Sensitivity Analysis: Avoided Post Neo-natal PM-related Mortality Incidences

Regulatory Alternative	Avoided Incidences (cases/year)			
	RADM-RPM		S-R Matrix	
	15 μg/m³	Back ground	15 μg/m³	Back ground
0.12 Trading	5	5	2	2
0.15 Trading	2	2	2	2
Regionality 1	2	2	1	1
0.20 Trading	2	2	1	1
0.25 Trading	1	1	1	1

4.3.2 Hospital Admissions

An individual's WTP to avoid a hospital admission will include, at a minimum, the amount of money they pay for medical expenses (i.e., what they pay towards the hospital charge and the associated physician charge) and the loss in earnings. In addition, however, an individual is likely to be willing to pay some amount to avoid the pain and suffering associated with the illness itself. That is, even if they incurred no medical expenses and no loss in earnings, most individuals would still be willing to pay something to avoid the illness.

Because medical expenditures are to a significant extent shared by society, via medical insurance, Medicare, etc., the medical expenditures actually incurred by the individual are likely to be less than the total medical cost to society. The total value to society of an individual's avoidance of hospital admission, then, might be thought of as having two components: (1) the cost of illness (COI) to society, including the total

4.4.1 Commodity Agricultural Crops

The economic value associated with varying levels of yield loss for ozone-sensitive commodity crops is analyzed using a revised and updated Regional Model Farm (RMF) agricultural benefits model (Mathtech, 1998a). The RMF is an agricultural benefits model for commodity crops that account for about 75 percent of all U.S. sales of agricultural crops. The RMF explicitly incorporates exposure-response functions into microeconomic models of agricultural producer behavior. The model uses the theory of applied welfare economics to value changes in ambient ozone concentrations brought about by particular policy actions such as the NOx SIP call.

The measure of benefits calculated by the model is the net change in consumers' and producers' surplus from baseline ozone concentrations to the ozone concentrations resulting from attainment of alternative standards. Using the baseline and post-control equilibria, the model calculates the change in net consumers' and producers' surplus on a crop-by-crop basis[23]. Dollar values are aggregated across crops for each standard. The total dollar value represents a measure of the change in social welfare associated with the regulatory alternative. Although the model calculates benefits under three alternative welfare measures (perfect competition, price supports, and modified agricultural policy), results presented here are based on the "perfect competition" measure to reflect recent changes in agricultural subsidy programs. Under the recently revised 1996 Farm Bill , most eligible farmers have enrolled in the program to phase out government crop price supports for the RMF-relevant crops: wheat, corn, sorghum, and cotton.

For the purpose of this analysis, the six most economically significant crops are analyzed: corn, cotton, peanuts, sorghum, soybean, and winter wheat. The model employs biological exposure-response information derived from controlled experiments conducted by the National Crop Loss Assessment Network (NCLAN) (Lee et al., 1996). Four main areas of the RMF have been updated to reflect the 1996 Farm Bill and USDA data projections to 2005 (the year farthest into the future for which projections are available). These four areas are yield per acre, acres harvested, production costs, and model farms. Documentation outlining the 2005 update is provided in EPA, 1997a.

Table 4-22 presents estimates of monetary benefits due to changes in the production of all six commodity crops associated with the five regulatory alternatives for the NOx SIP call. Estimates for both most and least ozone sensitive crops are presented in Table 4-22. If information on ozone-sensitivity of cultivars is available and farmers are responsive to this information, then crop losses will be reduced. However, ozone responsiveness is not well publicized, and, given the numerous other factors affecting crop yields, it would be very difficult for individual farmers to determine a direct relationship between increased ozone and decreased crop yields.

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[3] Agricultural benefits differ from other health and welfare endpoints in the length of the assumed ozone season. For agriculture, the ozone season is assumed to extend from April to September. This assumption is made to ensure proper calculation of the ozone statistic used in the exposure-response functions. The only crop affected by changes in ozone during April is winter wheat.

Table 4-24 presents estimates of monetary benefits of yield changes of commercial forests associated with the five policy alternatives for the NOx SIP call. EPA did not estimate monetary benefits for all policy alternatives. Benefits for excluded alternatives can be easily estimated using a ratio of estimated benefits to a similar benefit category, such as commodity crops. Benefits for the 0.25 trading and Regionality 1 alternatives are estimated by applying the ratio of forestry to agricultural benefits for the 0.15 trading alternative, equal to 0.59, to the agricultural benefits for these two alternatives.

Because of the long harvesting cycle of commercial forests and the cumulative effects of higher growth rates, the benefits to the future economy will be much larger than the estimates reported in Table 4-24. For example, the 0.12 trading policy alternative would result in about $8.0 billion additional forest inventories by 2040. The estimated annualized benefits for this alternative, $233 million, are much lower because of smaller benefits in earlier years (i.e., the 2010 and 2020 decades) and because the higher benefits realized in later years are heavily discounted.

Table 4-24

Commercial Forest Monetary Benefits Associated with the NOx SIP Call

Regulatory Alternative	Monetary Benefits (millions 1990$)
0.12 Trading	$233
0.15 Trading	$213
Regionality 1	$188
0.20 Trading	$185
0.25 Trading	$143

4.4.3 Nitrogen Deposition

Excess nutrient loads, especially that of nitrogen, are responsible for a variety of adverse consequences to the health of estuarine and coastal waters. These effects include toxic and/or noxious algal blooms such as brown and red tides, low (hypoxic) or zero (anoxic) concentrations of dissolved oxygen in bottom waters, the loss of submerged aquatic vegetation due to the light-filtering effect of thick algal mats, and fundamental shifts in phytoplankton community structure.

Direct concentration-response functions relating deposited nitrogen and reductions in estuarine benefits are not available. Instead of the preferred willingness-to-pay based measure of benefits, which depends on the availability of a concentration-response function, an avoided cost approach is used to generate estuary related benefits of the NOx SIP call.

while avoided costs is only a proxy for benefits, and should be viewed as inferior to willingness-to-pay based measures, it is preferred to excluding any quantitative estimate of benefits for this category. Current research is underway to develop other approaches for valuing estuarine benefits, including contingent valuation and hedonic property studies. However, this research is still sparse, and does not contain sufficient information on the marginal willingness-to-pay for changes in concentrations of nitrogen (or changes in water quality or water resources as a result of changes in nitrogen concentrations). As more studies become available, more complete estimates of the commercial and ecological benefits of reduced atmospheric deposition of nitrogen can be incorporated into regulatory analyses.

The fixed capital costs for non-point controls in the case study estuaries is ranged from $0.61 to $45.27 per pound for agricultural and other rural best management practices and from $35 to $142.64 per pound for urban nonpoint source controls (stormwater controls, reservoir management, onsite disposal system changes, onsite BMPs). Using these as a base, the total fixed capital cost per pound (weighted on the basis of fractional relationship of nitrogen load controlled for the estuary goal) is calculated for each of the case-study estuaries and applied in the valuation of their avoided nitrogen load controlled. The weighted capital costs per pound for the case-study estuaries are $32.88 for Albemarle-Pamlico Sounds, $22.31 for Chesapeake Bay, and $88.25 for Tampa Bay[4]. For the other nine estuaries, an average capital cost per pound of nitrogen (from the three case-estuaries) of $47.65/lb ($105/kg) is calculated and applied; this cost may understate or overstate the costs associated with reductions in these other estuaries. The other nine estuaries generally represent smaller, more urban estuaries (like Tampa Bay), which typically have fewer technical and financial options available to control nitrogen loadings from nonpoint sources. This may result in higher control costs more similar to the Tampa Bay case. On the other hand, these estuaries may have opportunities to achieve additional point source controls at a lower costs. Also, increased public awareness of nutrification issues and technological innovation may, in the future, result in States finding lower cost solutions to nitrogen removal.

The 12 estuaries directly analyzed represent approximately 48% of the estuarine watershed area along the East Coast (there are 43 East Coast estuaries of which 10 were in the sample, and 31 Gulf of Mexico estuaries of which 2 are in the sample). Because NOAA data indicate that approximately 89% (92.6% by watershed area plus surface area) of East Coast estuaries are highly or moderately nutrient sensitive, it is reasonable to expect that estuaries not included in this analysis would also benefit from reduced deposition of atmospheric nitrogen. Total benefits from the 12 representative estuaries are scaled-up to include the remainder of the nutrient sensitive estuaries along the East Coast (92.6% of all East Coast estuaries) on the basis of estuary watershed plus water surface area. Since the 12 representative estuaries account for 48 percent of total eastern estuarine area, estimates are scaled up by multiplying the estimate for the 12 estuaries by 2.083 and then taking 92.6 percent of this estimate to adjust for nutrient sensitivity.

All capital cost estimates are then annualized based on a 7% discount rate and a typical implementation horizon for control strategies. Based on information from the three case study estuaries, this typically ranges from 5 to 10 years. EPA has used a midpoint 7.5 years for annualization, which yields an annualization factor is 0.1759. Non-capital installation costs and annual operating and maintenance costs are not included in these annual cost estimates. Depending upon the control strategy, these costs can be

[4] The value for Tampa Bay is not a true weighted cost per pound, but a midpoint of a range of $58.54 to $117.65 developed by Apogee Research for the control possibilities (mostly urban BMPs) in the Tampa Bay estuary.

Recreational Visibility

The value of visibility improvements in certain National Parks in the Southeast is based on the results of a 1990 Cooperative Agreement project jointly funded by the EPA and the National Park Service, "Preservation Values For Visibility Protection at the National Parks". Based on that contingent valuation study of visibility improvements, Chestnut (1997) calculates a household willingness to pay (WTP) for visibility improvements, capturing both use and non-use recreational values, and accounts for geographic variations in the willingness to pay. This method was used in the PM and ozone NAAQS RIA analysis, and is adopted for the SIP call benefits analysis.

The Preservation Values study examined the demand for visibility in three broad regions of the country, but only the Southeast region is directly relevant for the SIP call. ~~Within~~ Respondents both inside and outside the Southeast region~~, the Preservation Values study~~ were asked ~~respondents for~~ their willingness to pay to protect visibility at four National Parks in the region: Shenandoah, Mammoth Cave, Great Smoky Mountains, and Everglades National Parks. Photos from Shenandoah (the "indicator park" in the Southeast region) were provided as part of the survey instrument. Respondents were first asked for their value for preserving "only visibility at National Parks in the Southeast". They were later asked to state what portion of their stated total value was for visibility at the indicator park alone. Prior to providing their values, respondents were instructed that "These questions concern only visibility at national parks in the Southeast and assume there will be no change in visibility at national parks in other regions. Other households are being asked about visibility, human health and vegetation protection in urban areas and at national parks in other regions". Therefore, the estimated valuation functions for the Southeastern National Parks are specifically designed to be in addition to any value for urban visibility. Note that the total value of recreational visibility improvements in Southeastern National Parks is the sum of the value for indicator and non-indicator parks. The high Southeast recreational visibility estimate applies the ~~Southeastern~~ "in-region" value ~~to all Southeastern populations~~for Southeastern visibility changes to the total population inside the Southeastern region, and the ~~Southeastern~~ "out-of-region" value for Southeastern visibility changes to all other populations in the U.S. The total in-region WTP per household is $6.50 per deciview change, while the total out-of-region WTP per household is $4 per deciview change.

To take into account the possibility that the study did not fully account for double-counting, the low Southeast recreational visibility estimate will apply values of non-Southeast residents for Southeastern National Parks to populations both in and out of the Southeast region. The out-of-region value should not include any value for improved residential visibility, because non-Southeast residents, by definition, live outside the region, and thus are not included in the Southeast residential visibility calculation.

Table 4-28 presents estimates of monetary benefits arising improvements in recreational visibility due to reductions in PM associated with the five regulatory alternatives for the NOx SIP call. Table 4-28 includes both unadjusted visibility values and values adjusted based on the average adjustment factor of 0.82 for the RADM-RPM set. As described in the beginning of this section, recreational visibility results generated using the S-R Matrix do not need to be adjusted.

4.6.1 Projected Income Growth

This analysis does not attempt to adjust benefits estimates to reflect expected growth in real income. Economic theory argues, however, that WTP for most goods (such as environmental protection) will increase if real incomes increase. The degree to which WTP may increase for the specific health and welfare benefits provided by the NOx SIP call cannot be estimated due to insufficient income elasticity information. Thus, all else being equal, the benefit estimates presented in this analysis are likely to be understated.

4.6.2 Unquantifiable Benefits

In considering the monetized benefits estimates, the reader should be aware that many limitations for conducting these analyses are mentioned throughout this RIA. One significant limitation of both the health and welfare benefits analyses is the inability to quantify many PM and ozone-induced adverse effects. Table 4-2 lists the categories of benefits that this analysis is able to quantify and those discussed only in a qualitative manner. In general, if it were possible to include the unquantified benefits categories in the total monetized benefits, the benefits estimates presented in this RIA would increase. Specific examples of unquantified benefits explored in more detail below include other human health effects, urban ornamentals, aesthetic injury to forests, nitrogen in drinking water, and brown clouds.

The benefits of reductions in a number of ozone- and PM-induced health effects have not been quantified due to the unavailability of concentration-response and/or economic valuation data. These effects include: reduced pulmonary function, morphological changes, altered host defense mechanisms, cancer, other chronic respiratory diseases, infant mortality, airway responsiveness, increased susceptibility to respiratory infection, pulmonary inflammation, acute inflammation and respiratory cell damage, and premature aging of the lungs.

In addition to the above non-monetized health benefits, there are a number of non-monetized welfare benefits of NOx emission controls from reduced adverse effects on vegetation, forests, and other natural ecosystems. The CAA and other statutes, through requirements to protect natural and ecological systems, indicate that these are scarce and highly valued resources. ~~In a recent attempt to estimate the "marginal" value (changes in quantity or quality) of ecosystem services, Costanza *et al.* (1997) state that policy decisions often give little weight to the value of ecosystem services because their value cannot be fully quantified or monetized in commercial market terms. Costanza *et al.* warn that "this neglect may ultimately compromise the sustainability of humans in the biosphere".~~ Lack of comprehensive information, insufficient valuation tools, and significant uncertainties result in understated welfare benefits estimates in this RIA. However, a number of expert biologists, ecologists, and economists (Costanza, 1997) argue that the benefits of protecting natural resources are enormous and increasing as ecosystems become more stressed and scarce in the future. ~~Just the value of the cultural services (i.e., aesthetics, artistic, educational, spiritual and scientific) may be considered infinite by some, albeit in the realm of moral considerations.~~ Additionally, agricultural, forest and ecological scientists (Heck, 1997) believe that vegetation appears to be more sensitive to ozone than humans and consequently, that damage is occurring to vegetation and natural resources at concentrations below the ozone NAAQS. Experts also believe that the effect of ozone on plants is both cumulative and long-term. The specific non-monetized benefits from reductions in ambient ozone concentrations would accrue from: decreased foliar injury; averted growth reduction of trees in natural forests; maintained integrity of forest