DEVELOPING LONG-TERM STRATEGIES FOR REGIONAL HAZE:

FINDINGS AND RECOMMENDATIONS OF THE VISIBILITY TASK FORCE

U.S. ENVIRONMENTAL PROTECTION AGENCY
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DEVELOPING LONG-TERM STRATEGIES FOR REGIONAL HAZE: FINDINGS AND RECOMMENDATIONS OF THE VISIBILITY TASK FORCE

INTRODUCTION

This report has been prepared by an interagency task force composed of professional staff members from a number of EPA offices, the National Park Service, the Forest Service, the Bureau of Land Management, the Department of Energy, the Tennessee Valley Authority, and the Department of Defense. The task force was established by EPA's Deputy Administrator in January 1984 to examine the issue of developing long-term strategies for visibility impairment from pollution-derived regional haze and to recommend a long-range (5-10 year) program to address it.

The task force report consists of this summary of findings and recommendations plus independent appendices covering the major subject areas listed below.

A. Characterization of current regional visibility conditions

B. Projecting future regional visibility

C. Visibility values and other criteria for evaluating alternative strategies

D. Alternative regulatory strategies

E. Research needs

F. Public comments to the task force

These appendices primarily reflect the perspectives and judgments of the individual authors and contributors listed on each appendix and have not undergone any formal peer-review process. They are not the official position of the agencies and offices represented on the task force. The task force also has prepared an interim research needs document (March 1984) and a Federal Register notice and supporting materials soliciting public comment on regional haze issues (November 1984). In addition, two draft contractor analyses have been prepared in support of the task force (SAI, 1984; SAI, 1985).

SUMMARY OF FINDINGS

Historically, visibility impairment has been among the most frequently reported effects of air pollution. The Clean Air Act of 1970 authorized protection of visibility generally through the ambient standards (Sections 108-110) and other programs intended to protect public welfare (Section 302h). In the 1977 amendments to the Act, Congress called for special protection of visibility in certain Federal lands such as national parks and wilderness areas under Sections 169A(a)(1) and 165, and established "as a national goal,

the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution."

It is useful to refer to two categories of visibility impairment: 1) visible plumes of smoke, dust, or colored gas that obscure the sky relatively near their source of emission, and 2) regional haze, which reduces visual range and the contrast of form, color, and texture and which can occur on a geographic scale ranging from a large urban area to multistate regions. In some transition cases, individual plumes or hazes can appear as bands or layers of discoloration.

Haze is the result of light scattering and absorption by particles (mostly fine particles smaller than 2.5 μm) and to a much lesser extent, by NO_2. The composition of haze particles varies with time and location but usually includes "secondary" particles (e.g., sulfate, nitrate, and organic species formed in the atmosphere from "precursor" gases including SO_2, NO_x, and VOC), carbonaceous materials (elemental carbon and some organics), condensed atmospheric water and other trace components. Important sources of hazes include natural sources (blue sky scatter, fog, dust, forest fires, volcanoes, sea spray, and biologic sources) and anthropogenic sources of sulfur oxides, particles, nitrogen oxides and volatile organics. Humidity and other meteorological variables have a major influence on the nature of pollution-derived haze. The long-range transport and atmospheric transformations of precursor gases and haze producing particles add substantially to the complexity of source receptor relationships.

State and local visibility regulations and the first phase of Section 169A visibility requirements (1980, 1984) have focused on readily identifiable sources of visible plumes. Decisions on programs for regional haze - both for class I areas and in the context of ambient air quality standards - have been deferred for several related reasons:

1. the complexities associated with multiple pollutants, long range transport, and atmospheric transformations;

2. the need for improved scientific and technical information; and

3. the absence of any coordinated examination of how regional haze programs might be integrated with current or future programs for related pollutants (e.g., SO_x, NO_x, PM, VOC) and problems (e.g., acidic deposition, regional oxidants).

Indeed, much remains to be learned about the origins and composition of regional haze, source receptor relationships, perception, and values through continued research. Nevertheless, a substantial body of data and analytical capability exists at present. When understood in light of the uncertainties, these can provide useful information on long-term approaches to regional haze problems. The following discussion outlines major findings in each of the key areas addressed by the task force. These findings form the basis for the recommendations that are presented in the concluding section.

Characterization of Current Regional Visibility Conditions and Historical Trends

Because active visibility monitoring networks have only recently been established, human observations of visibility at airports have been the main data used to examine the geographical distribution and trends in the intensity of regional haze. These data have recognized limitations, but are useful in distinguishing overall trends and geographical distributions. The airport data show a major difference between East and West with substantially higher visibilities in the Rocky Mountains and desert southwest (Figure 1). Analysis of trends from 1948 to the present show clear shifts in seasonal airport visibilities in various regions. In the northeast quadrant of the U.S., wintertime visibilities appear to have improved, while the intensity and areal extent of summertime regional hazes worsened from 1948 to 1972, with some improvement since 1972. In the Gulf Coast and South Atlantic States, visibility appears to have deteriorated in all seasons. Current median visibility (Figure 2) in the East ranges from 8 to 25 miles (13 to 40 km) with summer as the season of worst visibility. Based on the available information, anthropogenic particulate pollution appears to dominate eastern regional haze. Estimates of natural background visibility in the Appalachians range between 30 to 50 miles (50 to 80 kilometers), while actual summertime visibility tends to be 1/3 to 1/5 that distance (Trijonis, 1981; Ferman et al., 1981).

More detailed information on regional visibility in the West, derived mostly from the National Park Service network, is displayed in Figure 3. Present day visibilities in some areas of the West often approach the theoretical limits set by air molecules, corresponding to a visual range on the order of 400 km (240 miles). In such conditions, even small additions to regional fine particle loadings can result in a perceptible degradation of visibility. The airport data from 1948 through 1976 indicate mixed trends in the southwest with a general decrease from the early 1950's to the early 1970's and some improvement thereafter, especially in southern Arizona. In California, airport visibility declined in most areas from 1948 through 1966 and improved thereafter, but overall trends differed in various locations. Trends are also mixed in the Pacific Northwest and the Northern Plains.

A view of regional visibility conditions in class I areas is afforded by the preliminary subjective judgment of the Federal Land Managers response to a 1978 analysis (Figure 4). In that analysis, about one-third of the managers reported undesirable conditions and/or the need to evaluate suspected anthropogenic impacts, usually haze ascribed to various source mixes.

Sources of Haze and Projected Trends

Information on sources of visibility impairment comes from fine particle and visibility monitoring (Table 1), receptor modeling, emissions inventories, predictive models. Although current data do not permit precise quantitative conclusions, the major pollutants and sources involved in various regions can be identified. In the East, important sources of haze producing pollution include sulfur oxide emissions from utility and industrial coal and oil combustion; primary carbonaceous particles from these and other industrial sources, heating, automobiles and fires; and organic emissions from various sources. Because sulfates currently may account for 40 to 80% of regional haze in much of the East -- with less known about remaining fine particle

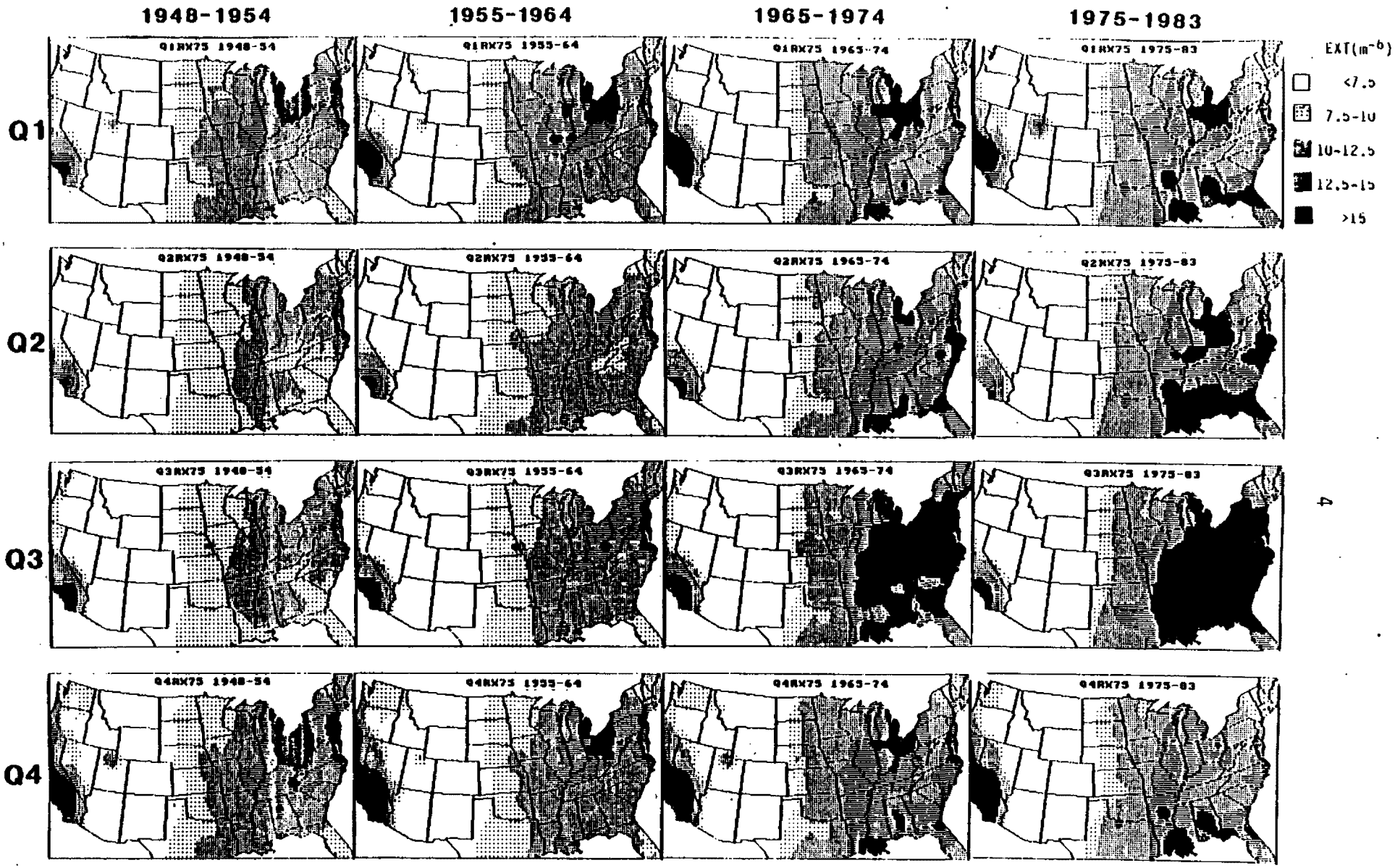

Figure 1. Geographical distribution and trends in U.S. haze (Husar, 1985). Data represent average light "extinction" coefficient (3.9/visual range) from airport observation, excluding precipitation events and adjusted for relative humidity and limitations in target distances. As adjusted, the measurements provide a fair picture of coarse spatial and temporal patterns of haze derived from anthropogenic and natural fine particles. A marked difference exists between east and west and among seasons. The summer season (Q3) currently shows the highest haziness (worst visibility) and also exhibits the largest declines. The scales chosen mask some trends, notedly a stabilization or modest improvement in some areas of the southeast and southwest from 1972 to date. In cool seasons the major trends are a marked increase in haze in the gulf coast states and some improvement in the northeast quadrant.

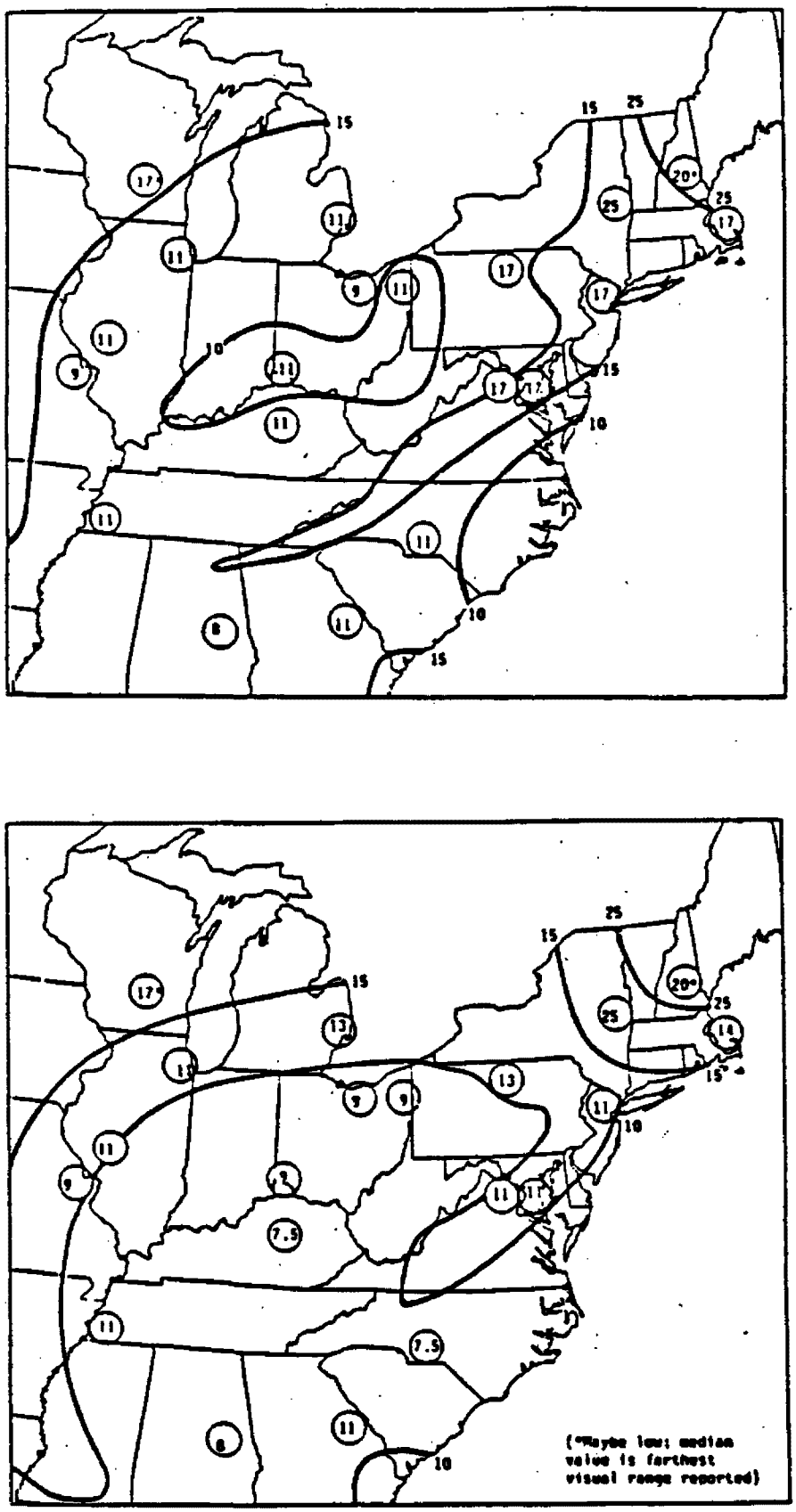

FIGURE 2. Observed median visibilities (miles) at selected airports for 1982 and historical isopleths (1974-76). Top Figure, annual median; Bottom Figure, summertime median (SAI, 1984).

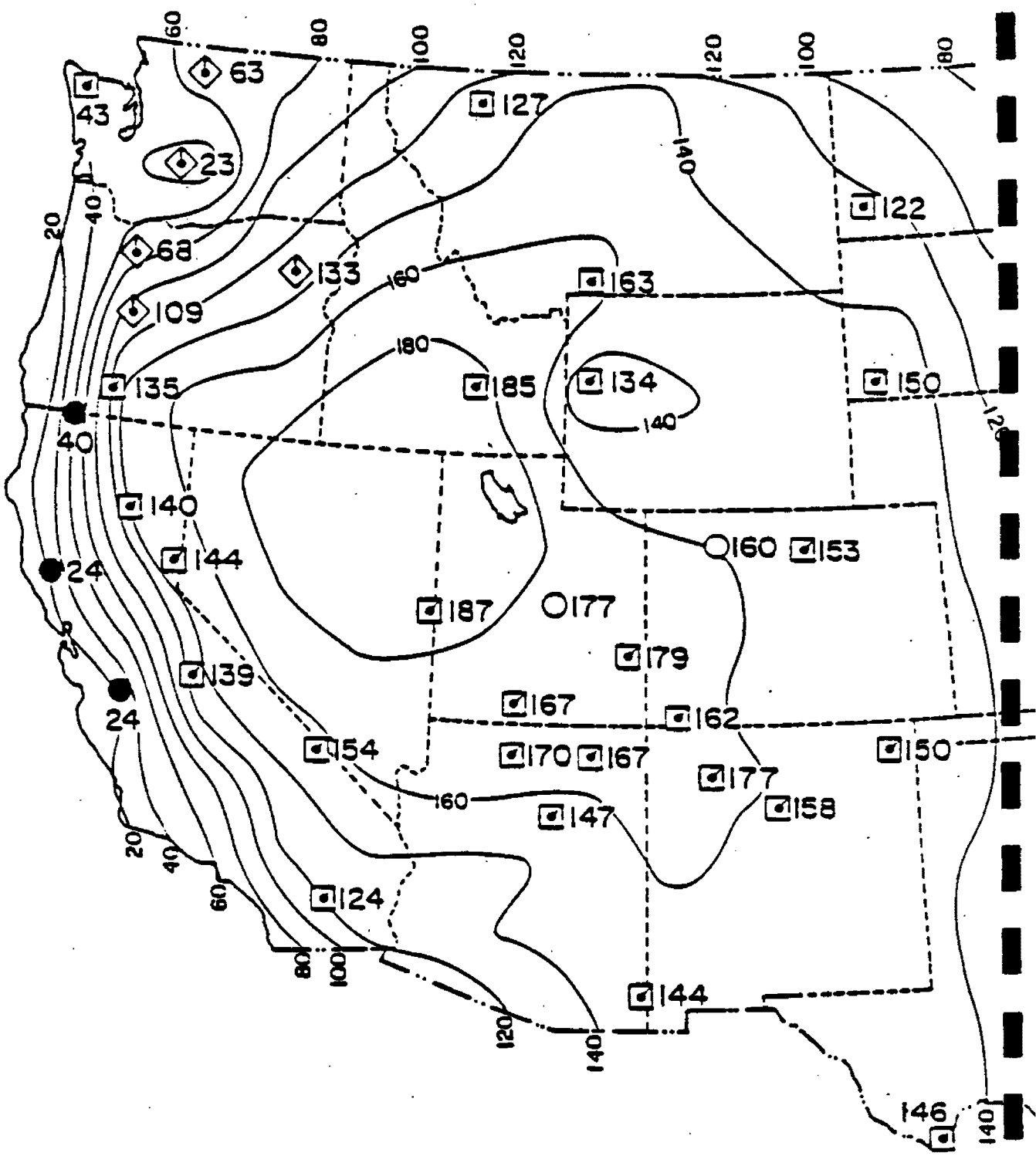

FIGURE 3. Isopleths of standard visual range (km) over the western United States for the summer of 1982. Squares reflect data from NPS, teleradiometer network. Circles reflect airport visibility readings by human observers (Malm et al., 1984).

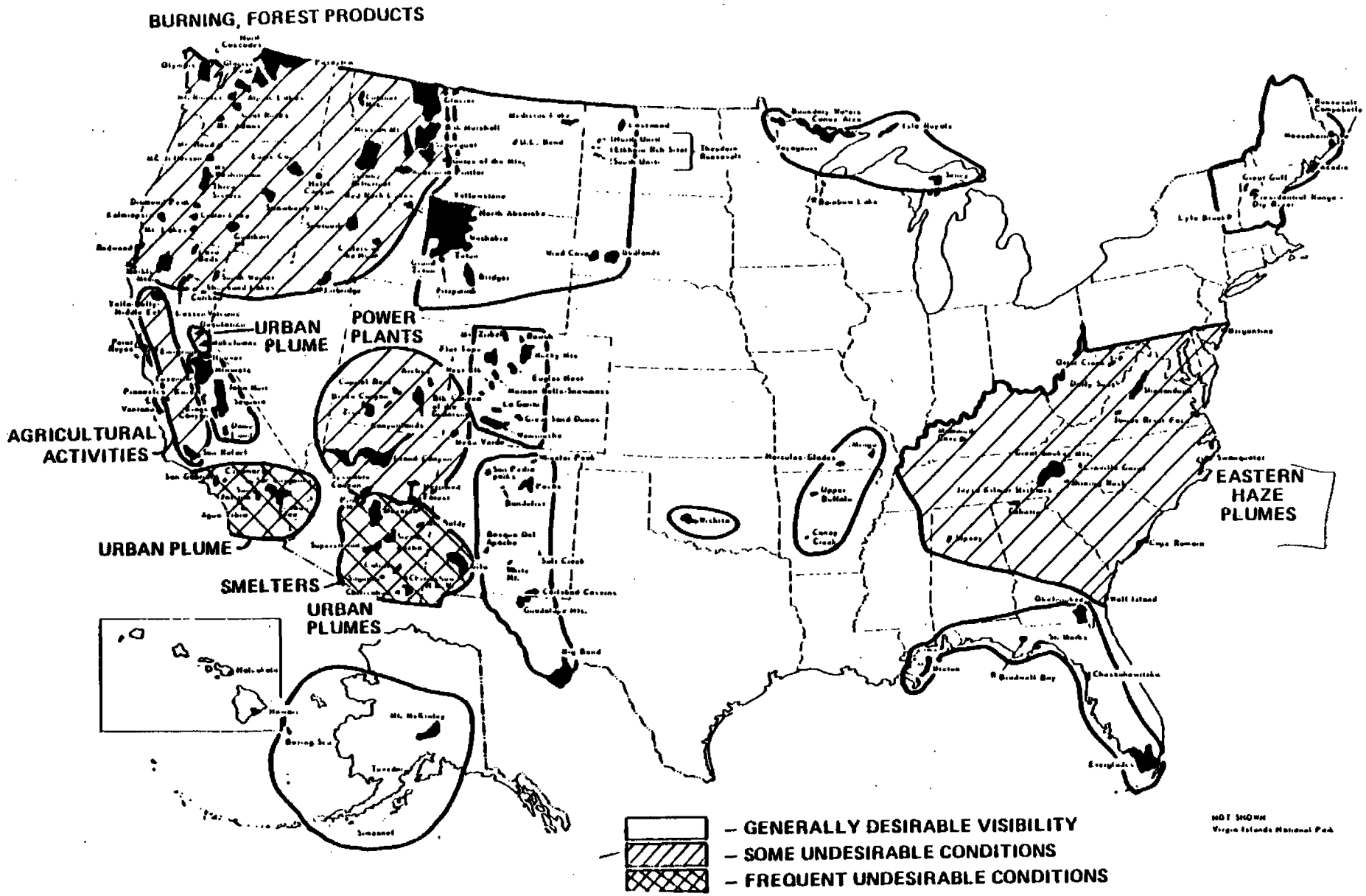

Figure 4. Preliminary class I area visibility status reported by Federal Land Managers (EPA, 1979). Synopsis of 150 visibility workbooks representing observations by individual managers of visibility impairment and their subjective judgments on the desirability and acceptibility of the existing conditions. Because the level of experience, perception, and criteria for judgment vary significantly, these results are preliminary. About 2/3 of the areas report "generally desirable" conditions, but few if any areas are free from anthropogenic influence. In areas with undesirable conditions, the major categories reported by the land managers are noted.

TABLE 1. HAZE (EXTINCTION) BUDGETS. Data derived from a variety of fine particle/visibility monitoring studies of varying methodology and reliability. Many represent short-term "snapshots;" more spatially and temporarily representative data are needed. Key implications are: 1) sulfates are the single most important contributor in the east, 2) in the west, organics, nitrates, and solid dust are relatively more important, 3) comparisons suggest the possibility of an unmeasured "volatile" aerosol that acts to inflate the apparent importance of sulfate, making apportionments uncertain, particularly in the west.

	Percent Contribution to Haze for:						
Location/Ref.	Sulfates[1]	Carbonaceous (Soot & Organics)	Nitrates	Soil Derived	NO_2	Blue Sky Scatter	Other (May Include Sever of the Listed Species No Measured)
East-Urban							
Detroit (Wolff et al, 1982)	62	20	NA	NA	NA	4	11
5 airport-regression (Trijonis and Yuan, 1978)	47	NA	1	NA	NA	NA	52
4 airport-regression (Leaderer and Stolwick, 1979)	68	NA	3	NA	NA	NA	28
East-Non Urban (summer)							
Shenandoah (Ferman et al, 1981)	78	13	-	-	-	5	4
Louisiana (Wolff et al, 1981)	82	NA	NA	NA	NA	NA	18
West-Urban							
Houston (Dzubay et al, 1982)	48	17-24	0.5	3	5	6	15
Denver (Hasan and Dzubay, 1982; Grublicki et al., 1981)	5-20	40-60	6-17	NA	6-9	6	6-21
Los Angeles (White and Roberts, 1977)	39	9	19	NA	NA	NA	33
West-Non Urban							
"Representative" (Appendix A)							
Regression	50-60	12	NA	20	NA	Not Included	16
Theoretical	33	19-30	NA	15	NA		20-40
4 Corners Region - 1 day (Macias et al., 1981)	28	10	2	16	-	44	-

[1]Includes cations and water.

mass -- and because of the relationship of regional sulfate loadings to the acid deposition phenomenon, the task force has placed most attention on projecting future trends and control options for regional sulfur oxide emissions.

Historical emissions analysis show that the long-term trend of increasing SO_x emissions was halted with the onset of Federal, state and local control programs in 1970-72 and that from 1974 to 1983, SO_2 emissions nationally declined by about 23% (EPA, 1984). Projected trends for emissions in 31 eastern States indicated that without further control, a modest (10%) increase in emissions is possible through 1995. Assuming no major changes in other haze related pollutants, this would probably lead to little overall change in eastern haze. Depending upon factors that are difficult to predict with confidence, in the long term future (2020 to 2030) substantial decreases in SO_x emissions might occur through improved new source controls and retirement of existing facilities. Implementation of potential acid deposition or other control programs could result in significant decreases sooner.

The draft contractor analysis of eastern visibility (SAI, 1984) used a regional air quality model (RTM-LT) to examine visibility impacts of alternative SO_x rollback scenarios, including several acid rain programs. Factors such as uncertainties in emission projections and treatment of important meteorological, transport, and transformation processes impose significant limits on the results. A detailed review of the study sponsored by the Utility Air Regulatory Group (UARG) suggests that the results may overstate visibility improvements. Comments from ORD task force members suggest components of the analysis may understate improvements. The analysis is currently undergoing external peer review. The available results do suggest, however, that:

1. large (30 to 50%) reductions in SO_2 emissions in 31 eastern states could result in substantial improvements (15 to 33% or more) in annual and summertime visibility in large portions of the East;

2. smaller emissions reductions (e.g., $\leq$ 20%) spread over 31 states or more targeted acid deposition approaches are less likely to result in perceptible improvement over current baselines; and

3. simultaneous reductions in other visibility impairing pollutants (fine particles and possibly VOC and NO_x) might markedly improve the perceived effectiveness of SO_x reductions. Conversely, increases in such pollutants could negate some of the benefits associated with SO_x control.

In the West, important sources of regional haze vary with location but can include smelters, urban "plumes" consisting of particles derived from numerous area and point sources, energy development activities, fugitive dust, and controlled burning. Preliminary efforts to apportion sources by receptor and predictive modeling are in reasonably close agreement, but important uncertainties remain, particularly in identifying the importance of nitrates, organics, and carbon and identifying the relative influence of various source regions (Table 2). Under current regulatory programs, preliminary estimates indicate relatively modest growth through 1995 in total emissions in six southwestern states from these categories, with a potential substantial

TABLE 2. MODELED CONTRIBUTION BY POLLUTANT AND SOURCE CATEGORY TO ANNUAL AVERAGE ANTHROPOGENIC-DERIVED HAZE IN THE GRAND CANYON (SAI, 1985). Results illustrate model outputs. Although in rough agreement with empirical studies of anthropogenic source influence (Appendix A), such predictions are extremely uncertain. At relatively clean sites such as this, "blue sky" scatter by air molecules is larger than the average anthropogenic extinction.

	Percent (%) Contribution							
Source Category	SO4	NO3	ORG	Soot	Other PM-2.5	Coarse PM-10	NO2	Total
Utilities	6.9	7.9	0.0	0.0	1.1	0.1	1.5	17.5
Smelters	15.2	0.0	0.0	0.0	0.9	0.1	0.0	16.2
Oil Industry	10.2	1.3	0.0	0.0	0.1	0.0	0.2	11.7
Other Industrial	3.9	2.4	0.0	0.0	0.1	0.1	0.3	6.8
Residential/Comm	0.9	1.3	0.0	0.0	0.1	0.1	0.2	2.6
Gasoline Vehicles	1.1	6.9	0.3	0.6	0.6	0.4	0.8	10.7
Diesel Vehicles	1.3	4.4	0.1	0.8	0.1	0.0	0.5	7.3
Other Mobile	2.7	1.8	0.0	0.0	0.0	0.0	0.2	4.8
Evaporative	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Fugitive Dust	0.0	0.0	0.0	0.0	7.0	2.6	0.0	9.6
Pres Burns/F.F.	0.0	0.0	0.0	2.8	1.1	0.0	0.0	4.0
Wood Stoves/F.P.	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Extraregional Trans	8.5	0.0	0.0	0.0	0.0	0.0	0.0	8.5
TOTAL	50.7	25.9	0.8	4.3	11.0	3.6	3.6	100.0

decrease in U.S. smelter emissions (Pechan, 1985). The major near-term increase in emissions of concern to regional haze is from new smelter construction in Northern Mexico, but some growth is also projected in primary particle emissions from mobile and other area sources.

In addition to projecting emissions for this region, the draft study done for the task force used a regional model (RIVAD) to examine potential visibility impacts under a "base" and two alternative emissions growth scenarios (SAI, 1985). The preliminary nature of the modeling tools and large uncertanties in current and projected emissions, meteorological and other inputs, and treatment of dispersion, chemistry, and removal cannot be overemphasized. Nevertheless, the available results can provide useful insights. Figure 5 displays the change in regional visibility by 1995 predicted by this exercise under current regulatory programs. The analysis suggests that, with implementation of current programs and the expected low growth in energy development, no large decrements are likely in regional visibility in the southwest for the near term. In the longer-term future (2000 and beyond), however, continued population increases and growth in energy development offer the potential for more significant increases in visibility impairing pollution and more serious impacts on the regional visibility resource.

Value of Visibility

Regional haze can affect public welfare in essentially two areas: 1) the subjective enjoyment of the environment (aesthetics, general well being) and 2) transportation. Evidence of such effects can be drawn from studies of perception and social awareness of air pollution and scenic beauty, economic studies, and visibility/air transport relationships. Key examples are illustrated in Table 3. The available information indicates that the public is concerned about visibility and is willing to pay for maintaining or improving air quality in a variety of contexts. Our ability to calculate this value in comprehensive and reliable quantitative terms is, however, limited.

A number of economic studies of visibility values in urban and non-urban contexts have been examined in detail by the task force (Appendix C). These have been used to provide estimates of economic benefits associated with strategies that improve visibility (Table 4). They suggest that visibility benefits might pay for a substantial fraction of control costs, even in the East. Major uncertainties in such estimates must be considered. These derive from:

1) available survey approaches (contingent valuation) may provide biased estimates and cannot be verified for a non-market good like visibility;

2) competing claims for multiple public goods may lower estimated visibility values;

3) methods for extrapolation of results to small changes in average visibility, over time and consideration of the full temporal distribution of visibility changes are quite limited by current information on perception; and

4) options and existence values are not well understood.

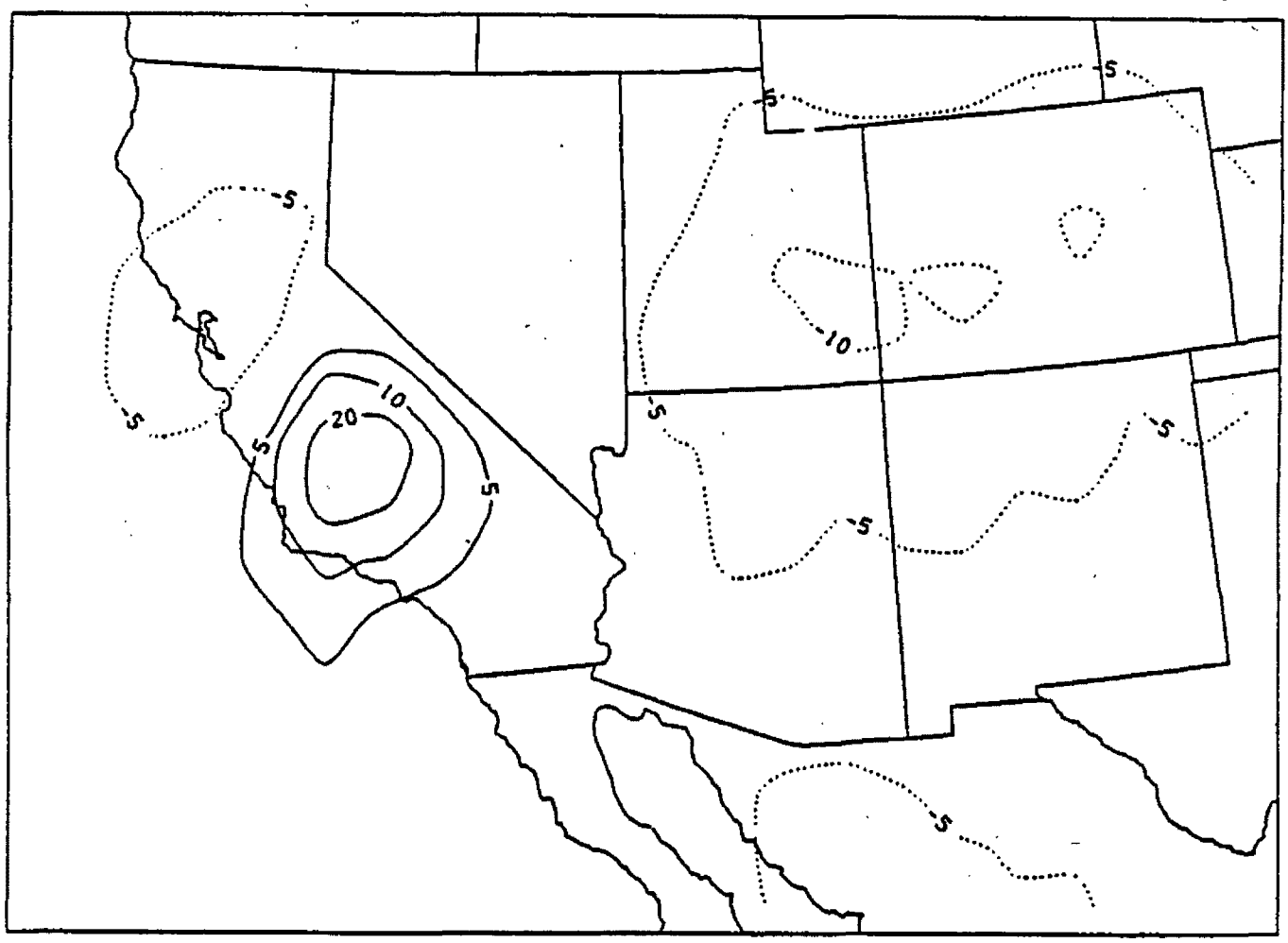

Figure 5. Percent change in modeled annual visual range from 1980 to 1995 (base scenario). The predictions suggest that with implementation of current programs as planned, regional visibility in 1995 will not be substantially different from current levels in most of the southwest. The estimates are, however, sensitive to uncertainties in emissions, transport and transformations meteorological data and other model related factors (SAI, 1985).

TABLE 3. SUMMARY OF QUALITATIVE EVIDENCE FOR VISIBILITY RELATED VALUES

	Effect of Increased Visibility	Affected Groups	Supporting Observation
Aesthetic:			
Perception	Decreased perception of air pollution		
	a) urban settings	Substantial percentage of general population; urban areas	Perception of air pollution in Los Angeles significantly related to visibility for all averaging times (Flachburt and Phillips, 1980) Perceived visual air quality significantly related to particle scattering (Middleton et al., 1984)
	b) natural settings	Outdoor recreationists, campers, tourists	Visual air quality related to awareness of haze for Grand Canyon visitors (Ross et al., 1984) Scenic Beauty estimates related to contrast transmittance (Malm et al., 1981)
	Improved view of night sky	Amateur astronomers, other star watchers	Decrease in star brightness by fine particles (Leonard et al., 1977)
Economic Studies	Increased property values	Home owners	Property values related to perception of air pollution, hence visibility (Brookshire et al., 1979; Thay and Trijonis, 1981 Lohman, et al., 1981)
	Enhanced enjoyment (user or activity values) of environment in:		
	a) urban settings	Urban dwellers	Willingness to pay for increased visibility in several eastern and western urban areas (Brookshire et al., 1979; Tolley et al., 1984; Rae, 1984)
	b) natural settings	Outdoor recreationists, campers, residents of non-urban areas	Willingness to pay for preservation, improvement and accept compensation for degradation in national parks (Rae et al., 1980; Rae et al., 1982)
	Options values; maintaining or increasing opportunity to visit less impaired natural and urban settings	Outdoor recreationists, campers, tourists	Aggregate of activity values in iterative bidding studies suggests importance of options values (Rowe and Chestnut, 1981)
	Existence values, maintaining pristine environments	General population	Existence values may far outweigh activity or user values (Rowe and Chestnut, 1981)
Psycho-logical Studies	Enhanced enjoyment in natural areas (user and options)	Outdoor recreationists, campers, tourists	Visual air quality attributes rank high among visitors to both Mesa Verde and Grand Canyon. Knowing park resources protected most valued psychological attribute (Ross et al., 1984)
	Less concern over perceived health effects	General population, urban areas	About 2/3 of bid for improved visibility in Los Angeles was related to concern over potential health effects (Brookshire et al., 1979)
Transporta-tion	More efficient, lower risk operations, visual approach permitted	Airport users, operators	Visual approaches permitted when visibility >3-5 miles; airport specific (FAA, 1980a)
	Increased opportunity to operate aircraft	General aviation aircraft (non-instrument capable pilots, aircraft)	Visual flight rules permitted when visibility >3 miles (FAA, 1980b)
	Increased opportunity to conduct aircraft and weapons testing	DOD testing facilities in Desert Southwest	Basis for location of facilities in part due to high visibility

TABLE 4. ECONOMIC VALUATION OF EASTERN HAZE REDUCTION (Appendix C)

4A. EASTERN URBAN SURVEYS (CONTINGENT VALUE STUDIES). Based on interviews of urban resident using photographs to depict large visibility changes. While subject to potential limitations and biases (see text), they are the best means for economic appraisal of some non-market environmental goods like visibility. Data used to fit exponential bid function for valuing smaller visibility changes in the control scenarios below.

Study	Change in Visual Range Valued (miles)	Willingness to Pay $/mile/yr/household
Chicago; six Cities (Atlanta, Boston, Cincinnai, Miami, Mobile, Washington) (Tolley et al., 1979)	10 to 5 (annual)	13-51 (avoid decrement)
	10 to 20 (annual)	6-26
	10 to 30 (annual)	4-17
Cincinnati (Rae, 1984)		
Survey 1	8 to 25 (most of time)	24-34
Survey 2	11.5 to 16.5 (most of time)	79-110

4B. ESTIMATES OF VISIBILITY BENEFITS ASSOCIATED WITH SO_2 CONTROL SCENARIOS. Even modest bids and changes in visual range can lead to substantial benefits estimates when aggregated over the urban population of 31 eastern states. Results for such changes are, however, highly sensitive to assumptions about the extent to which people can perceive such changes.

SO_x Scenario (ICF, 1984)	Annualized Costs (Billion $/yr)	Visibility Change[1]	Alternative Benefit Estimates (Billion $/yr)[2]			
			Low Bid + 15% "perception" threshold	Mean Bid; "perception" threshold 15%	5%	High Bid + No percepti threshold
10 State	1.7	5%	0	0	0.4	1.3
"8" million ton 31 State	3.7	11%	0.2	0.4	1.1	2.9
"12" million ton 31 State	9.2	16%	0.6	1.3	1.6	4.1

[1]Predicted annual increase in visual range averaged over 31 states based on regional modeling. May over (or under) estimate improvements.
[2]Low bid ($6/mile/household-yr) and mean bid ($12)based on Tolley et al., data. High bid ($40) from Rae. None include options or existence values. Alternative treatment of thresholds for the Utility Air Regulatory Group leads to substantially lower estimates than shown here (Zanetti et al., 1985; Rudd, 1985).

Alternative Control Strategies

In considering potential long-term regulatory strategies for regional haze, it is useful to treat the regional haze phenomena in the East and West separately. Regional haze characteristics, intensity, sources, and associated air quality problems are sufficiently different between West and East that distinct control program goals and approaches should be considered within each region. Furthermore, specific control approaches could be tailored for certain source categories, sub-regions, or urban areas in both East and West.

Given the complexity and variability of regional haze, both from a pollution and public perception standpoint, it is questionable whether any single regulatory approach will have the flexibility needed to provide efficient and effective control of regional haze. Rather a combination of approaches - - some designed specifically to protect visibility, some implemented to meet other air quality objectives - - may be more appropriate.

The task force examined a number of alternatives for limiting or reducing emissions of precursors of regional haze. The various approaches can be categorized into three classes with respect to legislative authorities:

1. those capable of being implemented using the existing legislative and regulatory authorities in the Clean Air Act;

2. those requiring modifications to existing legislative authorities; and

3. those that rely on addition of new legislative authorities.

The approaches also can be categorized according to environmental goals: 1) reduction of regional haze as a primary objective, 2) regional haze control as a partial or supplemental objective, or 3) reduction of some other adverse effect. The degree to which haze reduction is used to justify regulatory action, then, forms a second conceptualizing dimension.

These two categorizations are used to organize alternative strategies in Table 5. To the extent possible, each of the approaches listed within the matrix has undergone a preliminary qualitative examination with respect to appropriate criteria including cost-effectiveness, equity, ease of understanding, enforceability, flexibility, compatibility with existing air pollution control programs, and acceptability to affected parties (Appendix D). As noted above two major approaches - various SO_2 rollbacks and targeted acid deposition scenarios were examined more quantitatively in the contractor analyses.

Based on its examination of strategies as they might be applied to the somewhat distinct problems associated with regional haze in the East and the West, the task force offers the findings listed below.

1. Maintaining current regulatory programs will likely result in approximately the present level of episodic regional haze in the East

TABLE 5. MATRIX OF REGULATORY OPTIONS[1]

AUTHORITY	GOAL		
	I. Haze Principally	II. Haze Secondarily	III. Other Objectives
A. Existing	1) Secondary NAAQS - fine particles, sulfates, extinction, other 2) "Phase II" visibility programs-class I areas	1) PSD Requirements 2) Interstate Pollution Control 3) International Air Pollution 4) NSPS, BACT/LAER major source categories	1) Primary NAAQS PM, SO_2 2) Motor Vehicle Emissions Standards
B. Modified Existing	1) Codify integral vistas 2) Modifications to 169A 3) Modify PSD 4) State based programs	1) Modify Interstate Pollution Control 2) Regional Secondary NAAQS; NAAQS "Criteria" 3) Episode Control 4) Revised NSPS requirements 5) Requirements for "Nontraditional" Sources	1) Emissions trading 2) "Reasonable Effort" for SNAAQS 3) Modify PSD
C. New	1) Visibility Standards	1) SO_2 Rollback 2) Age Based Controls	1) Acid Rain

[1]Options are described and discussed in Appendix D.

through about 2030, with potential improvement thereafter. More rapid improvements would require regional reductions of SO_2 emissions.

2. The analysis of SO_2 control strategies suggests that the benefits of improved visibility estimated for SO_2 roll backs are uncertain, but might be substantial. Even at the higher end of the uncertainty range, however, they are unlikely to equal or exceed control costs by themselves. Some of the more "targeted" strategies designed to control acid-deposition produce visibility improvements that are limited in extent and magnitude. If accelerated reductions of SO_2 emissions are judged appropriate, the most effective long-term regulatory approach would be to develop cost-effective regional strategies designed to maximize all of the known and anticipated multiple environmental benefits of SO_2 control, including haze reduction. Implementation of such a strategy is best accomplished with new legislation.

3. Although less timely and more difficult to implement than a mandated control strategy, if it is decided that accelerated reduction of eastern haze is warranted, consideration should be given to developing a fine particle SNAAQS. Outside groups may attempt to force action on such a standard in any case, and in the absence of new legislation mandating regional SO_2 reduction, a standard could guide long-term sulfur oxides and other control programs by establishing an acceptable target. Some modifications to current Clean Air Act authorities might improve the design and implementation of SNAAQS for fine particles, especially if haze control is the major objective.

4. A supplemental (or alternative) long-term strategy for reducing SO_2 is control of sources based after a defined source life-time. This could act to ensure and accelerate reductions projected from retirement (or control) of higher emitting existing sources and their replacement with cleaner new facilities.

5. Protection of western visibility may be effected well enough without new legislation. Assuming implementation of current regulatory programs, the western analyses suggests that delaying development of new regional haze programs for several years while awaiting improved source-receptor information would probably not result in unacceptable or irreversible degradation. As new research results improve our ability to predict regional impacts of emission source limitations, "phase II" regulations can be developed under the existing section 169A. Protecting visibility in class I areas while implementing existing NAAQS, PSD, and mobile source controls will provide substantial protection against impairment from haze throughout the West.

Public Comments

Oral comments were received from interested parties at two public meetings and written comments were also submitted in response to a Federal Register notice (Appendix F). The meetings were well attended and the discussion, particularly at the Denver meeting, was informative and productive.

Among the points made by various commenters are the following:

1. A concensus exists among industry and environmental groups that EPA should expand research on regional haze and facilitate coordination among public and private sector research.

2. A consensus also exists on the desirability of integrating visibility programs with other air quality management programs and evaluating multiple benefits of particular strategies.

3. With respect to western visibility, environmental, industry, and state groups commented that the principal focus for the Federal program should be on protecting visibility in class I areas. In this regard commenters also generally agree that Section 169A does not have to be amended to deal with haze. Commenters also indicate the need for additional guidance under current regulations with respect to modeling, monitoring, and determination of "adverse" impacts.

4. With respect to Eastern visibility, environmental groups prefer legislative amendments that would effect regional haze reductions, but continue to recommend use of current authorities in the near future. Industry feels more research is needed to determine whether the public is dissatisfied with current visibility and whether SO_2 controls would result in visibility improvements of significant value.

RECOMMENDATIONS

Based on the findings from its examination of relevant data and analysis the task force makes recommendations in three areas relevant to a long-term program for developing strategies for regional haze:

1. Research,

2. Policy Analysis, and

3. Regulations and Legislation.

Research Needs

The first major examination of interagency visibility strategies and information needs was presented in the 1979 report to Congress (EPA, 1979). Progress has been made, but significant opportunities were lost by subsequent reductions in EPA's visibility research program. The Park Service, Department of Defense and industry groups have all mounted various programs, but all cite the need to restore EPA to a leadership role in visibility research. The reduction of uncertainties in a number of key areas, particularly in modeling, perception and values, is the highest priority for the development and implementation of credible long-term strategies for regional haze. Although the Task Force recognizes that visibility is not the highest EPA research priority, it is nevertheless important to restore at least a moderate program that takes maximum advantage of coordination with other visibility and related research programs. The task force therefore recommends:

1. EPA should establish and maintain a visibility research coordination function that involves other Federal agencies, private sector sponsors of research, and environmental groups. It appears feasible to establish such a function under the auspices of the Science Advisory Board. Visibility

work should also be closely coordinated with related programs, particularly acidic deposition.

2. EPA should maintain or encourage research in the following areas:

   i) studies of human perception and improved indices of visibility;

   ii) development of improved monitoring;

   iii) characterization of current regional visibility conditions and pollutant/visibility relationships in representative regions;

   iv) investigation of important source categories of visibility impairment;

   v) improvement of emissions inventories and models for predicting visibility impacts; and

   vi) studies on the value of visibility.

These general needs are discussed in Appendix E. Near-term research priorities for EPA budget planning are more fully documented in the interim needs statement and have already been factored into FY-85 and FY-86 budget planning.

3. EPA, in cooperation with other groups, should provide a periodic summary of current information in these key areas for research planners and for policy makers. This function could be accomplished in association with the research coordination work.

Policy Analyses

Current understanding of regional haze, values, and source-receptor relationships permits the identification and some analysis of alternative emission control approaches and regulatory strategies. Nevertheless, important information gaps remain. This state of knowledge suggests the following approaches for developing a long-term haze strategies:

1. wait for new research efforts to address key unknowns before evaluating strategy alternatives in detail;

2. recognizing the limitations and uncertainties, conduct in-depth analyses of key strategy alternatives using available tools;

3. use regional haze impacts analyses to help guide decisions on regulatory or legislative alternatives whose principal goal is not related to regional haze; and

4. use regional haze impacts analyses to develop and establish regulatory approaches whose principal goal is regional haze control.

The choice on the most appropriate course -- particularly for the normative judgments involved in the use of results in options 3 and 4 -- must be made by the responsible decision maker, after considering the available data and the

nature of the current and projected problem. The task force has found both the eastern and western modeling analyses to be of significant value for answering and raising important policy and research questions. Task force recommendations with respect to future analyses, are listed below.

1. EPA should encourage development and evaluation of more advanced policy analyses tools for urban and regional scale haze. Following the peer review of the present analyses, OAR, ORD, and OPPE should develop consensus criteria for conducting haze related benefits analyses using readily available tools and specifying relevant uncertainties. Coordinated efforts to enhancing current capabilities should be promoted. Improved approaches as needed for dealing with perception and predicting episodic as well as seasonal and average changes.

2. Based on the examination of the alternative strategies, the following regional haze control alternatives should be examined in future policy analyses:

i) Alternative fine particle and sulfate NAAQS, with a focus on the eastern U.S., plus a typical western urban area. This approach should examine projections and controls for non-sulfur related fine particles as well as SO_2;

ii) Accelerated NSPS, age based control options. DOE has already projected emissions for such alternatives. The timing of extent and value of possible visibility benefits should be examined. The regional effects of planned and alternative control of mobile sources, particuarly diesels, should also be examined further;

iii) Promising alternative cost-effective SO_2 rollbacks in the East as they are developed; and

iv) Alternative offset, emission limit policies for smelters, urban areas, new sources, and prescribed burning in the West. This would follow up the projections for current scenarios with an examination of various control approaches.

In conducting such analyses, where possible, the work should include or facilitate calculation of non-visibility air quality related benefits associated with each strategy.

3. Analyses of acid deposition control strategies, by EPA and NAPAP, and other regulatory and policy analysis of strategies that might effect visibility on a regional scale should, where possible, include or facilitate analysis of visibility benefits.

Interim Regulatory and Legislative Considerations

As noted above, the available projections suggest that regional visibility in both the East and West is likely to be stable for the next decade - the East experiencing continued episodic regional haze and the West maintaining relatively good current conditions. Smaller areas within these regions may, however, experience visibility degradation depending upon local emissions and meteorology. In this context, the task force makes the following recommendations regarding legislative initiatives and regulations:

1. Decisions on legislative recommendations or regulatory policy that would affect acid deposition or regional sulfur oxide emissions in the East also affect the occurrence of regional haze. Although actions might not be taken solely on the basis of reducing eastern haze, policy makers should recognize this linkage.

2. Although projections suggest development of comprehensive "phase II" haze programs under Section 169A can be deferred in the West, this finding is predicated on vigorous enforcement of current regulations, particularly those designed to attain the current NAAQS. For example, major SO_2 emissions decreases are projected from U.S. smelters under current programs. It is also desirable to continue negotiations to achieve controls of the two large Mexican smelters.

3. In the interim, ongoing and planned implementation of current visibility regulations under Sections 169A and 165 should, wherever possible, proceed in such a way as to permit an orderly transition to subsequent phases. Specific recommendations for achieving this are made in the areas listed below.

i) Documentation of current impairment by regional haze. EPA will promulgate a monitoring strategy and new source review requirements for many States in June. Background information from such monitoring will include information on regional haze episodes; the monitoring strategy should facilitate accurate recording and analysis of such impairment.

ii) Criteria for impairment. EPA and the Land Managers have not developed specific, quantitative criteria for determining whether impacts of new sources are adverse. This will eventually lead to implementation problems. In development of these criteria, definitions applied to plumes may have implications for future programs on regional haze and so should be specified carefully.

iii) Resolution of integral vistas. EPA is currently acting to resolve issues on integral vistas (views from within the class I area to points outside the park) with the land managers. Inclusion of such views might extend the effectiveness of regional haze programs in some cases, but make little difference in others.

iv) Long-term strategy coordination. EPA should issue guidance on how to examine the effect of ongoing implementation programs such as NAAQS and PSD on visibility. In some cases, ongoing strategies may conflict with visibility goals. For example, the current long-term strategy for ozone control in Los Angeles encourages diversion of residential and other growth to the desert (where a number of class I areas are located) to relieve ozone concentrations in the western part of the valley. Interim guidelines and policies should be examined for possible inclusion in the upcoming proposal dealing with long-term strategies.

v) Cumulative impacts of new sources. If many new sources have located near a class I area (e.g., development of a oil field), the total impact of these sources may have been underestimated if all permits were reviewed independently. This could lead to pockets of haze in some western areas, even if overall southwestern visibility is not greatly affected. Policy and guidelines are needed in this area.

vi) Prescribed burning policy. Some progress has been made to incorporate visibility impairment into the decision process used to plan prescribed burning schedules, but continued coordination among EPA, land managers and states is needed to develop guidelines for long-term implementation plans. Currently such policy could address reasonably attributable impairment and recognize the unique natural and temporary characteristics of prescribed burning. In the long-term, large scale coordination of burning should be examined.

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APPENDIX A. CHARACTERIZING CURRENT REGIONAL VISIBILITY TRENDS, AND POLLUTANT/VISIBILITY RELATIONSHIPS

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APPENDIX A. CHARACTERIZING CURRENT REGIONAL VISIBILITY TRENDS, AND POLLUTANT/VISIBILITY RELATIONSHIPS.

1.0 INTRODUCITON

1.1 Defining Regional Haze

Regional haze is a complex smorgasbord of man-made and natural gases and aerosols. Regional haze that can be attributed to man-made pollutants has been identified not only in urban environments but also in the remote areas of the continental United States.(1,2) Research on regional haze has emphasized the technical, economic and health aspects of the problem. However, haze also affects human behavior.(3) It affects the amount of time we spend outdoors, and the extent of our physical activity. It affects recreation patterns, task performance and interpersonal relationships.(3)

The natural atmosphere is composed primarily of nitrogen and oxygen along with some trace gases such as argon and hydrogen. Natural and man-made aerosol that are perceived as haze are condensed water vapor (water droplets), wind-blown dust, primary and secondary aerosols.

Primary aerosols are those emitted from a source as particulate matter, while secondary aerosols are airborne dispersions of particles formed by atmospheric reaction of gaseous "precursor" emissions. Gases are converted into aerosols through very complex reactions that have only recently been understood. The gas to aerosol conversion process takes place by essentially two processes; condensation and nucleation.(4) Condensation involves gaseous vapors condensing or combining with existing small nuclei, usually referred to as condensation nuclei. The small condensation nuclei may have their origin in sea salts or from combustion processes. Gases may also interact and combine with droplets of their own kind and form larger aerosols. This process is referred to as homogenous nucleation. Once aerosols are formed they can grow in size by a process called coagulation. In coagulation, particles essentially bump into each other and "stick" together. Aerosols also may result from reactions in cloud droplets and subsequent evaporation of droplet water.

Man-made fine particles and gases such as sulfur oxides, nitrogen oxides, and hydrocarbons are emitted from urban and industrial sources. Immediately upon emission many of the gases begin to convert to aerosols of various composition and sizes. Sulfur oxides convert into sulfuric acid and ammonium sulfate, nitrogen oxides convert to nitric acid and ammonium nitrate and hydrocarbons became organic aerosols.(4) Near (within 0-100 km) a source region such as an urban center, haze is a mixture of gases, primary and secondary aerosol.(5) After the pollutants are transported hundreds of kilometers, regional haze is primarily made up of fine primary and secondary aerosols such as ammonium sulfate and organic aerosols.(6)

Perception of regional haze involves air quality effects on light, the psychophysics of the eye-brain system, and ultimately psychological reactions. It is therefore important to investigate the meaning and metrics for visibility. Should visibility be defined strictly in terms which concern

themselves with exact measurements of illumination, threshold contrast and precisely measured distances? Or is visibility more closely allied with value judgments of an observer viewing a scenic vista?

Historically, "visibility" has been defined as "the greatest distance at which an observer can just see a black object viewed against the horizon sky."(7) An object is usually referred to as at threshold contrast when the difference between the brightness of the sky and the brightness of the object is reduced to such a degree that an observer can just see the object.

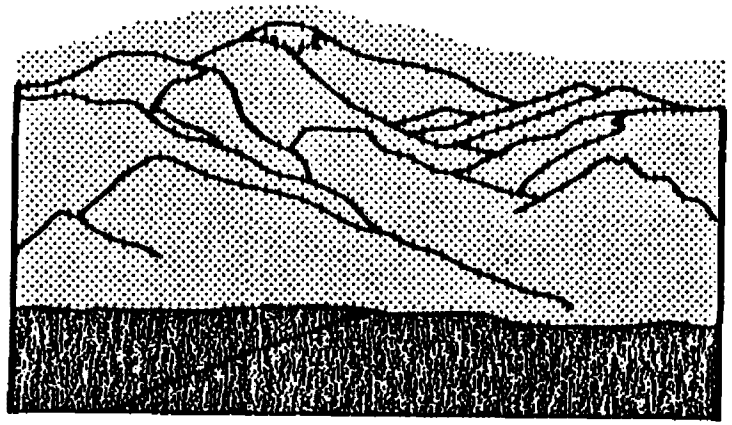
However, visibility is really more than being able to see a black object at a distance for which the contrast reaches a threshold value. Coming upon a scenic vista an observer does not ask, "How far do I have to back away before the vista disappears?" Rather, the observer may comment on the color in the vista, on the amount of snow cover resulting from a recent storm system, on the contrast detail of nearby geological structures or on shadows cast by overhead clouds.

Visibility is more closely associated with the atmospheric conditions which allow appreciation of the inherent beauty of landscape features. Visitors to class I areas are interested in being able to see and appreciate the form, contrast detail, and color of near and distant features. It is the ease with which an observer can see and appreciate scenic vistas under various atmospheric and illumination conditions.(11,12,13,14)

Generally, regional air pollution manifests itself as a uniform haze that masks both natural and urban landscapes. The effect that uniform haze has on a vista is to reduce the contrast of form, color, and texture. Distant mountains and structures can no longer be seen, while detail and color in nearby vistas become washed out. Even cumulus clouds, which have sharp edges on clear days seem to fade into a continuum on hazy days.

Regional haze can also appear as a layered haze under certain atmospheric conditions. A layered haze is a distribution of pollutants which results in a spectral (color) discontinuity between that haze and either a sky or terrain background. However, pollutants which are emitted from nearby sources and may be reasonable attributable to that source will also manifest themselves as layered haze while regional hazes, which are usually well dispersed, have a uniform appearance.(12) Schematic diagrams of regional and layered haze are shown in Figure A-1.

Visibility monitoring programs have shown that in excess of 90% of the time the ease with which scenic vistas can be seen and appreciated is impaired at all monitoring locations within the continental United States. Even in remote areas such as Grand Canyon National Park, visitors are sometimes denied the pleasure of seeing the opposite canyon rim or the great canyon depths because of poor visibility.(13) At Yosemite National Park, smoke from prescribed fires sometimes obscures the view of the massive cliffs and domes that have made the park internationally famous. In the



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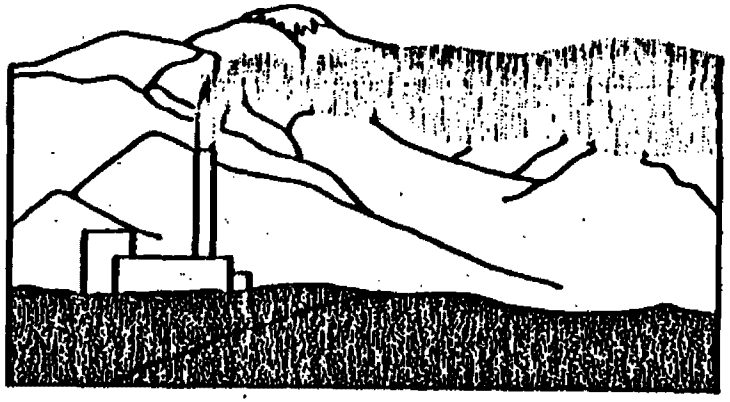

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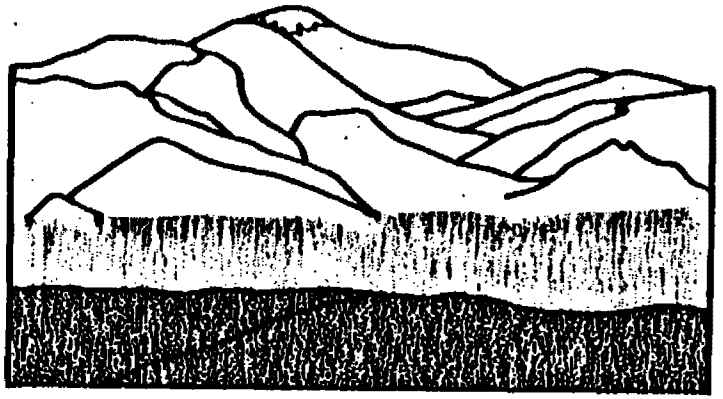


c.

FIGURE A-1. The three ways that air pollution can visually degrade a scenic vista. When there is sufficient sunlight to cause the atmosphere to become turbulent, pollutants emitted into the atmosphere become well mixed and appear as a uniform haze (a). During cold winter months, the atmosphere becomes stagnant. Pollutants emitted during these periods will appear either as a coherent plume (b) or as a layered haze (c).

enacting legislation for establishing Shenandoah National Park, congress spoke of being able to see the National Capital on a clear day.(14) Yet today the National Capital is never visible from Shenandoah.

1.2 Monitoring

An understanding of the relationship between visibility and visibility reducing aerosols requires a monitoring program with the capability of measuring both particulate concentrations and visibility related indices such as change in vista contrast, color, texture or atmospheric extinction.

Historically, atmospheric particulate concentrations and composition have been routinely measured with particle samplers that do not selectively measure particles of a known size range. However, recent developments in particulate monitoring allow for a more accurate determination of mass concentration and composition as a function of particle size. Most importantly, current particle monitoring systems allow for the selection and chemical analysis of particles (<2.5 μm) that are primarily responsible for visibility reduction (15).

Visibility may be mesaured by a variety of techniques. These include 1) human observer, 2) transmissometer, 3) telephotometer or teleradiometer, 4) photography, 5) and scattering by integrating nephelometer plus absorption by particles collected on a filter. Teleradiometry is most useful under ideal viewing conditions, i.e. no clouds on the horizon and black targets (16). Unfortunately, many applications of interest do not involve ideal conditions. However, for relatively low visibility conditions, artificial targets may be used with teleradiometers to yield precise measurements (17).

The first four techniques integrate visibility over the viewing path. The fifth technique is a point mesurement but is especially useful since it can be related to point measurements of aerosol properties. Human observer and instrumental techniques agree reasonably well when a contrast ratio of 5% is used (rather than the theoretical 2% for ideal conditions) (18).

Visibility monitoring has evolved from human observer-based measurements to the use of complex automated electro-optical instruments. Until recently, monitoring of visibility has been associated with establishing the furthest distance an observer could see a dark target (usually a tree-covered knoll or mountain) or appropriate size on the horizon. The National Weather Service has sponsored a nationwide program located primarily at airports to record "observer determined visual range" (7). Data from this network has been used to investigate visibility trends as far back as 1948.

More recently, the National Park Service has established 35 long-term (greater than five year) visibility monitoring sites at various remote locations throughout the continental United States (19). Other Federal and state agencies have operated shorter term programs, as have a number of industries.(18,20,21) Most monitoring programs operate, at a minimum, a teleradiometer measuring sky-target contrast at 550nm (green wavelength), a 35mm camera system and a size selective fine particulate monitor. In some cases where commercial power and environmental enclosures are available, integrating nephelometers have also been used.

In the last few years, some progress has been made toward automating measurements and toward instrument configurations that can operate on solar power for extended periods of time in remote, harsh environments. Also, new types of "scanning" radiometers have been developed to measure radiance at various wavelengths and at many points within a vista.(12,22) Although these types of radiometers are capable of collecting information on texture and color reductions and on haze layers, they have not been used in a routine monitoring program because theoretical formalisms have not been adequately developed to handle the millions of pieces of data produced by these instruments.

All instruments currently used in visibility monitoring have limitations. Although teleradiometers measure characteristics of the scene in a way that relates directly to the human eye-brain system, if it is desired to interpret contrast data in terms of extinction or visual range a whole series of assumptions must be made about inherent contrast, illumination and uniformity of aerosol distributions.(16,23) An integrating nephelometer makes a point measurement, does not measure absorption, underestimates scattering of large particles and, quite possibly, modifies the aerosol as it is drawn through the sampling chamber.(18)

Furthermore, particle samplers currently in use may underestimate nitrate concentrations and other volatile aerosol components. For instance, Appel et al. estimate that as much as 40% of the organics are lost during the sampling process.(26) During summer months when Southwest desert environments experience temperatures in excess of 100°F, Appel et al. suggest that current sampling techniques allow for as much as 90% of the nitrates to be reevaporated back into the atmosphere.(25)

There is a pressing need to develop instruments that measure the atmospheric extinction and scattering characteristics as they exist in the atmosphere, independent of meteorological and vista conditions. An "open air" integrating nephelometer measuring atmospheric scattering in conjunction with a long path transmissometer measuring atmospheric extinction would meet these needs.

There is also a need to assess the role of volatile aerosols on visibility reduction. If volatile aerosol scattering is significant, there will be a need to design new particle monitoring devices that better characterize those aerosols with low vapor pressures.

2.0 MONITORING RESULTS

2.1 Regional Visibility and Trends from Airport Observations

The most extensive monitoring data base for any air pollution-related parameter is the human observer visual range measurements of the National Weather Service (NWS). Several hundred weather stations in the US and Canada record visual range every hour. A computerized data base exists from 1948 to the present. Daily noon visibility isopleths for the US, covering the period from 1948 to 1978, have been calculated (26). These isopleths have been used to study regional trends in visibility from 1948 to 1978 (27,28,29). More recently, these analyses have been extended through 1983 (Figure A-2).

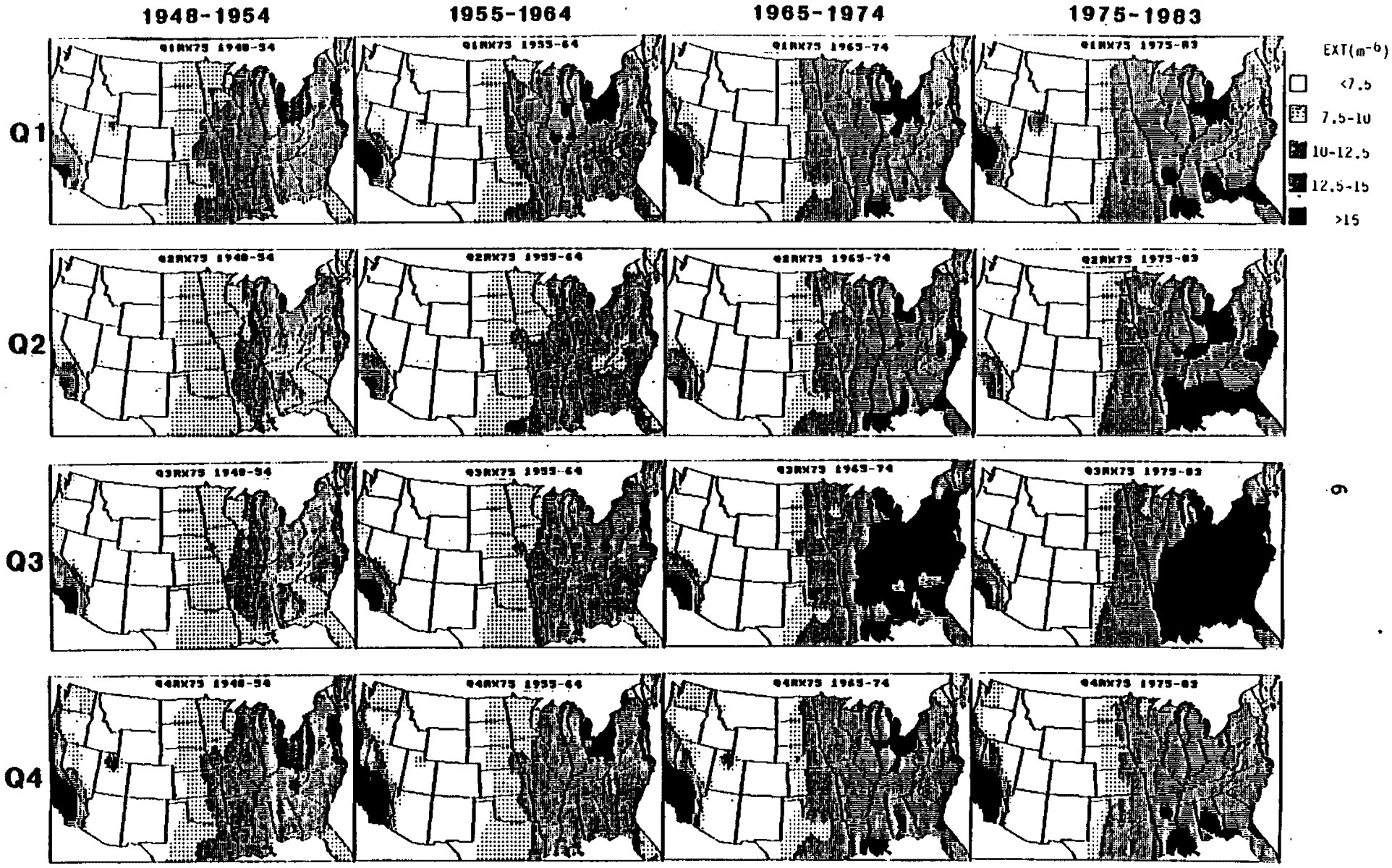


Figure A-2. Geographical distribution and trends in U.S. haze (Husar, 1985). Data represent average light "extinction" coefficient (3.9/visual range) from airport observation, excluding precipitation events and adjusted for relative humidity and limitations in target distances. As adjusted, the measurements provide a fair picture of coarse spatial and temporal patterns of haze derived from anthropogenic and natural fine particles. A marked difference exists between east and west and among seasons. The summer season (Q3) currently shows the highest haziness (worst visibility) and also exhibits the largest declines. The scales chosen mask some trends, notedly a stabilization or modest improvement in some areas of the southeast and southwest from 1972 to date. In cool seasons the major trends are a marked increase in haze in the gulf coast states and some improvement in the northeast quadrant.

2.2 Regional Haze in the East

Eastern regional haze can be observed in satellite photographs. In the summer haze blobs can be observed that cover several states. These areas of low visibility maintain some cohesiveness for several days and can be tracked as they undergo transport for 1000's of kilometers. Patterns of haze observed from satellites agree fairly well with isopleths of NWS visual range less than 6 miles (28,30).

Between 1948 and 1972 visibility reduction changed from a local to a regional phenomena (Fig. A-3)(28). At an urban airport, Washington National, low visibility has changed from being associated with low wind speeds to no relationship with wind speed indicating that low visibility no longer results from a build-up of urban pollution during stagnations. At a rural airport, Lambert Field, St. Louis, low visibility was initially associated with wind flow from the city but now shows no relationship with wind direction. These observations indicate that reduction in visibility is not associated with local urban sources but with a regional distribution of pollution.

The NWS visual range data from 1948 to 1978 has been used to analyze visibility trends on a regional and seasonal basis (22,28,29) to compare regional visibility trends with regional coal usage (Figure A-4a,b).

Visibility isopleths for 1979-1982 have been prepared recently and are currently being analyzed with earlier data for trends and patterns from 1948 to 1982. Some observations are fairly obvious and can be made by observation of the isopleths shown in Figure A-5. In the winter season there has been an improvement in visibility in New England and the north central U.S. However, there has been degradation of visiibility along the south east and gulf coasts and in south central U.S. In the spring season after 1970 there has been a degradation of visibility in the entire eastern U.S., especially along the gulf coast and the south and central east coast. The most dramatic changes, however, are evident during the summer season. A region of modest visibility in the northeastern U.S. (bscat = 0.24-0.30) during 1948-1952 steadily expanded and became worse until the entire eastern U.S. and southeastern Canada were affected. The fall season shows significant improvement in the north central industrial areas but degradation along the gulf coast.

Improvements in the mid- and northeastern U.S. during the 72-82 period may be associated with reduced industrial activity during the 80-82 recession (Figure A-6). Efforts are currently underway for both modelling and statistical analyses of these relationships.

2.3 REGIONAL HAZE IN THE WEST

2.3.1 Visibility Measurements

In spite of inherent limitations in instrumentation currently used to measure visibility, monitoring programs are yielding a wealth of information. Airport observations of visibility are useful sources of trend information in areas where visibilities are comparable to the distances to available targets.

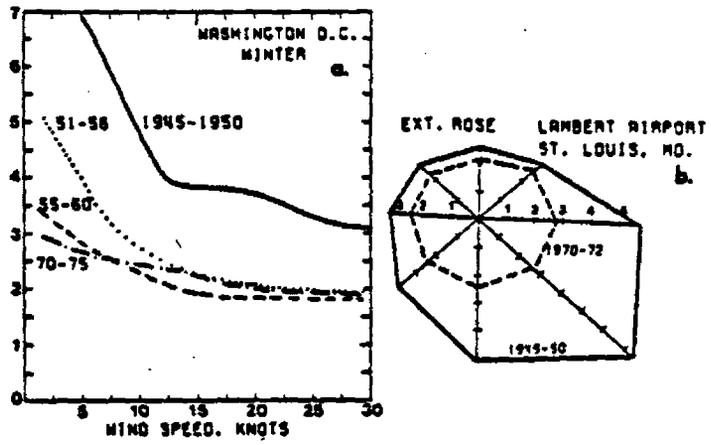


FIGURE A-3. (a) In the winters of 1945-50 at Washington, D.C., high extinctions were associated with low wind speeds. By the winters of 1970-75, the level of haziness declined and the wind speed dependence had essentially vanished. The obvious interpretation is that the winter haziness in 1970-75 was due to remote, rather than local, sources. (b) A haziness rose for Lambert Airport in St. Louis, Mo., shows that in 1945-50, the highest extinction levels were observed when the wind was from the city direction; by 1970-72, the haziness was essentially independent of wind direction. Here again, the conclusion is drawn that the haziness is currently due to distant, rather than local, sources (16).

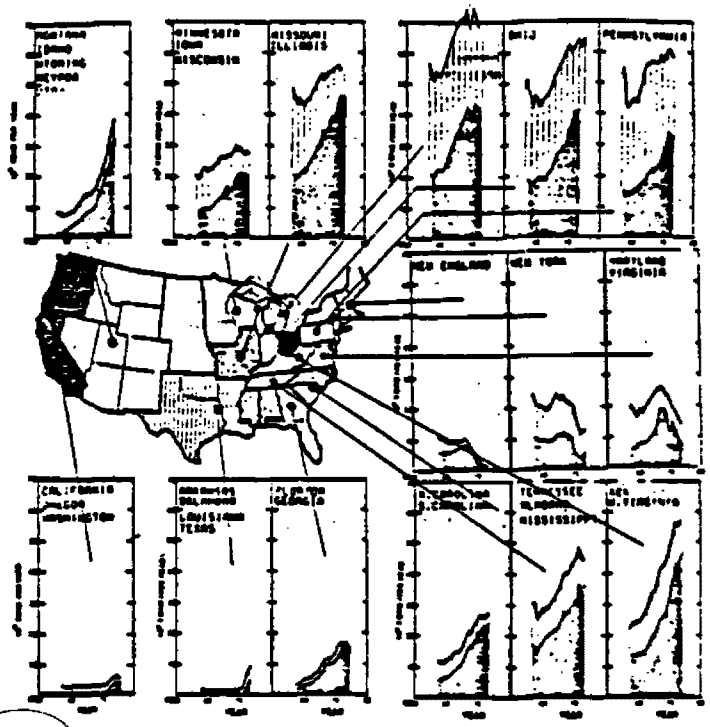


FIGURE A-4a. The trends of U.S. coal consumption in contiguous areas show strong regional dependence. Electric utility coal consumption is represented by the dark shading (16).

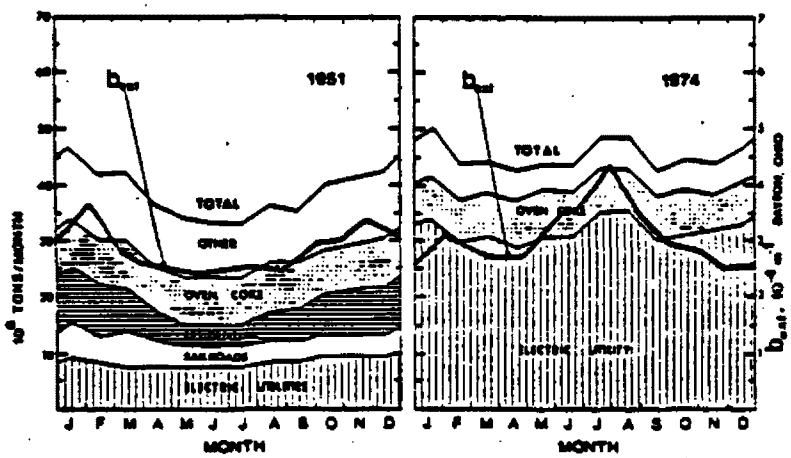


FIGURE A-4b. In the 1950's, the seasonal coal consumption peaked in the winter, primarily due to increased residential and railroad use. In 1974, the seasonal pattern of coal use was determined by the winter and summer peak of utility coal use (16).

MEDIAN EXTINCTION COEFFICIENT

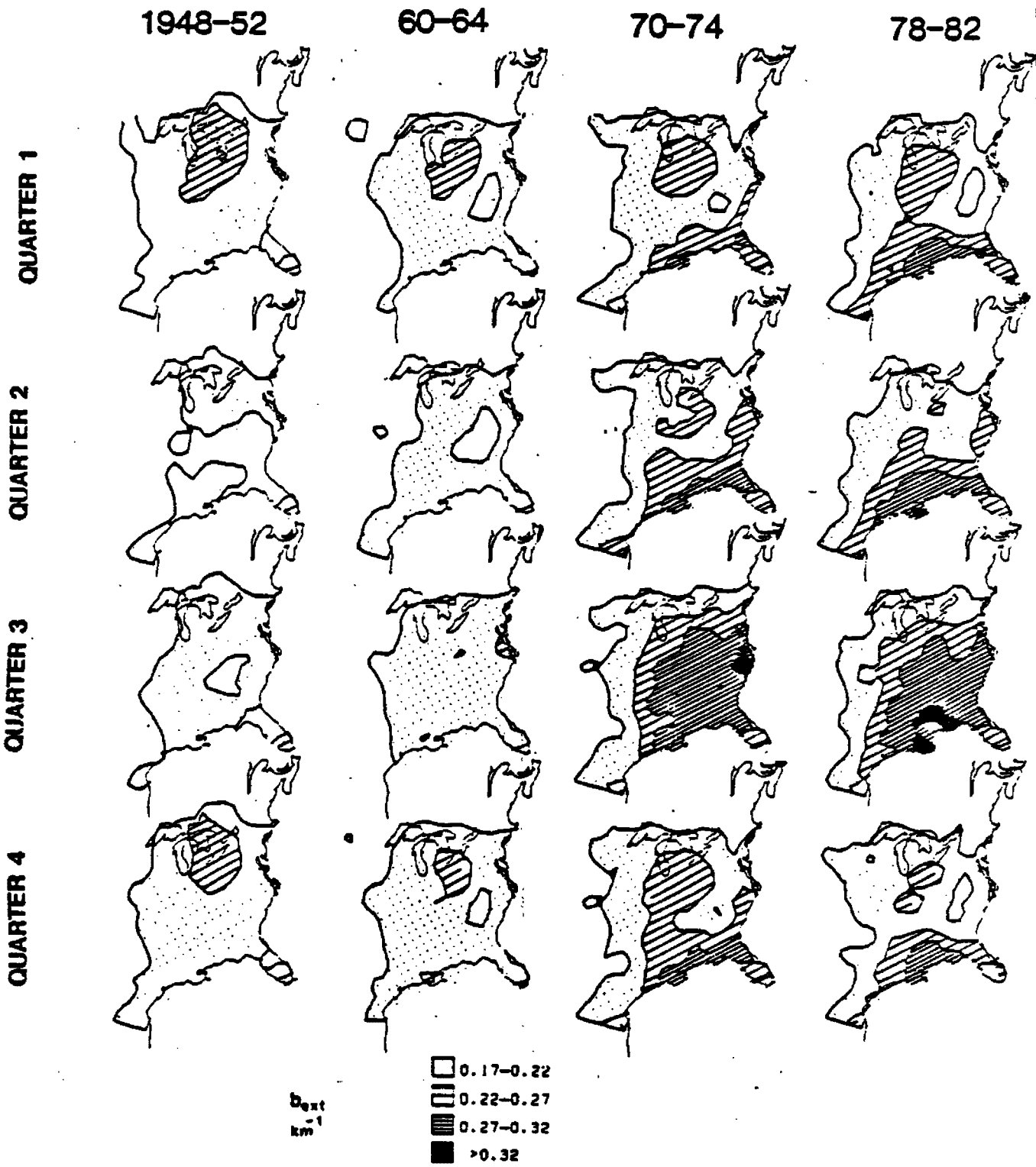


FIGURE A-5. Trends in median extinction coefficient (3.9/visual range) from airports in the Eastern U.S. Data are normalized to a standard relative humidity using an empirically derived correction (4).

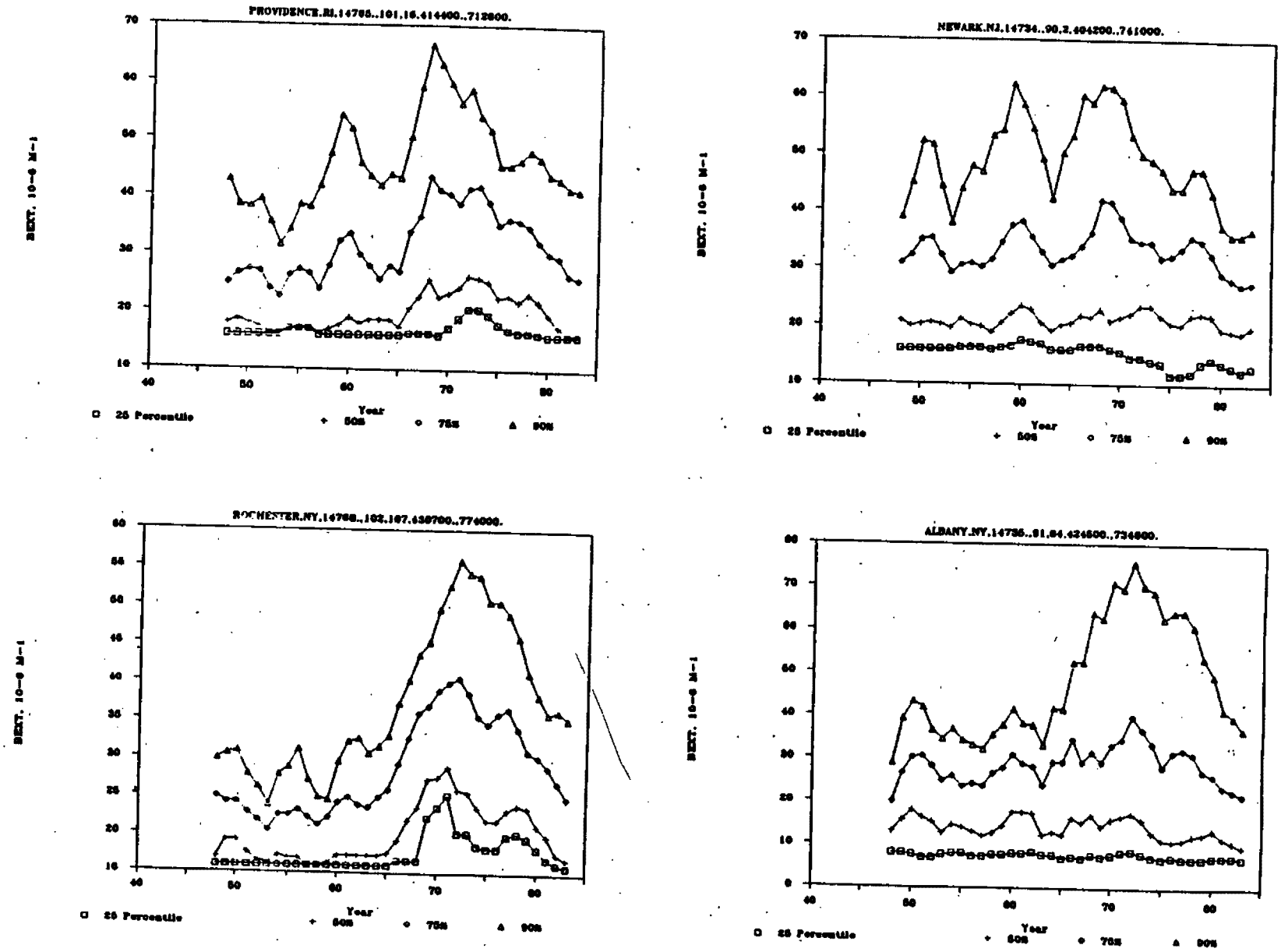


FIGURE A-6. Visibility Trends for the Northeastern States. Trends third quarter haziness for 4 sites in the northeast: Newark, NJ, Albany, NY, Rochester, NY, and Providence, RI. The trend clearly shows an increase of haziness from the 1940's to about 1970. Since around 1970 the haziness has declined at these and other northeast stations (30).

Trijonis et al.(28) examined airport visibility data for trends in visual air quality in the Rocky Mountain Southwest over the time period from 1948 to 1976. They found that in the late 1940's to the early/mid 1950's, visibility trends were mixed with some geographic areas showing a slight improvement and a lesser number of areas showing a slight deterioration. From the early/mid 1950's (1953 to 1955) to the early 1970's (1970-1972), most areas indicated a drop in visibility of approximately 10 to 30 percent. From the early 1970's (1970-1972) to the middle 1970's (1974-1976), visibility generally tended to increase by about 5-10 percent, especially at those sites in or near Arizona.

Trijonis also examined airport data at 67 sites in California.(32) Plots of long-term trends in median visibility (for all data with no sorting for meteorology) at the 19 study sites reveal that visibility trends in California tend to split into two general sub-periods, divided at approximately 1966. Before 1966, nearly all locations exhibit deteriorating visibility, with especially large visibility decreases occurring in and near the Central Valley. After 1966, nearly all locations have displayed improving visibility.

Over the entire two and one-half decades from 1949-1951 to 1974-1976, the major areas experiencing a net improvement in visibility were the central/coastal parts of both the South Coast Air Basin and the San Francisco Bay Area Air Basin. The densely populated, central/coastal portions of these metropolitan regions underwent net improvements in visibility on the order of 10 to 40%. Slight improvements in visibility also seem evident in north-eastern California and southern Oregon from 1949-1951 to 1974-1976. The major areas that experienced net deterioration in visibility -- on the order of 10 to 30% -- are the San Joaquin and southern Sacramento Valleys, the South Central Coast Air Basin, the inland part of the South Coast Air Basin, and the Southeast Desert Air Basin.

Other California visibility trends are reported by California Air Resources Board (CARB).(33,34,35) Their discussion centers around "adverse" and "superior" visibility. They define "adverse" visibility as having concentrations of visibility-reducing particles sufficient to reduce prevailing visibility to less than 10 miles when the relative humidity is less than 70%. Visibilities that are 30 miles or more are termed "superior".

The trend of the composite superior visibility for two pristine stations, Mt. Shasta and Bishop, is shown in Figure A-7 . It shows a gradual (about 1% per decade) decrease in average superior visibility occurrences in these pristine areas of California. The 20-year (1958-77) overall summertime trend of adverse visibilities in the great Central Valley (Red Bluff, Sacramento, Stockton, Fresno, Bakersfield) shows little change during the period 1958-1967 and marked improvement since then. The improving trend is statistically significant at the 1% level. These data are presented in Figure A-8. As shown by the trend line, the occurrence of adverse summertime visibilities in the Valley decreased from about 13% to less than 4% from 1967 to 1977.

The overall summertime trend of adverse midday visibilities in the coastal plains of California is presented in Figure A-9. As shown, the occurrence of adverse visibilities during this period decreased in the larger urban areas throughout this 20-year period. A similar decrease is also

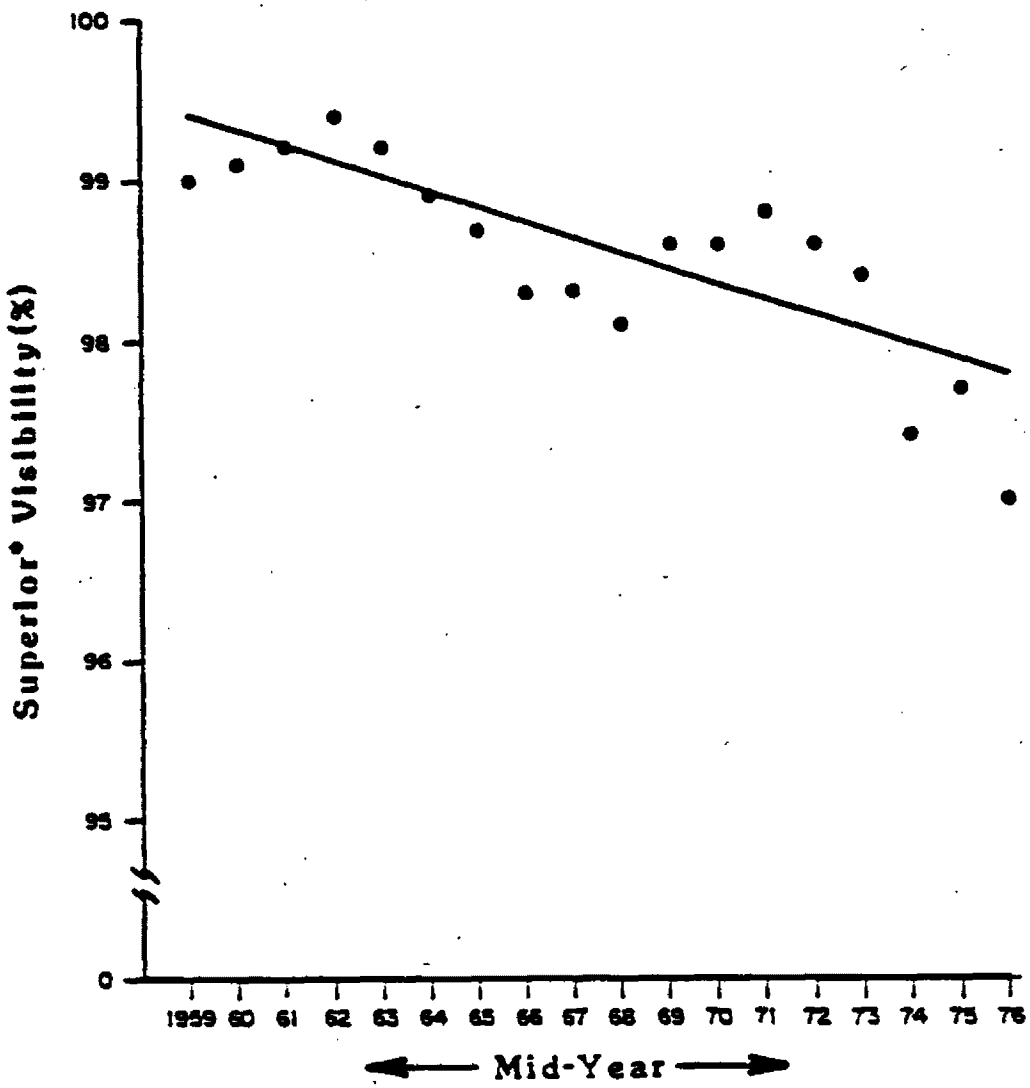


FIGURE A-7. Three year mean annual occurrence of superior midday visibilities in the pristine areas of California (1958-1977).

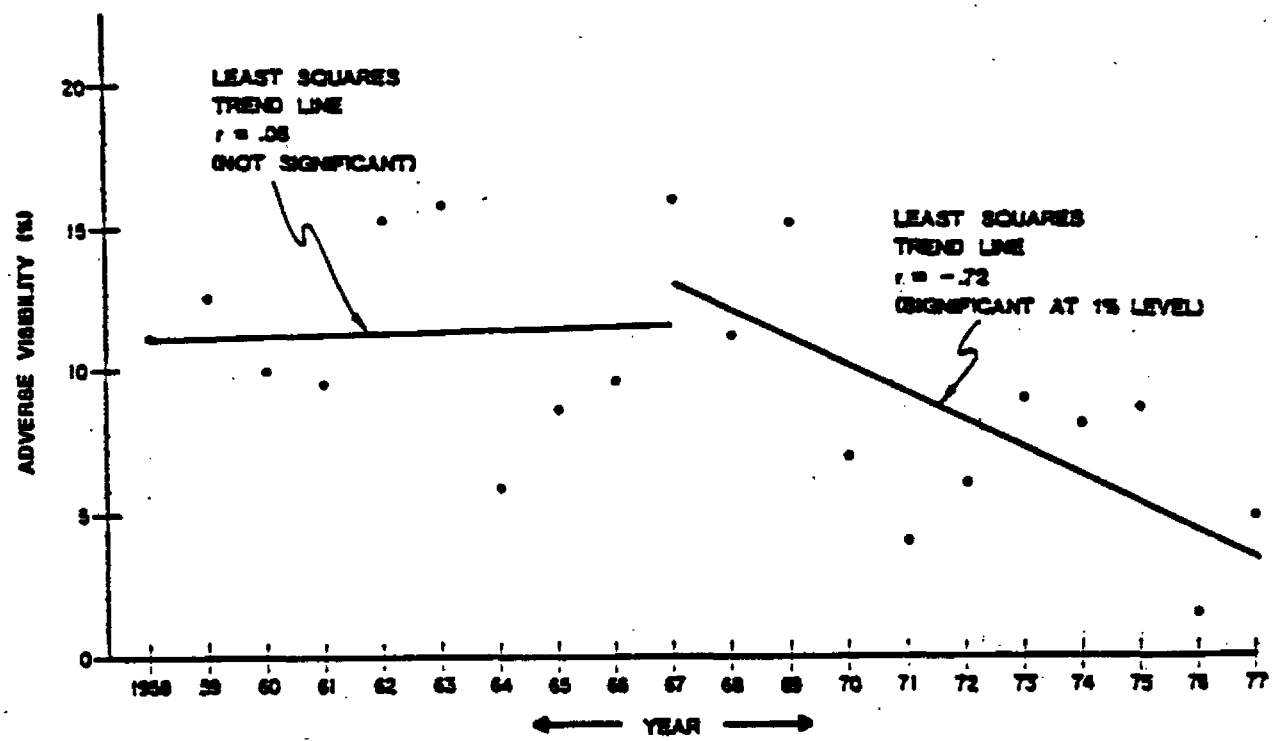


FIGURE A-8. Summertime occurrence of adverse midday visibilities in the Great Central Valley of California.

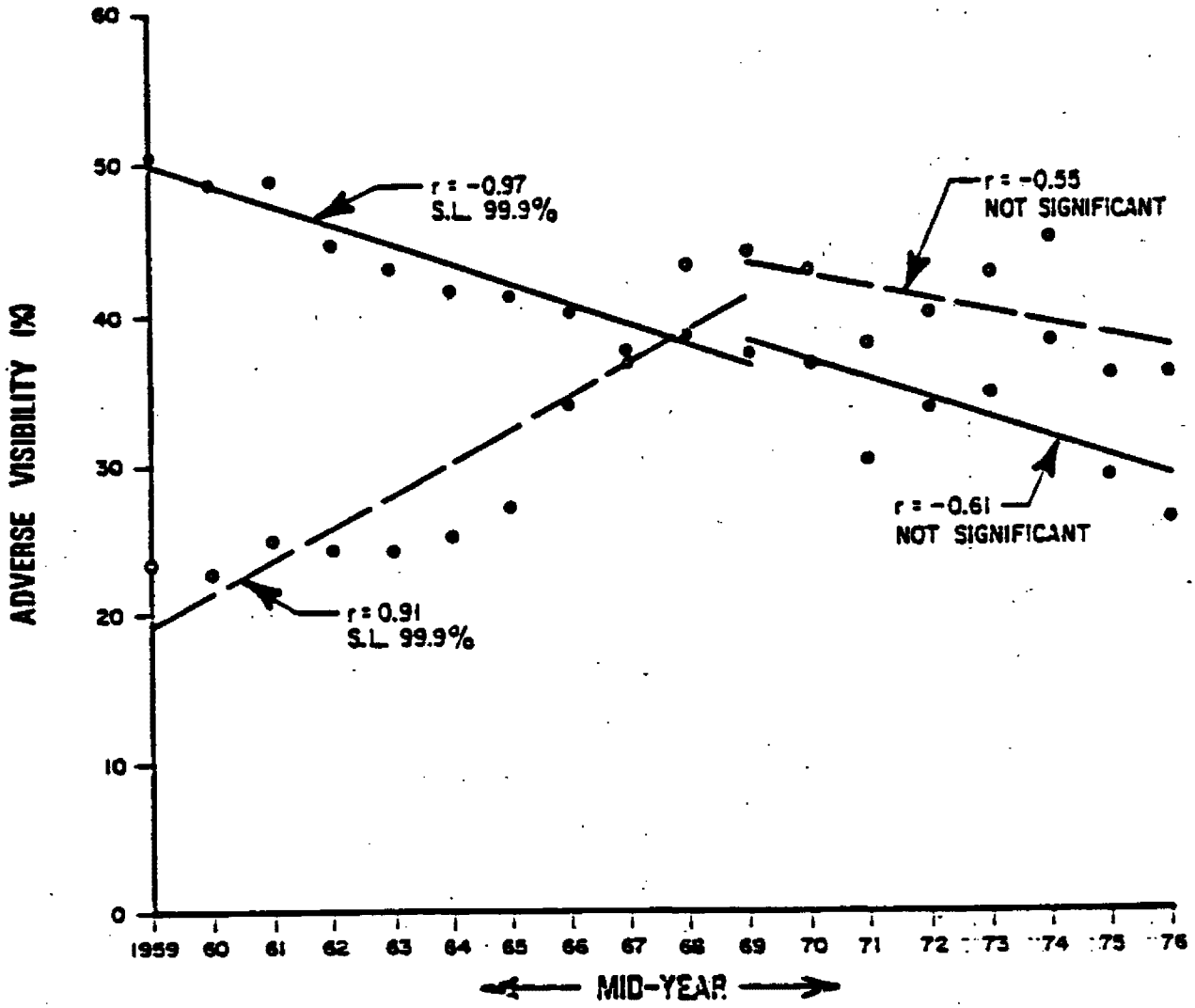


FIGURE A-9. Three-year means of percentage occurrence of adverse visibilities based on June-August (summer) data from (●) San Francisco, Oakland, Los Angeles, and Long Beach and from (○) Salinas, Santa Maria, Oxnard, Riverside, and San Diego. In the above figure, r is the correlation coefficient and S.L. is significance level.

evident in the smaller urban areas since 1969, while an increase is evident prior to that time. The all-season data show similar trends. The increase in adverse visibility in the smaller urban areas during the 1960's appears to be associated with the high rate of population growth during that period. The decrease since 1969 in all areas appears to be associated with a slowing in the rate of population growth and the effect of the various air pollution controls applied to mobile and stationary pollution emission sources.

The decade-to-decade change of adverse visibilities for all-season data is similar to the trend shown by the summertime data. The larger urban areas show a decade-to-decade decrease in adverse visibility ranging from 7 to 12% (San Francisco, Oakland, Los Angeles, and Long Beach). This change is consistent with the steadily decreasing trend shown by the summertime data (Figure A-9). The decade-to-decade change for the smaller urban areas, however, shows a net increase in adverse visibility ranging from 2 to 14% (Salinas, Santa Maria, Oxnard, Riverside, and San Diego). This change is consistent with the trend shown by the summertime data (Figure A-9).

Data from the recently implemented (fall 1979) National Park Service visibility monitoring network shows summertime visibility in the Colorado Plateau area, an area that encompasses Grand Canyon, Zion, Bryce Canyon, Canyonlands, and Mesa Verde National Parks to be decreasing from 1978 to 1981, and then increasing in 1982 and again in 1983.(19) Grand Canyon summertime visibility presented in Figure A-10 is representative of this short-term trend.

The National Park Service monitoring network has also yielded interesting seasonal trends. Figure A-11, a plot of seasonal visibility averaged over five years, shows that at Grand Canyon and Big Bend National Parks visibility is best during winter months, worst during summer season and intermediate during spring and fall. This trend is representative of seasonal variation at most monitoring sites in the western United States.

Seasonal patterns in median 1:00 p.m. visibility was also investigated in the Trijonis California visibility study.(32) It is found that the seasonal pattern in visibility is not uniform throughout California. The seasonal patterns are usually consistent, however, within individual air basins and major geographical sections of California.

Nearly all locations in southern California and along the central coast -- the South Coast, San Diego, Southeast Desert, South Central Coast, and North Central Coast Air Basins -- exhibit minimum visibility during the spring or summer (especially the summer), and maximum visibility during the fall and winter. Nearly all locations in the San Joaquin Valley, Sacramento Valley, and San Francisco Bay Area Air Basins display minimum visibility during the fall and winter and a distinct maximum during the spring; a similar pattern exists in the Northeast Plateau Air Basin (as well as some locations in the North Coast and Lake Tahoe Air Basin), except that maximum visibility is usually displaced from the spring to the summer.

The NPS monitoring program also shows a definite spatial distribution of visibility.(19) Figure A-12 shows isopleths of SVR_g over the western United States for summer of 1982. The highest visual range, SVR_g = 180 km, occurs in the northern parts of Nevada and Utah and the southern portion

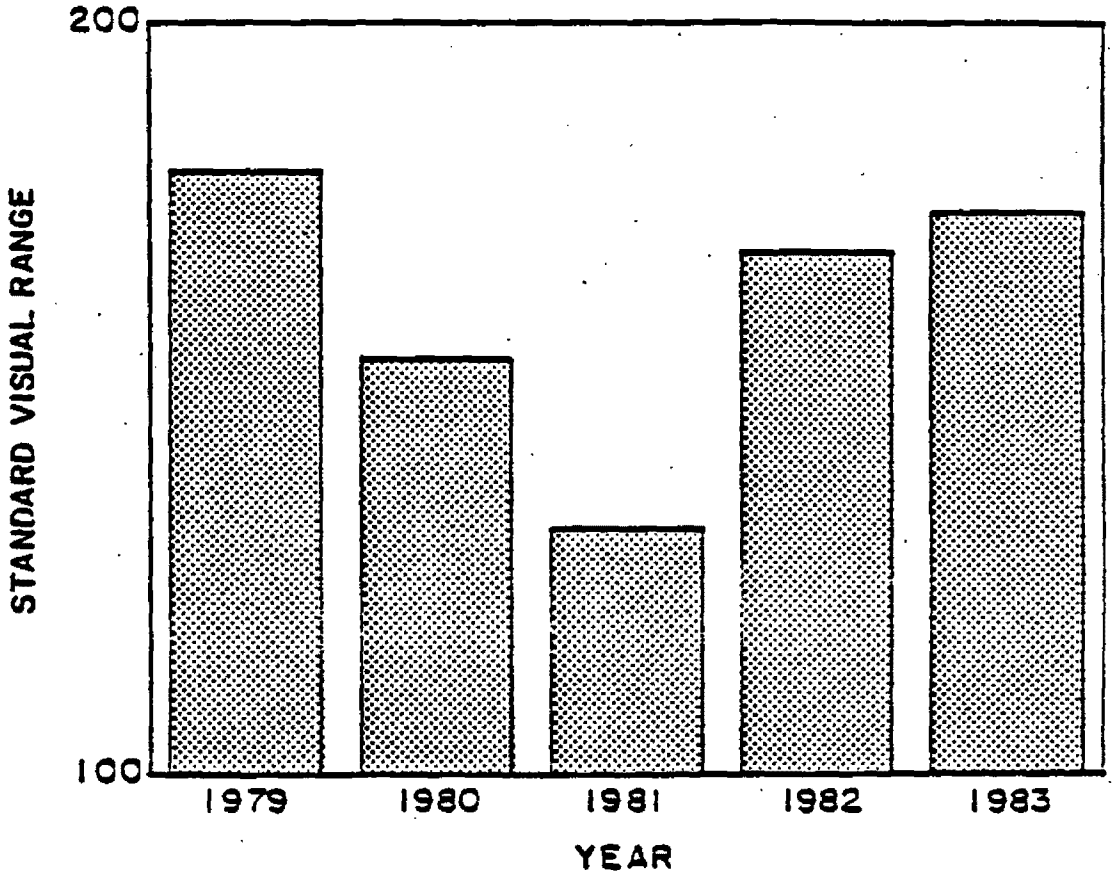


FIGURE A-10. Summertime standard visual range for Grand Canyon National Park.

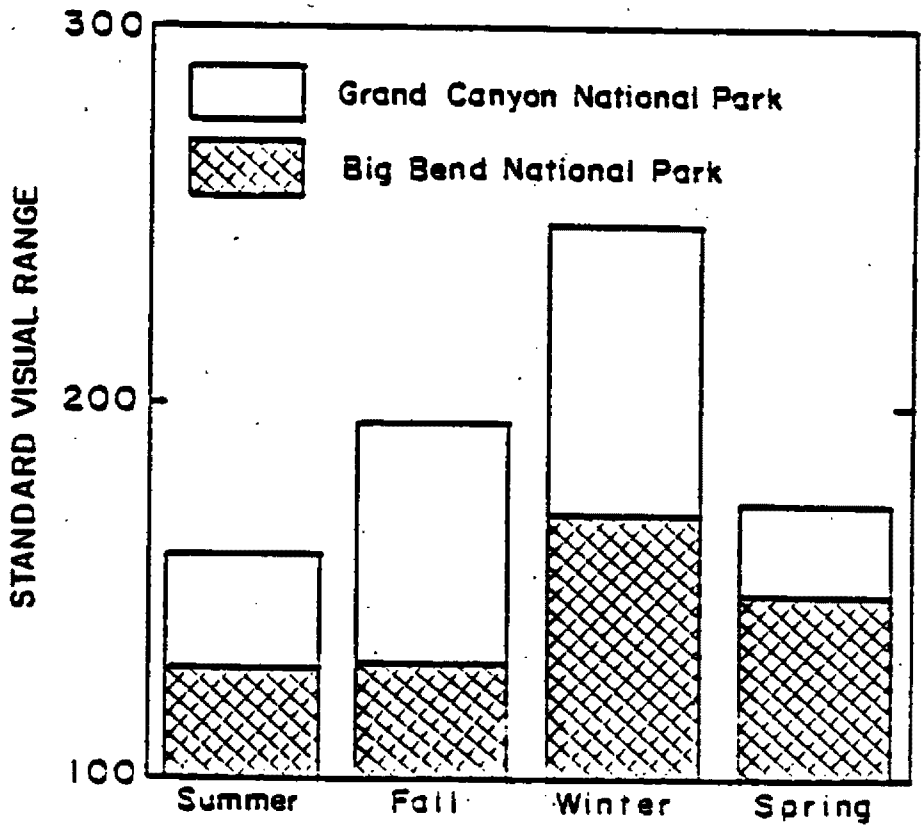


FIGURE A-11. Five year averaged seasonal visibility at Grand Canyon and Big Bend National Parks.

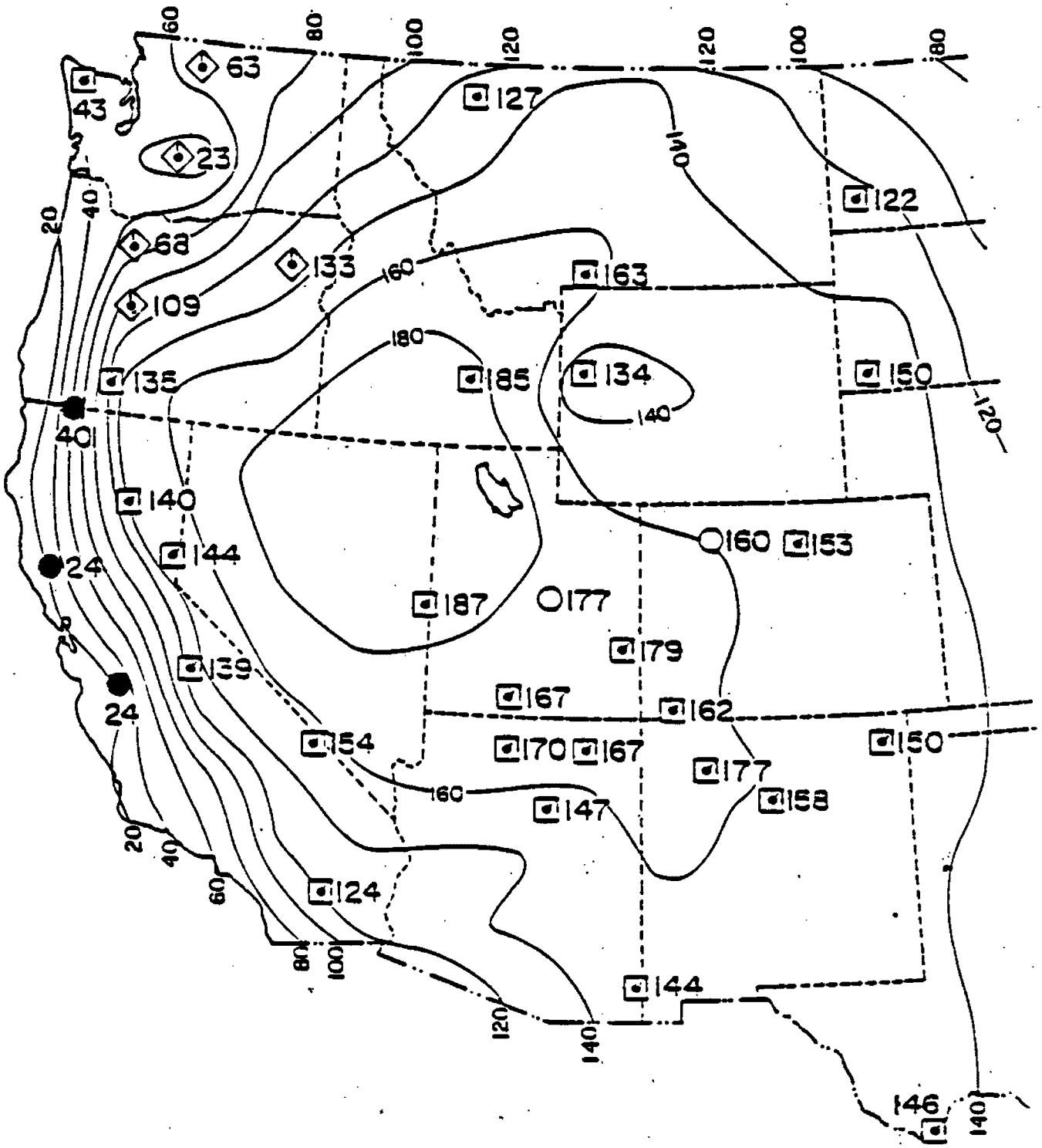


FIGURE A-12. Isopleths of $\overline{SVR}_g$ over the western United States for summer of 1982.

of Idaho. The region with the next highest visual range, SVR = 165 km, corresponds to that geographic area that contains Grand Canyon, Bryce Canyon and Canyonlands National Parks, commonly known as the Colorado Plateau. Southern Arizona, New Mexico and the "Front Range" area of the Rocky Mountains have SVR_g = 140 km. The lowest visual range is found in California near the populated urban areas and in areas where there is significant industrial and agricultural activity.

In addition, the NPS monitoring network has documented layered haze trapped by stable air masses at Bryce Canyon and Mesa Verde National Parks. On winter mornings, portions of Navajo Mountain as seen from Bryce Canyon are completely or partially obscured as much as 80% of the time that data was collected. Recent analysis suggests that this haze layer tends to be a result of local emissions into the Glen Canyon area.

Trijonis has investigated spatial variations in visibility throughout California in more detail.(32) Using 1:00 p.m. data for 1974-1976 at 67 locations, a detailed isopleth map, shown in Figure A-13, illustrates the geographical patterns of visibility in California. The map reveals that the spatial gradients of visibility in California are far more severe and complex than those observed anywhere else in the United States. Some parts of California exhibit among the best visibilities in the nation, while other parts experience among the worst visibilities in the nation.

The clearest air in California occurs along the Nevada border. One area along the border, Death Valley National Monument and the mountainous areas immediately northwest, experience median visibility exceeding 70 miles. This area is on the fringe of a large region in the desert/mountain southwest United States which exhibits the highest visibilities in the nation.

Median visibility is also quite good, 45 to 70 miles, in the plateaus and mountains of northern California, the mountains of central-eastern California, the desert near the Arizona border, and the Vallecitos Mountains east of San Diego. To the west of all these areas, very sharp gradients occur, with visibility falling to less than 15 miles along the entire coastline except the far northern coast near Oregon, where median visibility falls to less than 25 miles.

Two significant pockets of poor visibility occur between the coast and eastern California. Median visibility is less than 15 miles in the large area consisting of the central/southern San Joaquin Valley. Visibility is less than 10 miles in the center of the Los Angeles basin.

2.3.2 Particle Measurements

Fine particles (smaller than 2.5 μm) are generally responsible for a major share of visibility impairment. The pie diagrams in Figure A-14 show the average composition of fine particles at sites in the northern Great Plains, Arizona, Texas and Virginia.(36) The largest contribution is from sulfates, especially at Shenandoah. Soils contribute around 10% to 20% of the fine mass in the west but much less at Shenandoah.(36) More detailed studies have shown that these fine soil particles are larger than 1 μm. Whereas smoke tends to

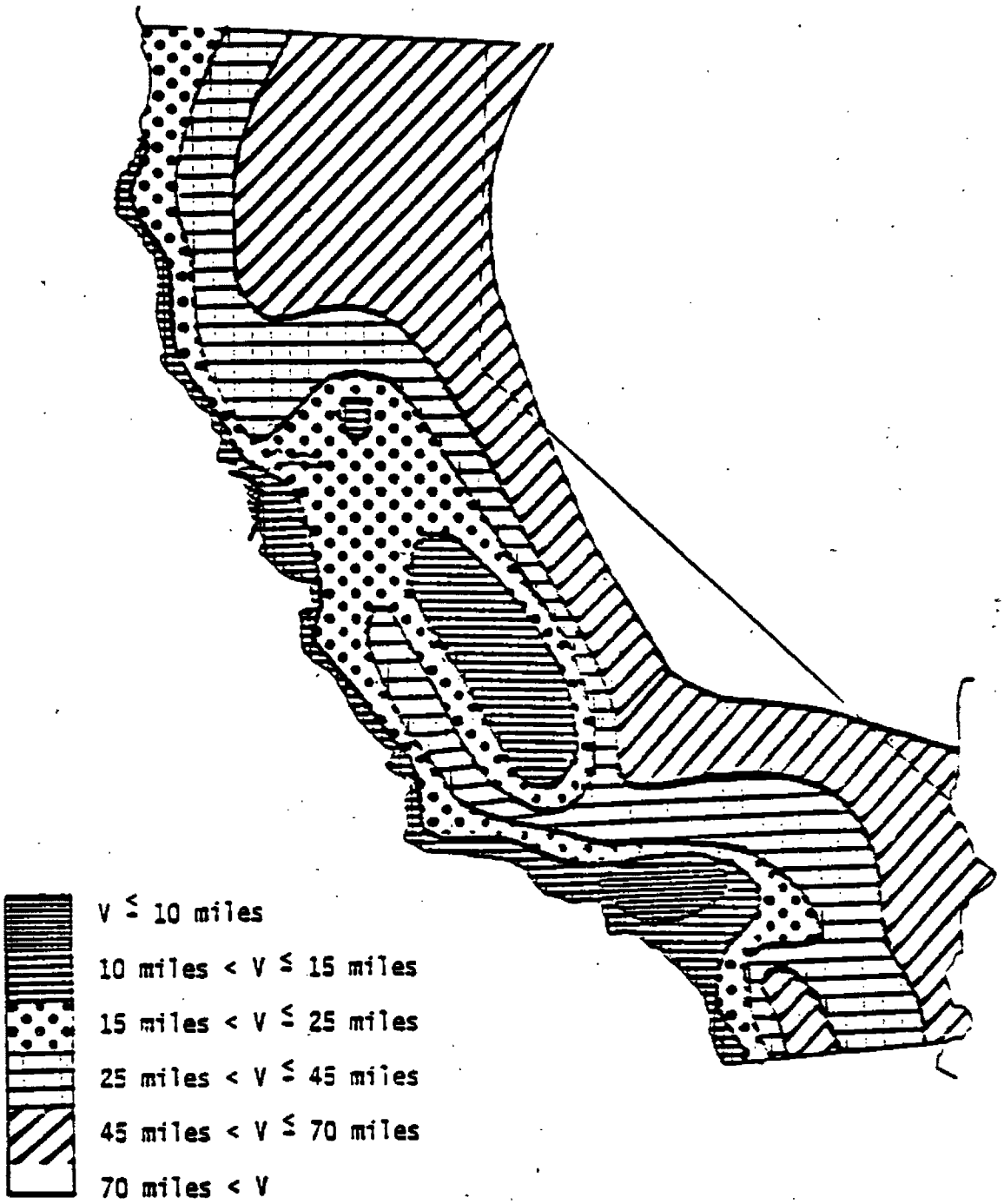


FIGURE A-13. Shaded isopleth map for median 1 p.m. visibilities in California.

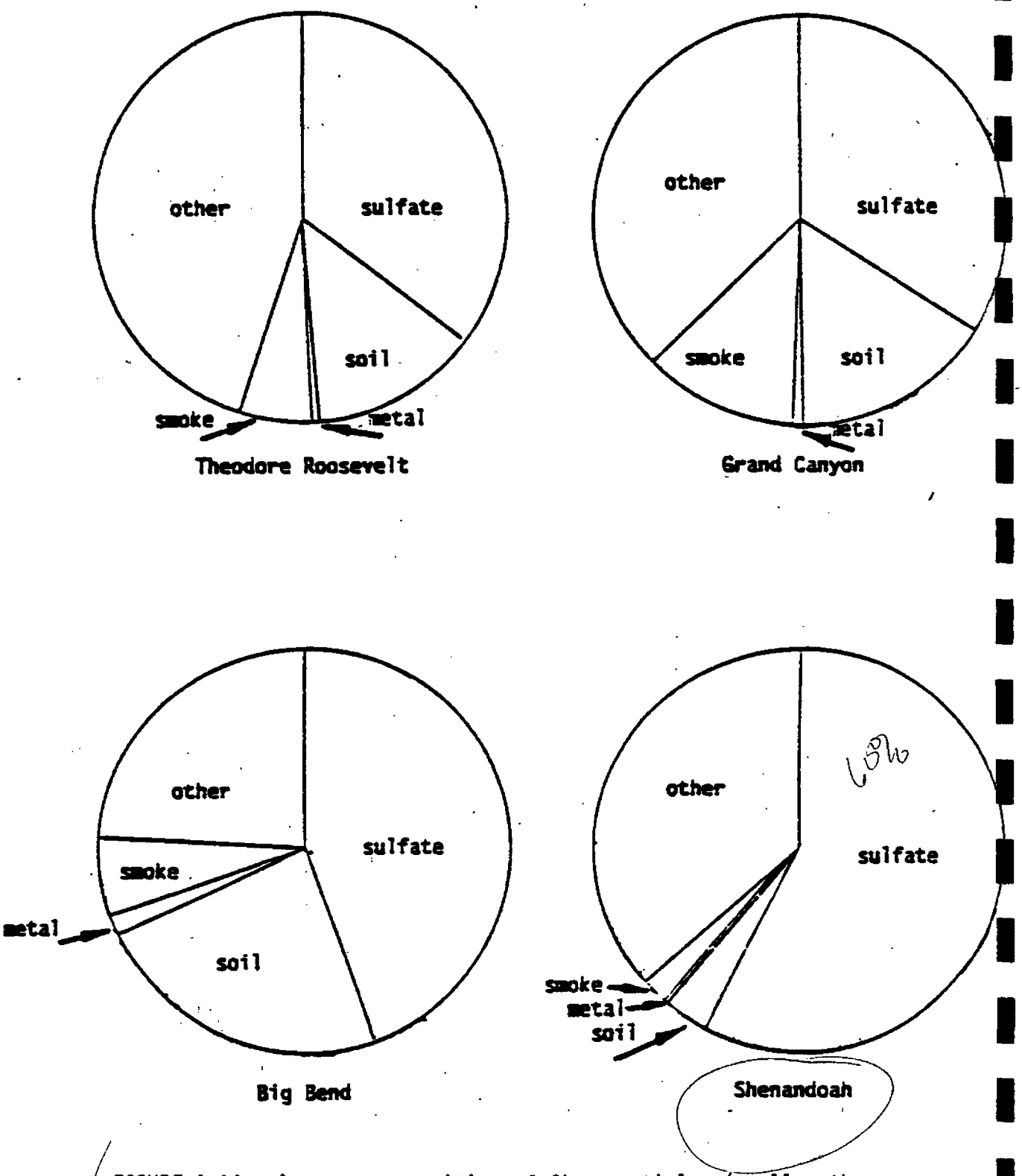


FIGURE A-14. Average composition of fine particles (smaller than 2.5 μm) at sites in the northern Great Plains, Arizona, Texas and Virginia.

contribute less than 10% of fine mass in the Southwest, it can contribute in excess of 60% of the mass in the Northwest.(37) The component labeled "other" includes organic material, nitrates and water incorporated in the particles.

Figure A-15, "bubble" maps for summer 1983, shows the geographic distribution of coarse soil, fine mass, fine sulfate, and fine nonsulfate. Shenandoah's sulfate value is shown for comparison purposes. The component labeled "fine other" shows the nonsulfate portion of the fine mass, including smoke. Glacier and Grand Teton had consistently high nonsulfate in the fall and winter, while Yosemite had high values in summer and fall.(36)

The contour plots of fine sulfur, shown in Figure A-16, indicate that over a season there are well defined regions of relatively constant sulfate concentration. The values in Oregon and northern California are comparable to those measured at the cleanest sites in the world, while southern California, Arizona, New Mexico, western Texas and the western Great Plains have the highest sulfur concentrations in the western United States. It should also be noted that sulfur concentrations are highest during summer and lowest during winter months.

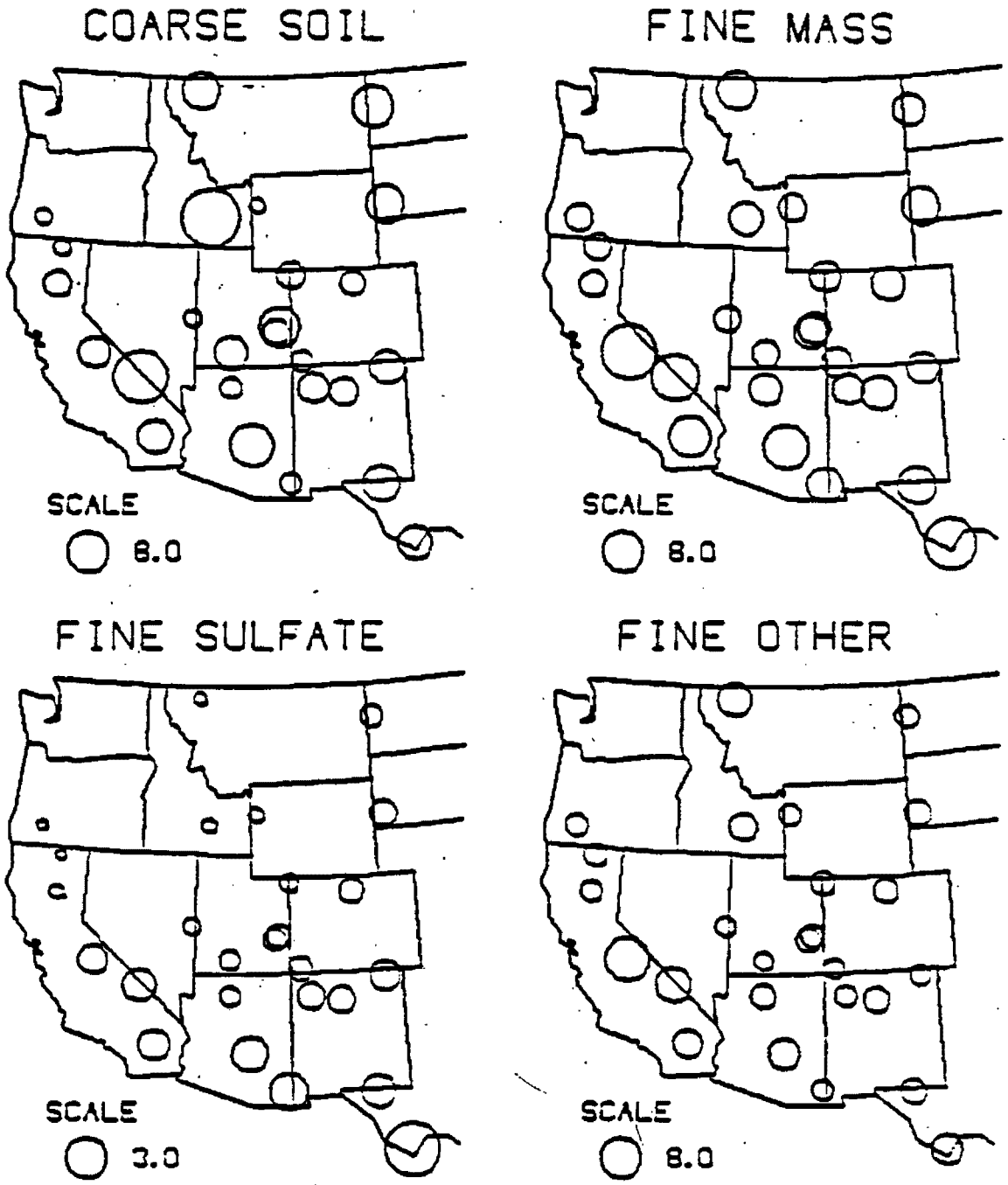
The time plot of fine nonsoil potassium (K) shown in Figure A-17, for sites in Arizona, New Mexico and Utah shows a remarkably regular pattern of impact every June. These particles are associated with smoke, and while the sources are still uncertain, they may represent transport from Mexico.(36)

Composition of aerosols in western urban centers differ considerably from what is found in both eastern (urban and rural) and remote western national parks and wilderness areas. Figure A-18, the composition of Denver fine aerosol that is $\leq$ 2.5 μm, is typical of most western cities(6). C_o and C_e refer to organic and elemental carbon respectively. In urban settings, sulfates are a smaller fraction of total aerosol mass, while organic carbon and nitrates make up a significantly greater fraction of the mass than they do in remote areas. It should be pointed out that the total mass concentration in urban settings is considerably higher than in class I areas. Mean concentrations of fine particulate mass associated with the pie diagram shown in Figure A-7 was 39.5 $\mu g/m^3$, whereas mean fine mass concentrations in the rural west are 5-10 $\mu g/m^3$. However, sulfate concentrations are similar in western urban and rural areas.

2.4 SOURCES OF VISIBILITY IMPAIRMENT

Visibility data, when combined with particle composition and concentration, allow for developing an understanding of which of the many atmospheric constituents are responsible for visibility reduction (light extinction budgets). Because different size particles reduce visibility with varying degrees of efficiency, it does not automatically follow that an aerosol species making up a certain fraction of total mass will be responsible for that same fraction of visibility reduction. For instance, coarse windblown dust may constitute 60% of total mass and yet be responsible for only 20% of the visibility reduction.(36,15)

Two techniques have been used to date to develop light extinction budgets--"theoretical" (or "first principle") and "statistical". Each has its own advantages and disadvantages.(38)



AVERAGE SEASONAL CONCENTRATION IN MICROGRAMS/M**3
FOR SITE IS PROPORTIONAL TO DIAMETER OF CIRCLE
FINE OTHER - FINE MASS - FINE SULFATE

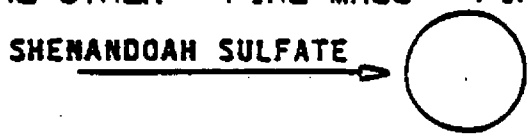
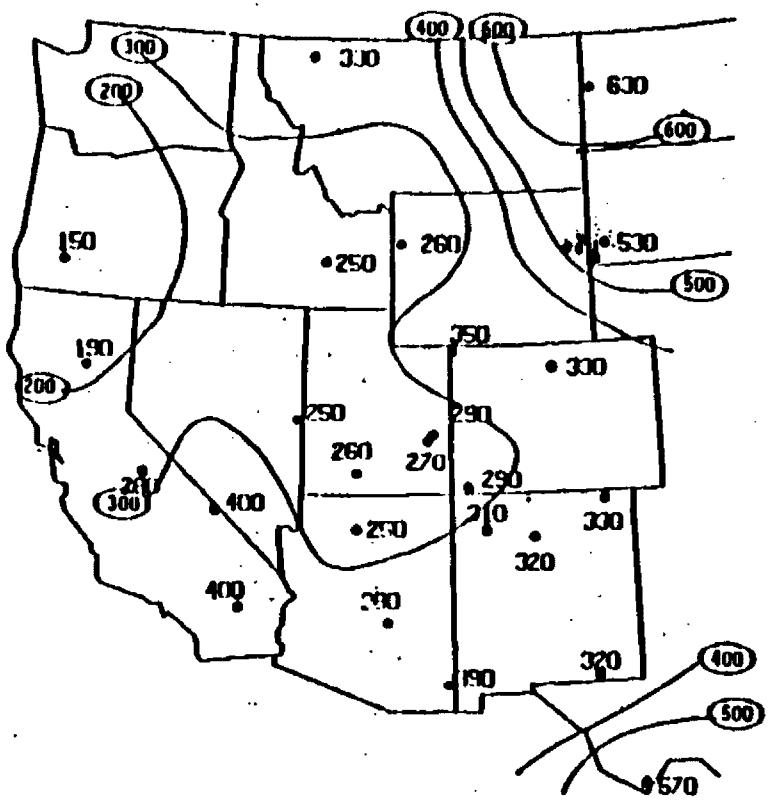


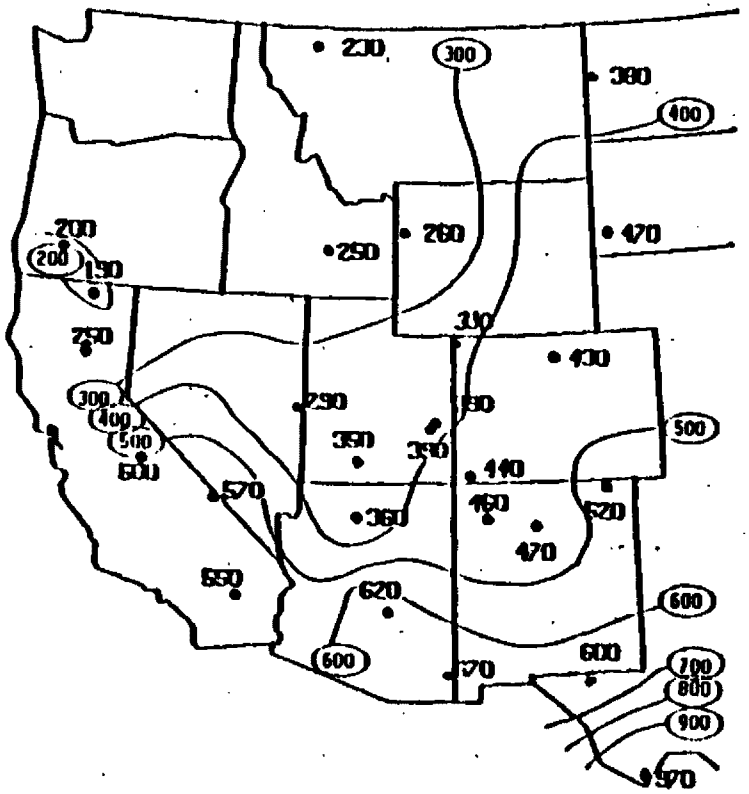
FIGURE A-15. Geographic distribution of coarse soil, fine mass, fine sulfate, and fine nonsulfate for summer 1983. Shenandoah's sulfate value is shown for comparison purposes.

NPS PARTICULATE MONITORING NETWORK
MAR - MAY 1983 (SPRING)
CONTOUR MAP OF FINE SULFUR



CONTOUR LINES SHOW REGIONS OF EQUAL CONCENTRATIONS
BASED ON INDICATED AVERAGES IN NANOGRAMS/M**3.
CONTOUR LEVELS AT EVERY 100 NANOGRAMS/M**3.

NPS PARTICULATE MONITORING NETWORK
JUN - AUG 1983 (SUMMER)
CONTOUR MAP OF FINE SULFUR



CONTOUR LINES SHOW REGIONS OF EQUAL CONCENTRATIONS
BASED ON INDICATED AVERAGES IN NANOGRAMS/M**3.
CONTOUR LEVELS AT EVERY 100 NANOGRAMS/M**3.

FIGURE A-16. Contour plots of fine sulfur for spring and summer 1983.

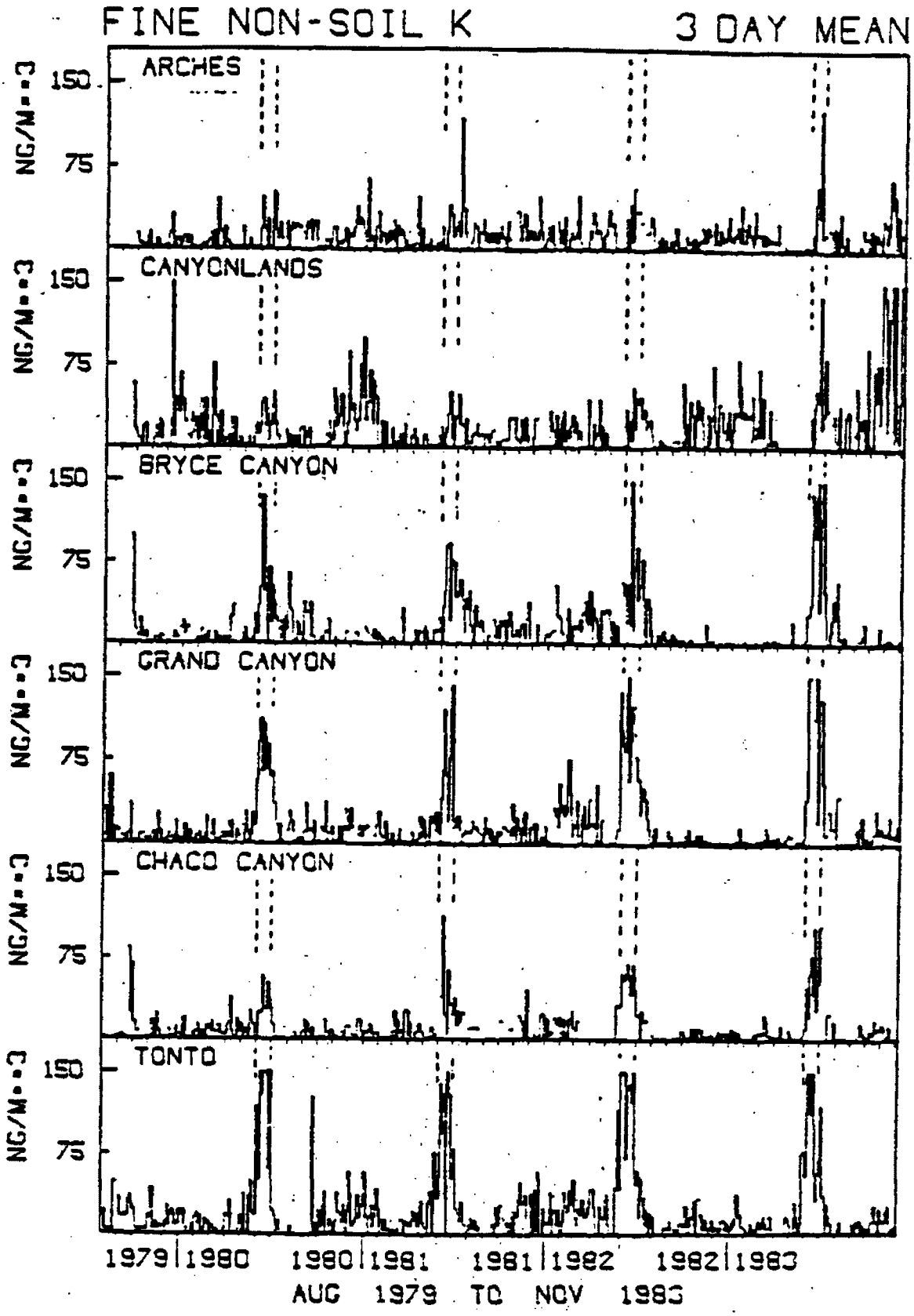


FIGURE A-17. Time plot of fine nonsoil potassium (K) for sites in Arizona, New Mexico and Utah.

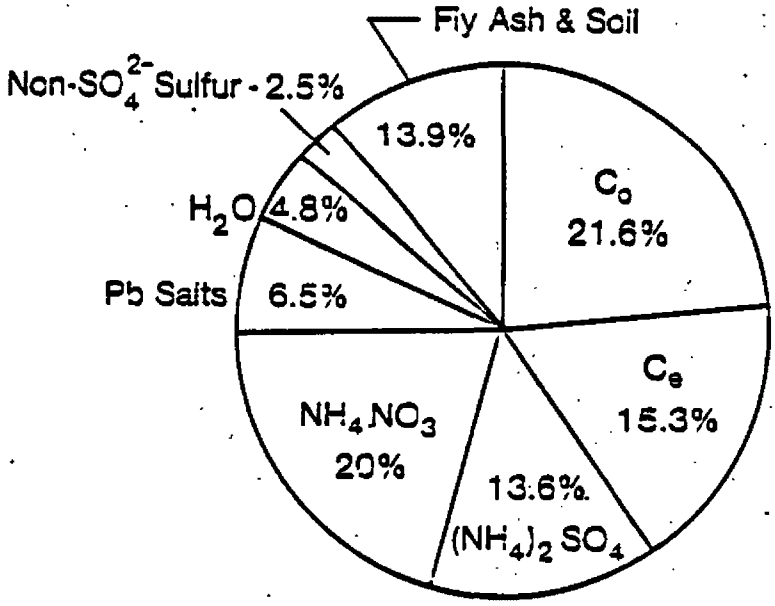


FIGURE A-18. Mean chemical composition of fine particulate mass of the Denver aerosol.

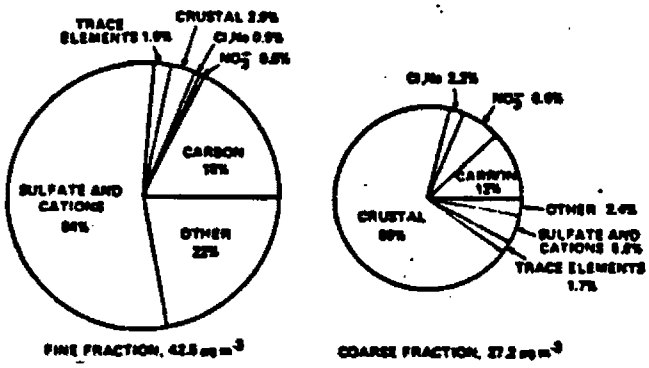


FIGURE A-19a. Eight-day average of daytime fine- and coarse-fraction mass concentrations apportioned by chemical species in Houston from September 11 to 19, 1980.

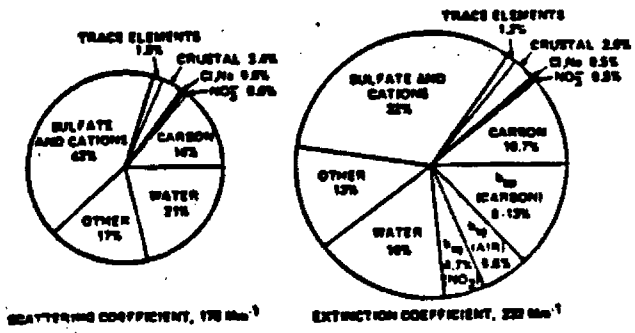


FIGURE A-19b. Eight-day average of daytime light scattering and extinction coefficients apportioned by chemical species in Houston from September 11 to 19, 1980.

The theoretical technique requires the size distribution and chemical composition of each aerosol species to calculate the aerosol extinction efficiency. This technique assumes that the size distributions of all species are properly measured and the properties of the mixture are known. Aerosol composition data are generally incomplete: specifically, current monitoring techniques do not properly account for water and other volatile aerosol components, nor do they allow for complete specialization of the various aerosol components.(24,25)

The second approach used for developing extinction budgets requires a longer-term data base. It is listed here as the statistical technique, in that it seeks to fit measured light extinction coefficient and species mass concentration data to a linear relationship (linear regression analysis). As with the theoretical approach, assumptions about aerosol optical properties are required. If the assumptions are satisfied, multiple regression analysis applied to measurements of the extinction coefficient and the masses of individual chemical species may be expected to yield reasonable estimates of the average species extinction efficiency.

A number of studies have employed multivariate statistical techniques to examine relationships between atmospheric extinction and various atmospheric pollutants.(5,15,39-44) Fewer studies have been designed to gather data necessary to theoretically calculate extinction budgets and still fewer experiments have been designed to gather the detailed aerosol data required to make theoretical extinction to mass calculations and at the same time conducted over a long enough time period to allow for a statistical treatment.(38)

Whether the analysis has employed a theoretical or statistical approach it is clear that man-made aerosols are responsible for a significant portion of visibility reduction. Many studies have demonstrated a high correlation between sulfate, fine particle mass and light scattering (15,45,46,47,48). This is not unexpected. Fine particles are much more effective than coarse particles in scattering light (46). Sulfate is more effective than other aerosol components in scattering light because of the large amount of water associated with it. As relative humidity increases sulfate particles grow into the size range which most effectively scatters visable light (46). Carbon aerosol or soot is also important because it both scatters and absorbs light (13). Nitrate may be important in areas where there is sufficient ammonia to neutralize all the sulfuric acid aerosol (45,49). Organic aerosol may also be important in some situations.

An example of the kind of study that has attempted to identify all components of the aerosol and calculate the light extinction associated with each component (41) depicted in Figure A-19. Sulfate was found to be the most important visibility reducing component. Sulfate becomes even more important when the ammonium ion and water associated with it are included. This study may have underestimated the volatile components-water, organic, and nitrate-because of difficulties in measuring them. Carbon is very important in urban areas in the winter because of increased use of wood and coal in home heating. The importance of sulfate will increase in rural locations and during low visibility episodes (50). In general, the

importance of primary aerosols such as carbon soot, lead particles, road dust, etc. will decrease at increasing time or distance from the point of emission while the importance of secondary aerosol such as sulfate, nitrate and organic will increase. This is because although both types of aerosols are removed by deposition processes, secondary aerosols continue to be formed.

Table A-1 is a summary of extinction budgets from several studies. In spite of city variations, sulfates and carbonaceous material seem to consistently be major contributors to urban extinction. For instance, it was found that in Denver 20% and 12% of the extinction is associated with sulfate and organic carbon while 38% is associated with elemental carbon.

Recent studies in western rural areas including Grand Canyon, Bryce Canyon, Canyonlands and Theodore Roosevelt National Parks, and China Lake in the Mohave Desert also yielded data that, when analyzed using regressional techniques, indicated sulfur aerosol to be the dominant light scattering component. These studies show sulfate aerosol was a major contributor to visibility reduction, responsible for 30% to 80% of the atmospheric scattering associated with particulates with scattering-or extinction-to-mass ratios between 0.004 and $0.010 km^{-1}/\mu g/m^3$. A typical extinction budget for these areas is shown in Figure A-20. Twenty percent of the extinction is due to coarse mass and only 17% to other fine mass. Other fine mass is made up of organic carbon, elemental carbon and nitrates.

The major difference between urban and rural extinction budgets is the importance of nitrates. Ammonium nitrate typically is responsible for more extinction in the urban setting. The extinction budgets obtained through regression analysis should be compared to those obtained theoretically. Figure A-21 shows a typical "theoretical" extinction budget for rural Southwest. Thirty and 33% of the extinction is attributed to organic carbon and ammonium sulfate respectively. Coarse material, primarily dust, contributes 15%, while 12% of the extinction is attributed to soot (forest fires).

Another study designed to allow for theoretical as well as statistical determination of the extinction budget was carried out in the Mohave Desert (China Lake).(38) Results of the theoretical calculations associated with this experiment showed that 32% of the extinction was associated with sulfates, 19% with organics, 11% with crustal material and 39% unaccounted for, while regression analysis suggested that 50%, 12%, 18% and 16% of the extinction budget was associated with sulfates, organics, crustal, and unaccounted for, respectively.

Notice that regression analysis typically suggests sulfates are more efficient scatterers and are responsible for more of the extinction than does the theoretical approach. Regression analysis also suggests that organics are a small part of total extinction while the theoretical approach indicates organic carbon to be responsible for as much as 30% of total extinction.

A very plausible explanation for inflated extinction to sulfur scattering efficiencies is that current particle monitoring techniques do not adequately capture volatile aerosols. If volatile aerosols such as water, ammonium

TABLE A-1. Percent Extinction Budget for Several Cities.

City	Sulfate	Nitrate	NO_2	Carbon	Crustal	Water	Other	Rayleigh
Anaheim, CA (White and Roberts, 1977)	39	19	-	9	-	-	33	-
Denver, CO (Groblicki et al., 1981)	20.2[a]	17.2[a]	5.7	37.7	-	-	6.6[b]	-
Houston, TX (Dzubay et al., 1982)	32	-	4.7	20.2	2.5	16	13	5.6
Detroit, MI (Wolff et al., 1982)	65[a]	-	4	20	-	-	4[d]	7
Denver, CO[c] (Hasan and Dzubay, 1983)								
MLR	10	6	8	62	-	-	9[b]	6
Constant Coefficients	4.7	6.7	8.7	59.5	-	-	14.6[b]	5.8
Mie External Mix	7	10	9	48	-	-	20[b]	6
Mie Internal Mix	6	10	9	48	-	-	21[b]	6
Shenandoah (Ferman et al., 1981)	78[a]	-	-	13	-	-	4	5
Louisiana (Wolff et al., 1981)	82[a]	-	-	-	-	-	18	-

[a] includes water
[b] includes crustal
[c] water not included
[d] includes nitrate and crustal
MLR = Multiple linear regression

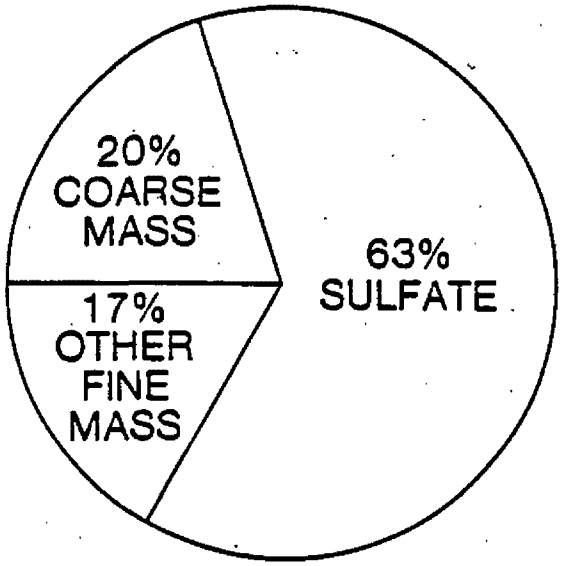


FIGURE A-20. Typical extinction budget for rural Southwest. (Grand Canyon, Arizona).

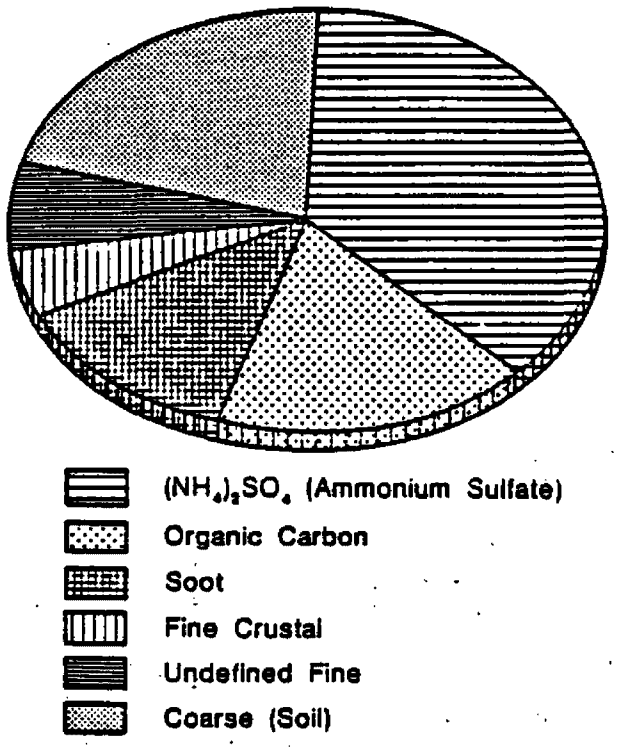


FIGURE A-21. Typical "theoretical" extinction budget for rural Southwest.

nitrate, organic aerosols, etc. are correlated with sulfate concentrations and are not captured by particle samplers, the result of a multiple linear regression analysis would be to artificially inflate $b_{ext}/[S]$ ratios. A very pressing research need is to explicitly examine the contribution of volatile aerosols to the overall extinction budget.

2.5 MODELING

2.5.1 Receptor Models

Once particles that contribute to visibility reduction are identified, it is of interest to determine their origin. Diagnostic receptor-oriented models have evolved as a clear alternative to source-oriented dispersion models.(51,52,53,54,55) Receptor models start with the measurement of a specific feature of the aerosol at the receptor, and after the fact calculate contributions of specific source types and/or source location. Historically, receptor models have been thought of in terms of chemical mass balance (CMB) analysis (or modifications thereof). If successfully applied, CMB achieves source apportionment but does not identify locations of source or source type. Recent developments in statistical treatment of back trajectory analysis techniques form another type of receptor modeling which identifies locations of various source types.(56).

Difficult questions arise as to the appropriateness of the various techniques. For instance, CMB requires among other assumptions, that source emission composition is known and that aerosols are non-reactive.(56) If sources that impact a receptor are hundreds of kilometers distant, identification of emission composition from all sources is impractical. Furthermore, over these distances, aerosols are created, change and are lost. The reaction mechanisms and rates for this evolution are not well understood. This is not to say that CMB cannot be used, but rather the conditions necessary for a specified degree of confidence must be clearly defined. Within proximity to the source, CMB has been used quite successfully.

On the other hand, back trajectory techniques have been applied quite successfully in remote areas such as the Colorado Plateau and western North Dakota region. Figure A-22 is an isopleth plot of the source contribution function (SCF) for "extreme" sulfur concentrations at Grand Canyon.(57) "Extreme" sulfur concentrations are defined to be those days when the sulfur concentration is 1 standard deviation greater than the mean. The geographic domain shown in Figure A-22 is subdivided into 1/2 by 1/2 degree grid cells. Each isopleth line corresponds to those grid areas that are associated with the same number of back trajectory end points. The numbers associated with each isopleth line is the probability that each grid area along the isopleth line will contribute to extreme sulfur contributions at Grand Canyon relative to the grid area that is most likely to contribute high concentrations. For instance, grid areas along the 0.73 line are 0.73 times as likely to contribute to high sulfur as the grid that has the highest source contribution value.

Based on this analysis, the major source of sulfate at Grand Canyon appears to be California's south coast air basin, not the copper smelter region in Southern Arizona as once assumed. Only under certain meteorological

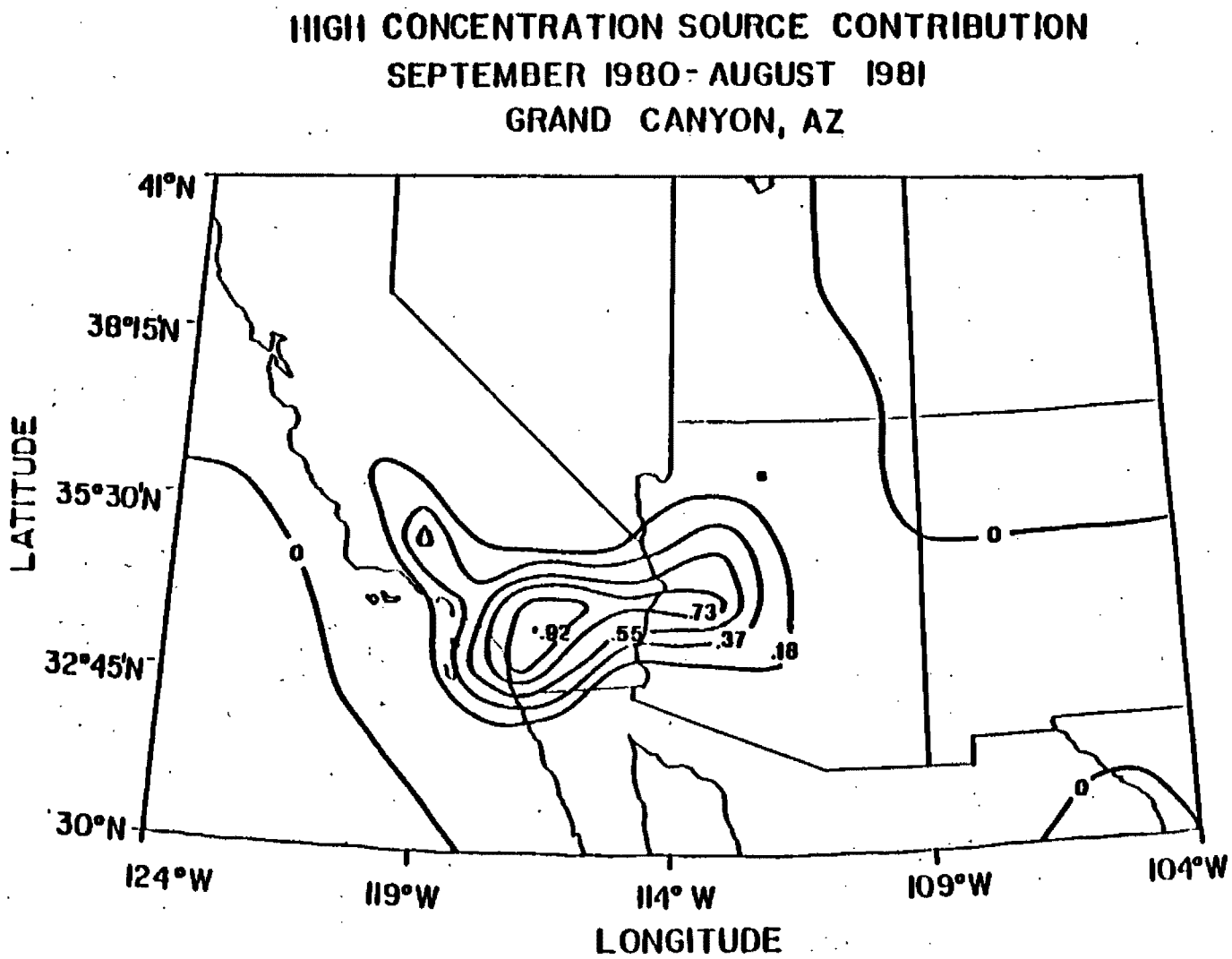


FIGURE A-22. Isopleth plot of the source contribution function (SCF) for "extreme" sulfur concentrations at Grand Canyon.

conditions do emissions from a smelter reach class I areas in the Colorado Plateau area.

Similar analysis for low sulfur days shows those source areas (or non-source areas) that correspond to air masses that arrive at Grand Canyon with low sulfur concentrations. To the north of Grand Canyon are those remote areas where there is an absence of urban centers or significant industrial activity.

Current thought concerning industrial siting criteria associated with new energy development suggests that extraction and processing of natural resources such as coal, tar sands, and oil shale should be carried out close to actual deposits. However, trajectory analysis suggests that the only days that Grand Canyon has clean air is when the air originates from those same areas that contain significant amounts of coal and tar sands. Development of industry that emits even small amounts of pollutants in either southern Utah or southern Colorado could impair the only remaining clean days that occur at Grand Canyon National Park.

Because back trajectory techniques rely on sparse meteorological data gathered by the National Weather Service, these techniques can only be expected to perform satisfactorily when applied to pollutant impacts that have their origin hundreds of kilometers distant from the receptors. They probably will perform poorly if impacts are due to sources that are less than 100km from the receptor site.

There is a need to understand the scale over which CMB and trajectory techniques are valid. When should analysis rely on CMB or trajectory techniques or when can they be used in combination? Ideally, new analysis techniques will evolve that will incorporate strong points of both approaches into one analysis technique.

One recent analysis did combine extinction budget analysis with receptor modeling techniques to determine a source extinction budget for a number of source categories at Lake Tahoe.(42) Results show a large seasonal variation in visibility impacts by wood smoke associated with residential heating. In a similar analysis, Albuquerque's overall contributions to extinction are as follows: mobile sources, 45.2%; wood burning, 51.6%; natural gas, 1.7%, and crustal, 1.5%. During the day, mobile sources dominate wood burning 78.2% compared to 19.0%, while during the night, wood burning dominates the mobile sources, 57.0% compared to 40.6%.(58)

Similar results were found in Denver, where no single source dominates visibility reduction.(5) Combustion sources, as a group, however, account for more than 80% of the visual range reduction (VRR). The largest contributor to VRR is motor vehicles which account for 27% VRR. Within this category, diesel trucks, which account for only 4% of the vehicle miles traveled (VMT), contribute 12% of the total VRR. These diesel truck particulates are dominated by elemental carbon which, by far, is the most effective visibility-reducing species. Light-duty catalyst vehicles which account for the largest part of the VMT (50%), contribute only 5% of the total VRR.

The second largest source category is coal combustion, which contributes 25% of the VRR. This source appears to be responsible for most of the sulfate (75%) and is the largest (39%) source of nitrate in Denver. Both of these species are secondary particulates, existing primarily as ammonium salts.

Based on a radiocarbon-dating technique and emissions testing, it is estimated that wood burning contributes 18% of the VRR during the winter in Denver. This source is the largest single source of both elemental carbon (39%) and organic carbon (29%) particulate in Denver.

Combustion of natural gas is estimated to account for 12% of the visual range reduction. These particulates, too, are essentially all carbon. Fuel-oil combustion contributes 8% of the VRR. The most important species from this source are elemental carbon, organic carbon and sulfate.

2.5.2 Predictive Modeling

Whereas receptor models tend to be used in a diagnostic sense--that is to determine the cause of visibility impairment--predictive models are used to determine visibility impacts of new proposed sources. Typically, visibility predictive models allow calculations of pollutant dispersion, chemical reaction between pollutants and between pollutants and "background" atmospheric constituents, and the effect that pollutants have on the ability to see a scenic vista.

Current models allow for prediction of the visual impact of plumes. (59,60,61) These models are typically built on Gaussian plume dispersion algorithms with subroutines to calculate chemical conversion of gases to optically active aerosols, and radiative transfer for specific lines of sight. These models have been evaluated by comparing model calculations and field measurements as part of a multi-agency funded research program. The evaluations indicate that plume visibility model performance is comparable to that of standard plume dispersion models and that most of the uncertainty in plume visibility models is in the specification of plume dispersion.

Plume visibility models and existing screening tools are inadequate to calculate cumulative regional effects. Regional visibility models are designed for this purpose.(62,63) These models utilize regional emissions and meteorology as input and calculate transport, dispersion, wet and dry deposition, chemical conversion, and resulting optical effects on a regional scale.

Several regional models have been applied to predict haze. Correlations with various indicators of experimental data vary from 0.4 to 0.8 (64,65). Problems in visibility models include those common to regional models plus the problems of going from an aerosol concentration to visibility.

Transport -- For realistic transport, models should use multilayer trajectories.

Dispersion -- Regional dispersion is governed by wind sheer and veer. The wind field derived from the twice daily NWS radiosondes is inadequate. Realistic dispersion requires more experimental detail, empirical parameterization, or theoretical wind field modelling to provide accurate interpolation.

Volatile Components -- Organic aerosol, nitrate aerosol and aerosol-bound water are not adequately measured by existing technology.

Carbon -- Carbon soot and organic aerosols are significant components. Emission inventories for soot, primary organic aerosols and aerosol forming organic vapors are inadequate. Chemical mechanisms and rates for the formation of secondary organic aerosols are not known well enough to predict organic aerosol formation. There is still some lack of agreement over appropriate technique for measuring aerosol absorption.

Size Distribution -- Aerosol dynamic models, especially for individual components, need further development.

Relative Humidity Effects -- Sulfate aerosols grow in size as relative humidity increases but the point of deliquescence depends on composition. As relative humidity decreases the point of crystallization (loss of water and change to solid) occurs at a lower RH the deliquescence (hysterisis). The RH at which crystal crystallization occurs may be very low (<10%) and depends on composition.

Relationship of Visibility to Aerosol Parameters -- Aerosol extinction can be calculated reasonably well from aerosol mass; however, it would be desirable to be able to do this for individual components.

Visibility Parameters -- There is no agreement as to which visibility parameters should be used when averages need to be calculated for comparison with data or for policy consideration-mean, median, upper quartile, number of days with visibility less than some value, or some other parameter.

Model Type -- Eulerian models permit use of detailed chemistry; Lagrangian models allow better depiction of source-receptor relationships. Monte Carlo models have advanced a useful compromise for some applications. However, there is no universal agreement of the best model or type of model to use.

Current models do not address certain transitional cases that produce ground based and layered hazes. During winter months, stable atmospheric conditions can persist for periods of between two and ten days. For instance, during winter months, ground based layered haze builds up in Glen Canyon (Lake Powell) to a point where portions of Navajo Mountain, as viewed from Bryce Canyon, disappear. Without adequate models, new source review processes cannot account for this potentially significant visibility impact. Consequently, there is a pressing need to develop predictive models that allow for determining visibility impact resulting from ground-based haze layers that are formed by pollutants emitted in stagnant air mass conditions.

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APPENDIX B. PROJECTING FUTURE REGIONAL VISIBILITY

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APPENDIX B. PROJECTING FUTURE REGIONAL VISIBILITY

1.0 INTRODUCTION

If we are to devise a sensible strategy to protect the air from visibility degradation, we need to estimate how large future emissions will be, where they will occur, and how they will affect visibility. To that end EPA has performed two major studies on future regional visibility. One looks at the 31-state region in the eastern U.S. that has been proposed as an acid rain control region. The other looks at a six-state region in the western U.S. that contains numerous Class I areas with pristine air quality.

Although these two studies do not cover every state in the U.S., they represent all types of visibility problems we are likely to encounter here. Ideally, we would like to study every region, but budgets are not adequate to allow us to cover such a broad area and still maintain the quality of analysis we want.

2.0 EASTERN STUDY

2.1 Description

As explained in Appendix A, visibility degradation in the eastern U.S. consists mostly of regional haze, a sort of soup, made up of pollutants from many sources that travel long distances and generally obscure the atmosphere. The largest single contributor to visibility degradation in the east is sulfates, secondary pollutants formed in the atmosphere from primary emissions of sulfur dioxide (SO2). Sulfates cause more than half of the light extinction in the East.

The eastern study looks at (1) current visibility, (2) expected visibility in 1995 if environmental regulations remain as they are now, and (3) expected visibility in 1995 if environmental controls on sources of SO2 emissions change.

The study was performed by Systems Applications, Inc. (SAI) of San Rafael, California, with two air quality dispersion models. The Regional Transport Model - Long Term (RTM-LT) is a long-term Eulerian model that does not consider near-source dispersion of spatial scales less than the size of an 80x80 km grid square. The Regional Impacts on Visibility and Acid Deposition (RIVAD) model is a plume-segment Lagrangian model that evaluates regional source-receptor relationships.

Visual range estimates are obtained from sulfate concentrations calculated by RTM-LT and RIVAD using theoretically and empirically

derived formulas. The study assumes that concentrations of nonsulfate species remain constant at 1977/1978 levels in all future control scenarios. Thus, only sulfate concentrations change in the control scenarios. Our results are limited by this assumption since the concentrations of other visibility-impairing pollutants may well change between the two study periods.

Evaluation of model performance showed that up to 60 percent of the variance in regional air quality is explained by the models used in this study. The evaluation was not capable of determining the ability of the models to predict specific source-receptor relationships, like the effect of emissions from a specific power plant on a specific National Park.

Estimates of emissions from most sources come from the National Emission Data System (NEDS) Snapshot Emission Inventory, developed for the National Acid Precipitation Assessment Program (NAPAP). However, because E.H. Pechan and Associates has more complete and accurate emission and stack data for electric utilities, SAI replaced the NEDS file with the Pechan file for that source. ICF, Inc., produced future emission estimates for the control scenarios.

SAI introduced seasonal variations in emissions by developing seasonal factors, one for each of four seasons, for utility, industrial, and area sources using the 1978 EPRI/SURE data base.

Emissions from sources outside the modeling region and emissions from sources within the region that are transported outside and then returned with changing wind direction are treated by assumed boundary conditions.

2.2 Study Results

Table B-1 presents SO2 emission estimates for 1980 and 1995 with no change in the regulatory status quo. Very little change in eastern U.S. and Canadian emissions is expected. Emissions in the entire region in 1980 were 24.1 million tons and in 1995 are projected to be 24.7 million tons. The differences in visual range calculated from the differences in emissions are concomitantly quite small. They are only about + 2 percent. (See Table A-2). This change is highly unlikely to be perceptible on an annual basis. Consequently, overall eastern regional visibility in 1995 will be about the same as it is today, unless a new emission control program is implemented.

In addition to estimating the change in visibility degradation in 1995 under the status quo, SAI examined several SO2 emission control scenarios that would improve visibility as well as other sulfur-related pollution problems such as acid rain. Reductions in SO2 emissions ranged from 3.8 to 12.0 million tons per year. Table 2 describes those scenarios. As expected, increasing improvements in visibility accompany further reduced SO2 emissions.

TABLE B-1. EASTERN SO2 EMISSIONS
(103 tons/year)

State	1980	1995
Alabama	751	695
Arkansas	102	203
Connecticut	69	70
Delaware	108	93
District of Columbia	10	7
Florida	1061	1268
Georgia	807	1005
Illinois	1455	1257
Indiana	2140	2145
Iowa	333	315
Kentucky	1142	969
Louisiana	300	485
Maine	95	99
Maryland	341	385
Massachusetts	327	331
Michigan	949	961
Minnesota	243	274
Mississippi	278	438
Missouri	1388	1383
New Hampshire	92	63
New Jersey	272	369
New York	943	855
North Carolina	612	651
Ohio	2660	2797
Pennsylvania	1978	1948
Rhode Island	15	7
South Carolina	323	387
Tennessee	1053	1146
Vermont	6	7
Virginia	355	415
West Virginia	1128	1172
Wisconsin	640	858
Total Eastern U.S.	21,976	23,058
Eastern Canada	2,108	1,625
TOTAL	24,084	24,683

TABLE B-2

SCENARIO	TARGETED STATES	Annual SO2 Reduction from 1980 (106 tons)
10-State	ME, VT, NH, MA, CT, RI, NY, PA WV, OH	3.8
12-State	Same as 10-state, plus IN, MI	5.2
12-State + 25% reduction in Canadian emissions	Same as 12-state, plus eastern Canada	5.6
31-State 8-million ton reduction	31 states east of and bordering on Mississippi River	8.0
31-State 12-million ton reduction	31 States east of and bordering on Mississippi River	12.0

Table B-3 shows percent improvements in visibility in 1995 for each of the emission reduction scenarios. The improvement in visual range is usually greatest in the middle Atlantic states (Delaware, Maryland, Virginia, and West Virginia), followed closely by New Jersey, Pennsylvania, Kentucky, North Carolina, New York, and Ohio. Visibility improvements for individual states range from none for Missouri in the 10-state control option to 32 percent in Maryland, Delaware, New Jersey, and Pennsylvania in the 12-million-ton control option.

The important question to ask is whether these changes in visibility are perceptible. For the 10-state control scenario, none of the time and state-averaged percent improvements in visual range reaches the 15 percent threshold of day-to-day perceptibility. In this case, the value of the SO2 reductions, in terms of visibility alone, would be near zero.

The costs of SO2 reduction in the U.S. for each of the control scenarios are presented below:

Scenario	Annualized Costs (billions of 1982 $/year)	$/ton SO2 Removed
10-state	2.0	349
12-state	2.4	348
12-state +25% Canada	2.4	348
31-state 8 million tons	4.3	371
31-state 12 million tons	9.8	667

As we increase the stringency of SO2 controls in each scenario, increasingly more states do reach perceptible changes in visibility and do reap positive economic benefits from controls. For the 12-million ton-per-year control scenario, 18 of the 31 states in the modeling region achieve perceptible improvement in summer visibility.

2.3 Major Uncertainties

It is important to note the limitations and uncertainties associated with the eastern analysis. Uncertainties in emisison projections, treatment of meteorological, transport and transformation processes, pollution-visibility relationships, and treatment of perception "thresholds" all impose significant limitations. The study is currently undergoing peer review. A detailed review of the study for the Utility Air Regulatory Group (Zanetti et al., 1985) concluded that the methods used "tended to provide estimates of visibility improvements and economic benefit that were greater

TABLE B-3. Improvement in yearly median visibility for different emission control scenarios.

State	1980 Visibility (km)	1995 Baseline Visibility (km)	Percent Improvement in 1995 Visibility: 10 State	12 State	12 State/25% reduction in Canadian-Emissions	31 State 8 million ton/yr.	31 State 12 million ton/yr.	Waxman-Sikorski	Current National Ambient Air Quality Standard	0.50 ppm Ambient Standard	0.25 ppm Ambient Standard
ALABAMA	14.4	14.3	1.9	2.6	2.6	6.5	9.1	5.7	1.5	2.6	5.6
ARKANSAS	14.6	14.6	0.2	0.5	0.6	1.5	2.2	1.5	0.4	0.7	1.3
CONNECTICUT	27.2	27.0	7.0	8.6	9.7	11.5	10.1	9.7	2.3	5.1	11.9
DELAWARE	25.1	24.0	12.6	15.3	16.2	21.1	30.6	18.6	3.0	8.0	20.6
GEORGIA	17.0	17.5	3.0	5.1	5.2	12.0	16.4	9.9	2.5	4.1	9.7
ILLINOIS	17.7	17.7	0.0	1.0	2.0	6.0	8.2	5.9	1.2	1.9	4.2
INDIANA	16.8	16.9	1.1	5.4	5.6	11.0	15.2	10.4	2.2	4.1	8.5
IOWA	20.7	20.7	0.4	0.5	0.7	1.4	1.9	1.3	-0.1	0.0	0.7
KENTUCKY	10.7	10.8	2.6	6.7	6.0	16.3	22.4	14.4	3.7	6.9	13.6
LOUISIANA	14.6	14.6	0.2	0.3	0.3	0.7	1.1	0.7	0.0	0.1	0.7
MAINE	33.5	33.0	2.0	3.6	4.0	5.0	8.0	4.3	1.0	2.1	5.0
MARYLAND	25.0	24.0	13.4	16.4	17.3	22.5	31.7	19.9	4.3	9.3	21.0
MASSACHUSETTS	20.5	20.6	4.7	6.0	7.1	8.3	13.9	7.0	1.6	3.6	8.9
MICHIGAN	18.0	18.6	2.0	4.4	5.0	7.0	11.0	7.2	0.8	2.3	5.6
MINNESOTA	24.5	24.5	0.2	0.3	1.1	0.6	1.1	0.6	-0.0	0.0	0.2
MISSISSIPPI	14.0	14.6	0.6	1.0	1.0	2.6	3.7	2.5	0.3	0.8	2.1
MISSOURI	18.0	18.2	0.1	0.6	0.7	3.0	5.0	3.9	1.4	1.9	3.3
NEW HAMPSHIRE	30.2	30.5	4.0	5.2	6.5	7.2	11.3	6.1	1.3	2.9	7.0
NEW JERSEY	25.3	24.9	9.7	11.6	12.5	16.0	24.7	14.0	2.6	6.5	16.0
NEW YORK	26.3	26.0	7.3	9.0	10.3	12.4	19.3	10.0	2.4	5.4	12.2
NORTH CAROLINA	17.1	16.9	5.5	7.9	8.1	14.7	20.7	12.2	2.6	5.3	12.9
OHIO	16.8	16.7	4.2	8.5	9.0	13.9	19.2	12.0	2.7	5.1	11.2
PENNSYLVANIA	19.1	18.8	9.0	12.4	13.2	16.3	22.9	15.1	3.3	6.4	14.6
RHODE ISLAND	27.6	27.5	6.0	7.5	8.6	10.2	16.3	8.4	2.0	4.4	10.7
SOUTH CAROLINA	17.5	17.3	4.6	6.3	6.5	12.0	17.0	10.6	2.3	4.4	11.2
TENNESSEE	15.7	15.7	1.9	3.9	4.0	10.4	13.9	9.4	2.7	4.9	9.2
VERMONT	30.4	30.7	4.2	5.4	6.9	7.3	10.9	6.3	1.4	2.9	6.0
VIRGINIA	24.7	24.3	11.3	14.7	15.3	23.6	33.3	19.8	4.3	8.9	20.9
WEST VIRGINIA	19.8	19.6	9.1	13.1	13.4	21.4	29.1	19.3	4.0	7.8	18.0
WISCONSIN	20.0	19.7	1.1	1.4	1.0	4.2	5.9	3.6	0.4	0.7	2.4
REGIONAL AVERAGE	20.1	20.0	4.5	6.6	7.1	11.1	15.0	9.9	2.1	4.3	9.7

than one might derive using unbiased estimates of emissions reductions, nonlinear atmospheric chemical reactions, the extinction efficiency of sulfate-containing particulate matter, intrinsic contrasts of targets, the range of human thresholds of response to visibility changes, and the economic value of visibility. We thus conclude that the SAI visibility improvement percentages tend to be close to the upper limit of our confidence range and, compared to our best unbiased estimate, they over-estimate visibility improvement by 50% for both the 8 MTPY and the 12 MTPY scenarios." The SAI authors have reviewed this critique and, while agreeing with some points, reject its major findings and feel their original analysis does not overstate visibility improvements. Based on the examination of the contribution of sulfates to eastern haze in Appendix, it could be argued that some components of the SAI work understate visibility improvements, while others may overstate sulfate reductions. Resolution of the implications of the uncertainties and potential biases following the peer review is of major importance. Based on the assessments to date, uncertainties in dealing with perceptibility of visibility changes appear more influential than the remaining uncertainties combined.

3.0 WESTERN STUDY

3.1 Description

The study projecting regional visibility in the West focuses on the six states of California, Nevada, Utah, Arizona, Colorado and New Mexico. These states contain over half of the Class I areas in the country, including the Golden Circle where many areas enjoy pristine air quality.

This study thus omits the Pacific Northwest, an area that is subject to periodic visibility degradation from controlled and uncontrolled fires. Controlled burning by farmers to manage soils and by foresters to manage forests and forestry, along with uncontrolled wild fires, emit large amounts of smoke. This smoke consists mostly of fine particles that are very efficient at obscuring the atmosphere. Hence, the Pacific Northwest suffers severe episodes of visibility degradation. An ongoing study (PANORAMAS) is investigating the frequency, extent, and sources of haze in that region. Other regions of the west contain fewer class I areas and do not report substantial haze problems.

The objective of the western study was to model current (1980) and projected (1995) visibility conditions in the six western states mentioned above and to calculate different source and pollutant contributions to visibility degradation. While the eastern study examined only the effects of sulfur dioxide emissions on visibility, the western analysis looked at the effects of volatile organic compounds (VOC), oxides of nitrogen (NOx), and particulate matter (PM) as well.

In the first phase of the study, E.H. Pechan and Associates, Inc. developed and refined detailed emission estimates for 1980 and 1995. Pechan used the NAPAP emission inventory as the primary source of data for total PM, SO2, NOx, and VOC. Where appropriate, however, data from other sources were substituted for the NAPAP data. For example, up-to-date EPA emission estimates for copper smelters and woodstoves were substituted, as were USDA Forest Service estimates for particulate emissions from wildfires and controlled burning.

Where possible, Pechan broke the four pollutant classes into those constituents which have the greatest impact on visibility. Total VOC emissions were partitioned into individual species, and the individual species emissions were then grouped into reactivity classes (e.g., olefins, aromatics, etc.). Primary sulfate emissions were estimated, and PM emissions were broken down into particle size distributions of less than 2.5 um, between 2.5 and 10 um, and greater than 10 um.

To project emissions to 1995, Pechan employed the Environmental Trends Analysis Model (ETAM), a model which they originally developed to assess the environmental implications of alternative energy futures. The method used to project emissions varied among the different source categories examined. For example, utility projections were made by using data on planned utility installations (e.g., unit size, fuel type), and by linking these data to various assumptions regarding service life, capacity factors, and other relevant parameters. Smelter emission projections consisted of two scenarios: one scenario assumed that smelters would control SO2 emissions by 1995, the other assumed that 1995 emissions would equal current emissions. The USDA Forest Service provided growth estimates and emission factors for wildfire and controlled burning PM emissions. Area source emissions were scaled up or down according to population projections. Emissions from refineries and other major industrial point sources were scaled by projected changes in industry earnings.

The western analysis is preliminary and has undergone only limited review to date. Substantial uncertainties exist in emissions inventories and projections, modeling tools and inputs, and extent of verification to date. The results should be viewed in light of these uncertainties and limitations.

3.2 Study Results

3.2.1 Emissions Projections

Tables B-4 and B-5 present emission figures by source for input to the western visibility model.

Next to fugitive dust, which is always the overwhelming contributor to total particulate emissions, burning and motor vehicles are the primary sources of PM. The greatest uncertainty

TABLE B-4. 1980 regional emissions. (SAI, 1985)

REGIONAL	1980 EMISSION TOTALS (1000 Tons/Yr)					
Source	Particulates			Gaseous Precursors		
Type	Total	PM10	SCOT	SOx	NOx	VOC
Utilities	72.9	67.0	0.0	469.6	585.0	4.3
Smelters	5.0	4.7	0.0	1405.2	4.5	0.1
Refineries *	58.7	51.9	0.0	364.3	115.6	159.7
Other Industrial	172.5	142.2	0.0	190.3	276.2	222.3
Residential/Comm	168.4	126.2	0.0	52.2	255.6	308.7
Gasoline Vehicles	640.5	417.3	10.3	30.4	617.3	1011.1
Diesel Vehicles	56.7	41.4	11.9	33.6	404.0	74.8
Other Mobile	30.6	28.5	0.0	79.1	172.7	114.1
Evaporative	0.0	0.0	0.0	0.0	0.0	888.2
Fugitive Dust	4785.2	2153.2	0.0	0.0	0.0	0.0
Pres Burns/F.F.	793.2	713.7	317.2	1.3	37.7	213.4
Wood Stoves/F.P.	17.7	17.6	6.1	0.1	0.7	1.2
TOTAL	6801.5	3763.8	345.5	2626.1	2469.3	2997.9

*In this and other tables, "refineries" represents emissions from all petroleum industry sources, including refineries and oil-field operations.

TABLE B-5. 1995 regional emissions. (SAI, 1985)

REGIONAL	1995 EMISSION TOTALS (1000 Tons/Yr)					
Source	Particulates			Gaseous Precursors		
Type	Total	PM10	SOOT	SOx	NOx	VOC
Utilities	38.3	31.9	0.0	485.8	893.7	7.2
Smelters	9.6	9.0	0.0	1420.2	7.8	0.1
Refineries	70.3	62.2	0.0	377.1	112.3	195.1
Other Industrial	266.4	219.7	0.0	310.5	424.2	333.1
Residential/Comm	186.4	139.7	0.0	53.7	289.8	339.7
Gasoline Vehicles	716.6	453.9	16.7	32.5	291.0	278.8
Diesel Vehicles	178.9	123.2	26.0	65.2	263.5	69.3
Other Mobile	40.2	37.4	0.0	103.5	227.2	150.1
Evaporative	0.0	0.0	0.0	0.0	0.0	871.2
Fugitive Dust	4785.2	2153.2	0.0	0.0	0.0	0.0
Pres Burns/F.F.	1189.7	1070.6	475.8	2.0	56.6	320.2
Wood Stoves/F.P.	38.3	38.1	13.3	0.2	1.5	2.6
TOTAL	7519.8	4338.8	531.9	2850.5	2567.7	2567.5

in the emissions inventory lies in the category of prescribed burning and wildfires. Substantial variation in particulate emission factors from various agencies exists for burning activities. For modeling purposes, SAI used the U.S. Forest Service emission factors of 100 lb/ton consumed by wildfire and 50 lb/ton consumed by prescribed burning. In addition, they partitioned particulate emissions into 70 percent < 2.5 um; 20 percent between 2.5 and 10 um; and 10 percent > 10 um.

Approximately 70 to 80 percent of the region's VOC emissions and 60 to 70 percent of the region's NOx emissions occur in the major urban areas and come from motor vehicles and various residential, commercial, and industrial sources located in those areas.

Copper smelters contribute 54 percent to the region's loadings of SO2 with utilities and petroleum industry sources contributing most of the rest. In spite of the projected 51 percent reduction in U.S. copper smelter emissions, total regional copper smelter SO2 emission are expected to remain fairly constant because of the projected significant increases in SO2 emissions of 680,000 tons per yer at two smeltrs in northwestern Mexico.

Table B-6 summarizes the percentage changes from 1980 to 1995 in regional emissions by source category for each chemical species. Particulate emissions for all source categories were projected to increase from 1980 to 1995, except utilities, for which particulate emissions were projected to decrease by approximately 50 percent. This decrease is largely attributable to particulate controls at the Four Corners power plant. Total PM-10 and soot emissions were projected to increase by 15 and 54, respectively. Total SO2 and NOx emissions would increase by only 9 and 4 percent, respectively. Primarily because of hydrocarbon controls on new motor vehicles, total regional VOC emissions were projected to decrease by 14 percent between 1980 and 1995.

3.2.2 Source Apportionment

Fine particles, including sulfates, nitrates, organics, and elemental carbon (soot) contribute most of the anthropogenic visibility impairment in the Southwest. Per unit mass, fine elemental carbon (soot) is most effective in causing visibility impairment because it both scatters and absorbs light. Sulfate and nitrate are also very effective because they are often associated with liquid water within the aerosol droplet, which increases the effective scattering area of the aerosol. Organic and elemental carbon aerosol is emitted directly from combustion sources, while some organics and most sulfate and nitrate are formed in the atmosphere from direct emissions of VOC, SO2, NOx.

The contribution of nitrate aerosol is difficult to predict because nitrate can exist as either nitric acid vapor, which does not impair visibility, or as ammonium nitrate aerosol, which very

TABLE B-6. Percentage changes in regional emissions by source category. (SAI, 1985)

REGIONAL	PERCENT CHANGE IN EMISSIONS FROM 1980 TO 1995					
Source	Particulates			Gaseous Precursors		
Type	Total	PM10	SCOT	SOx	NOx	VOC
Utilities	-47.5	-52.4	0.0	3.5	52.8	68.3
Smelters	91.1	91.2	0.0	1.1	73.9	81.6
Refineries	19.7	19.7	0.0	3.5	-2.9	22.2
Other Industrial	54.4	54.4	0.0	63.1	53.6	49.8
Residential/Comm	10.7	10.6	0.0	2.9	13.4	10.0
Gasoline Vehicles	11.9	8.8	62.0	6.6	-52.9	-72.4
Diesel Vehicles	215.4	197.6	118.4	94.0	-34.8	-7.3
Other Mobile	31.2	31.2	0.0	30.8	31.5	31.5
Evaporative	0.0	0.0	0.0	0.0	0.0	-1.9
Fugitive Dust	0.0	0.0	0.0	0.0	0.0	0.0
Pres Burns/F.F.	50.0	50.0	50.0	52.7	50.2	50.0
Wood Stoves/F.P.	116.4	117.1	117.9	217.6	127.2	122.1
TOTAL	10.6	15.3	53.9	8.5	4.0	-14.4

efficiently scatters light. The vapor/aerosol distribution depends on the ambient temperature, relative humidity, and concentrations of sulfate, nitrate, and ammonia. Although ammonia concentrations in the Southwest are variable and uncertain, there appears to be enough ammonia to form nitrate aerosol. Nitrate aerosol, however, is unstable and can volatilize at high ambient temperatures.

The modeling results suggest that much of the visibility impairment can be explained by the known anthropogenic emissions in the region in many nonurban areas of the Southwest, however, natural sources including blue-sky Rayleigh scatter, terpene-related organics, and soil dust contribute more than half of total extinction. Table B-7 lists the relative contributions of various chemical species to visibility degradation in urban and nonurban areas.

Figure B-1 presents current annual average visual range throughout the study region as modeled by SAI. The best visibility is in the northern and eastern parts of the area while the worst visibility occurs in California around large urban areas.

Sulfate is the species that contributes most to regional visibility impairment in the Southwest. In most areas sulfate aerosol contributes 50-60 percent of anthropogenic visibility impairment. In California and in the area in which most of the copper smelters are located and during summertime episodes throughout the region, sulfate is predicted to contribute even more (70-80 percent, See Figure B-2).

The next most important species is nitrate aerosol, which contributes up to 25 percent of anthropogenic extinction in many parts of the region. However, nitrate's contribution is very uncertain because it is volatile and difficult to predict. Although anthropogenic organic and elemental carbon aerosol appears to be a significant contributor to urban haze, this analysis suggests that these species are a relatively small contributor to regional haze (less than 10 percent). Biogenic organics (terpenes) appear to contribute more to visibility impairment than do anthropogenic organics in most parts of the region.

3.2.3 Visibility Projections

For future projections of western visibility, under the base scenario in most of the region, 1995 sulfate concentrations will be approximately the same as or slightly lower than 1980 concentrations. Significantly increased nitrate aerosol concentrations are predicted in large portions of the Four Corners states because of increased NOx emissions from urban areas and power plants. Soot concentrations are predicted to approximately double in much of the region because of assumed increases in the use of prescribed burning and diesel vehicles. Total PM-10 concentrations would

TABLE B-7. Percent contributions of various species to light extinction in "typical" urban and nonurban atmospheres. (SAI, 1985)

Species	Percent of Total Extinction		Percent of Anthropogenic Extinction	
	Urban	Nonurban	Urban	Nonurban
Blue-sky Rayleigh scatter	5.3	44.3	0	0
Fine Particles (< 2.5 μm)				
$SO_4^{=}$ (+ H_2O)	14.8	17.7	16.0	52.6
NO_3^- (+ H_2O)	6.3	0	6.9	0
Elemental carbon	34.2	5.8	37.2	17.1
Primary organic carbon	14.2	2.7	15.4	7.9
Secondary organic carbon	3.2	13.3	1.7	0
Other	9.5	1.3	10.3	3.9
Subtotal	82.2	40.8	87.5	81.5
Coarse particles (PM-10)				
Soil dust	0.6	5.3	0	0
Anthropogenic	1.9	5.3	2.1	14.3
Subtotal	2.5	10.6	2.1	14.3
Other TSP (> 10 μm)	1.1	3.5	0.7	0
Nitrogen dioxide gas (NO_2)	9.0	0.9	9.7	2.6
Total	100.0	100.0	100.0	100.0

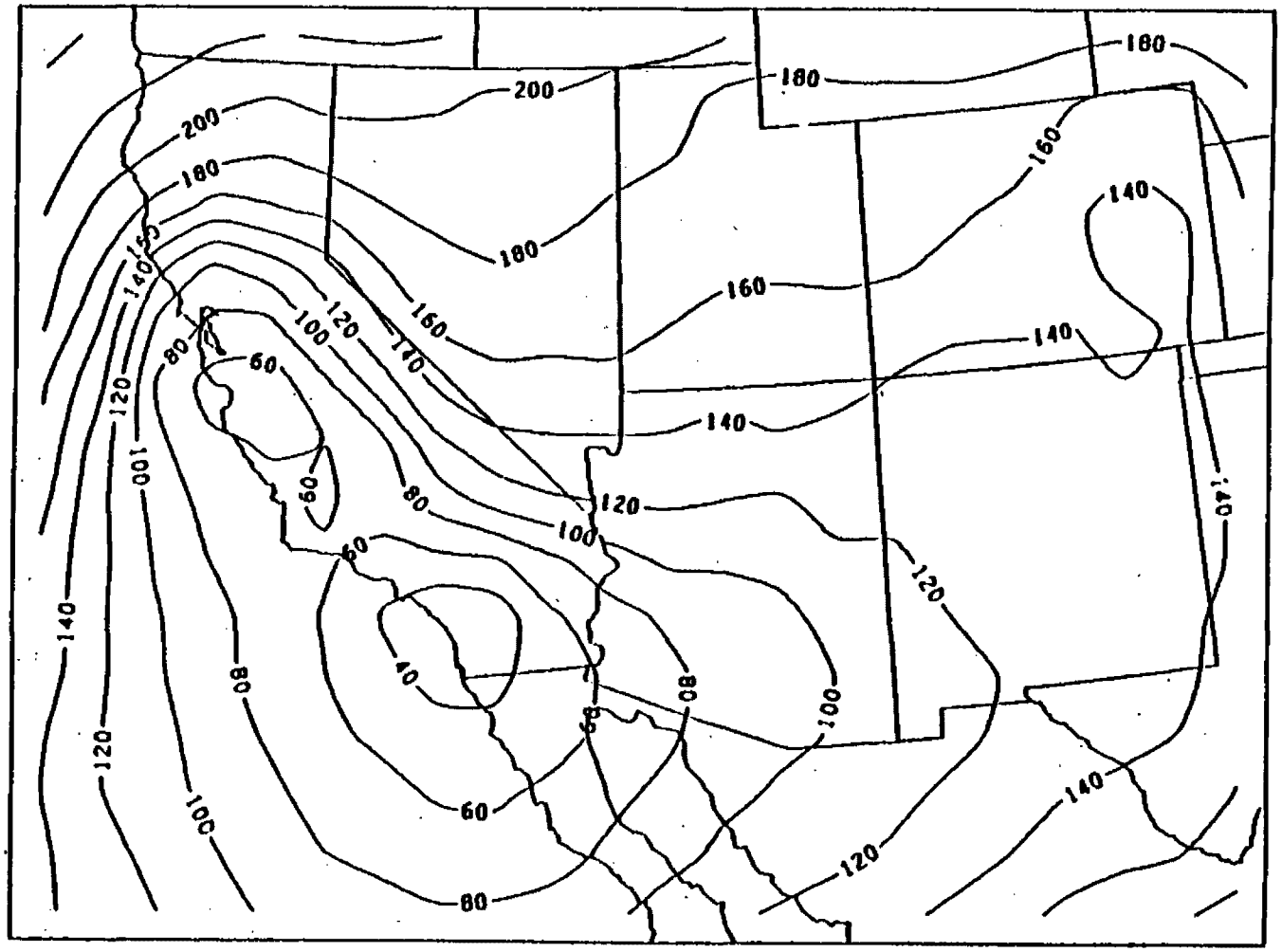

FIGURE B-1 . Annual average visual range (km) for 1980. (SAI, 1985)

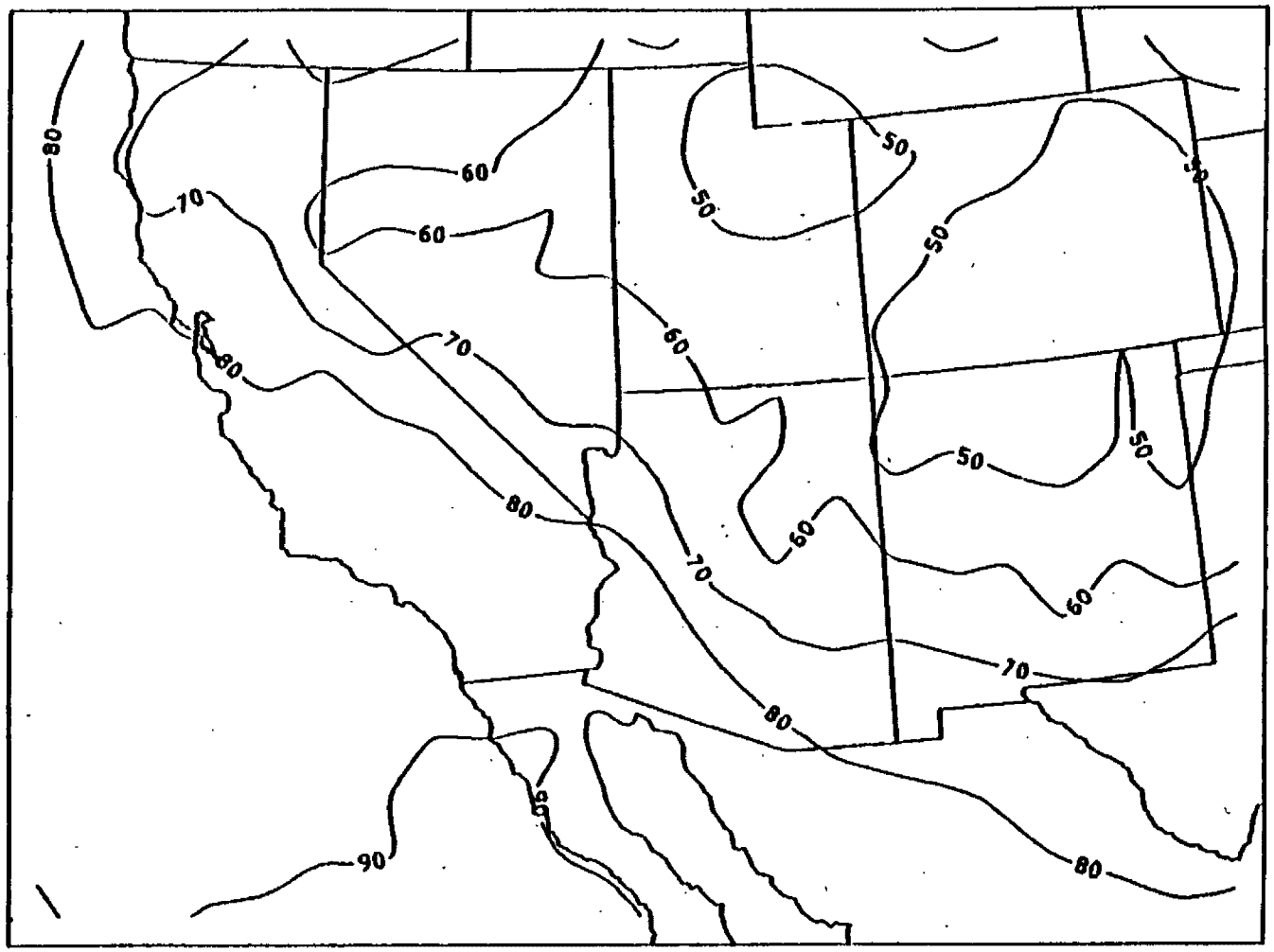

FIGURE B-2 . Percent contributions of SO4 to total anthropogenic annual average light extinction, for 1980. (SAI, 1985)

increase somewhat in the region. The maximum SO2 concentration in the region in 1995 will occur in Mexico because of significant increases in Mexican smelter emissions. (Decreases in U.S. smelter SO2 emissions are expected to be totally offset by increases in Mexican smelter emissions.) Because patterns of wet and dry sulfur deposition will move south, impacts in the sensitive areas of the Rocky Mountains are predicted to decrease slightly. Anthropogenic light extinction in California will decrease from 1980 to 1995, but in the rapidly growing areas of the Southwest it is predicted to increase, primarily as a result of increased NOx and soot emissions. However, these projections are highly uncertain because of uncertainties in current and future soot emission inventories and nitrate aerosol model input information.

Figure B-3 shows that regional visibility is projected to improve somewhat (2-20 percent) in California and Nevada but is projected to decline by roughly 5-10 percent in the Four Corners states. These subregional patterns are the result of local decreases and increases, respectively, in SO2 and NOx emissions that are projected to cause 70-80 percent of regional man-made haze.

As a variation on the 1995 base scenario, SAI evaluated the impacts associated with a low regional SO2 emission scenario for 1995 by starting with the 1995 base-case emissions but assuming an 80 percent SO2 emission cutback at the two Mexican smelters and the two largest coal-fired power plants (Mohave and Navajo). Sulfate concentrations in southern Arizona would drop from 2.5 to 1.5 ug/m3, or about 30 percent. Nonurban sulfate concentrations in national parks and wilderness areas in Utah, Arizona, and Colorado would drop 5-15 percent. Anthropogenic light extinction in souther Arizona would decrease nearly 20 percent, resulting in a 10 percent improvement in visual range. More typically, regional visibility would improve only slightly (<5 percent) compared to the base 1995 scenarios. (See Figure B-4).

Another variation on the 1995 base scenario was a high emission case where, in addition to the 1995 base emissions, SAI assumed that U.S. copper smelter emissions were not controlled in the period from 1980 to 1995 and that a large synfuel industry was developed in Utah and Colorado. The latter assumption is unrealistic for 1995, but reflects potential increases in the long-term future. The much larger U.S. copper smelter SO2 emissions would result in regional sulfate increases of 5-20 percent. Wet sulfur deposition in the Rocky Mountains would be 20 percent larger than the 1995 base, at an annual rate of 3 kg/ha sulfur. Light extinction in much of the region would be increased significantly, with large increases (up to 16 percent) in southern Arizona and New Mexico, and largest increases (up to 40 percent) in the oil shale development areas of Utah and Colorado. Visual ranges would be decreased significantly from the 1995 base by 2-8 percent in the southern Arizona area to 10-16 percent in the oil shale development area. (See Figure B-5).

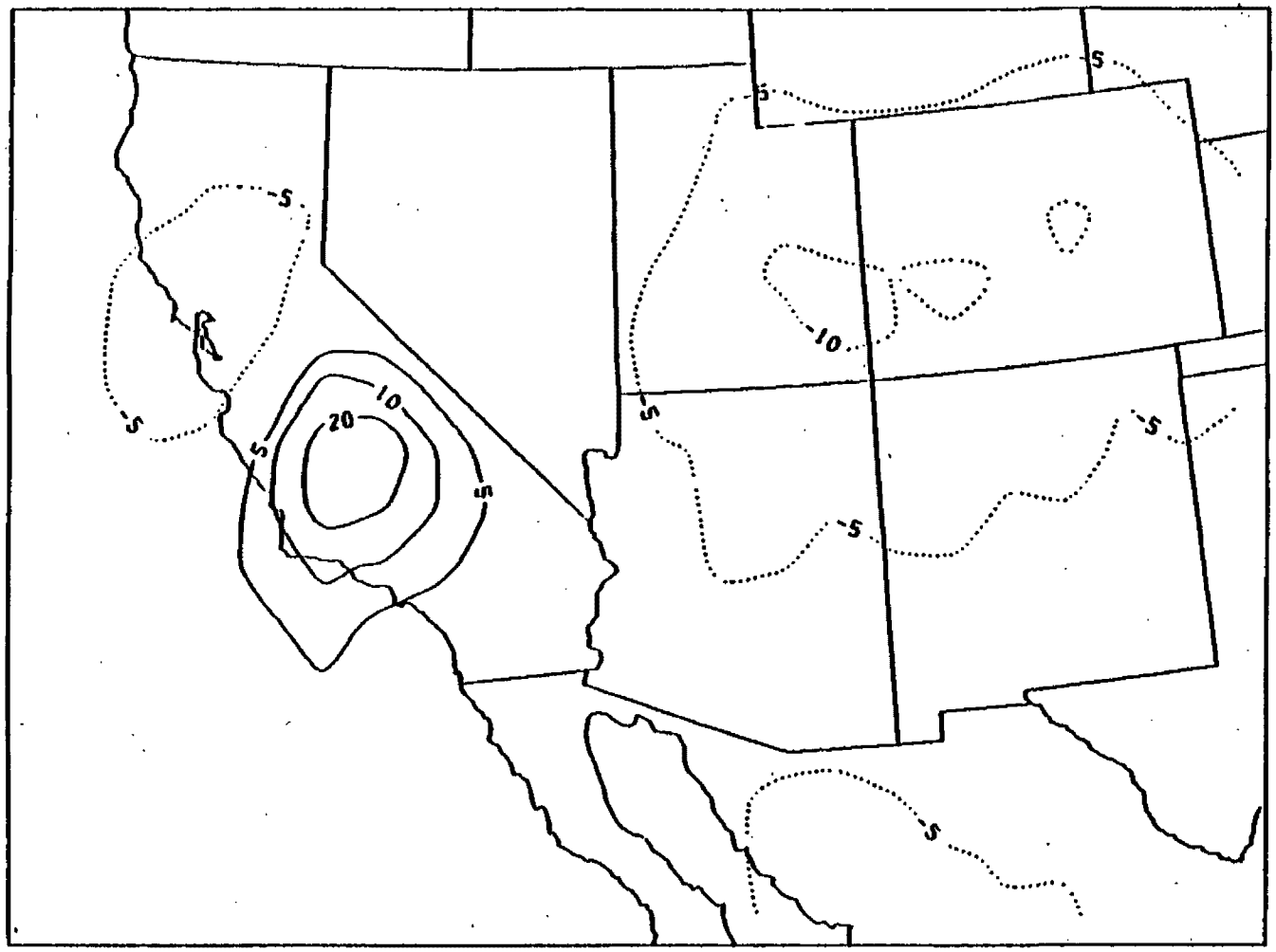

FIGURE B-3 . Percent change in annual visual range from 1980 to 1995 (base scenario). (SAI, 1985)

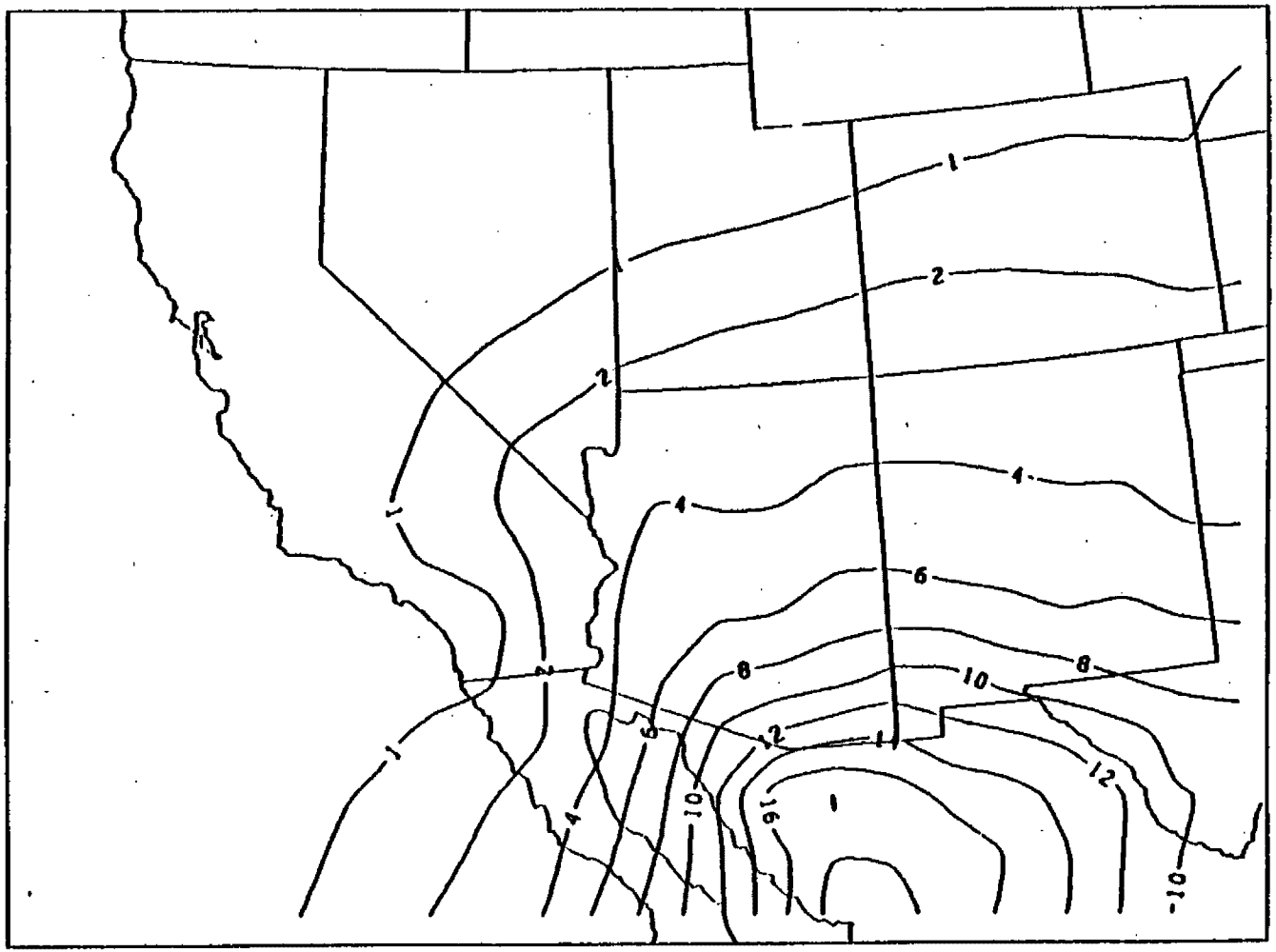

FIGURE B-4 . Percent change in annual visual range from 1995 (base) to 1995 (low emission scenario). (SAI, 1985)

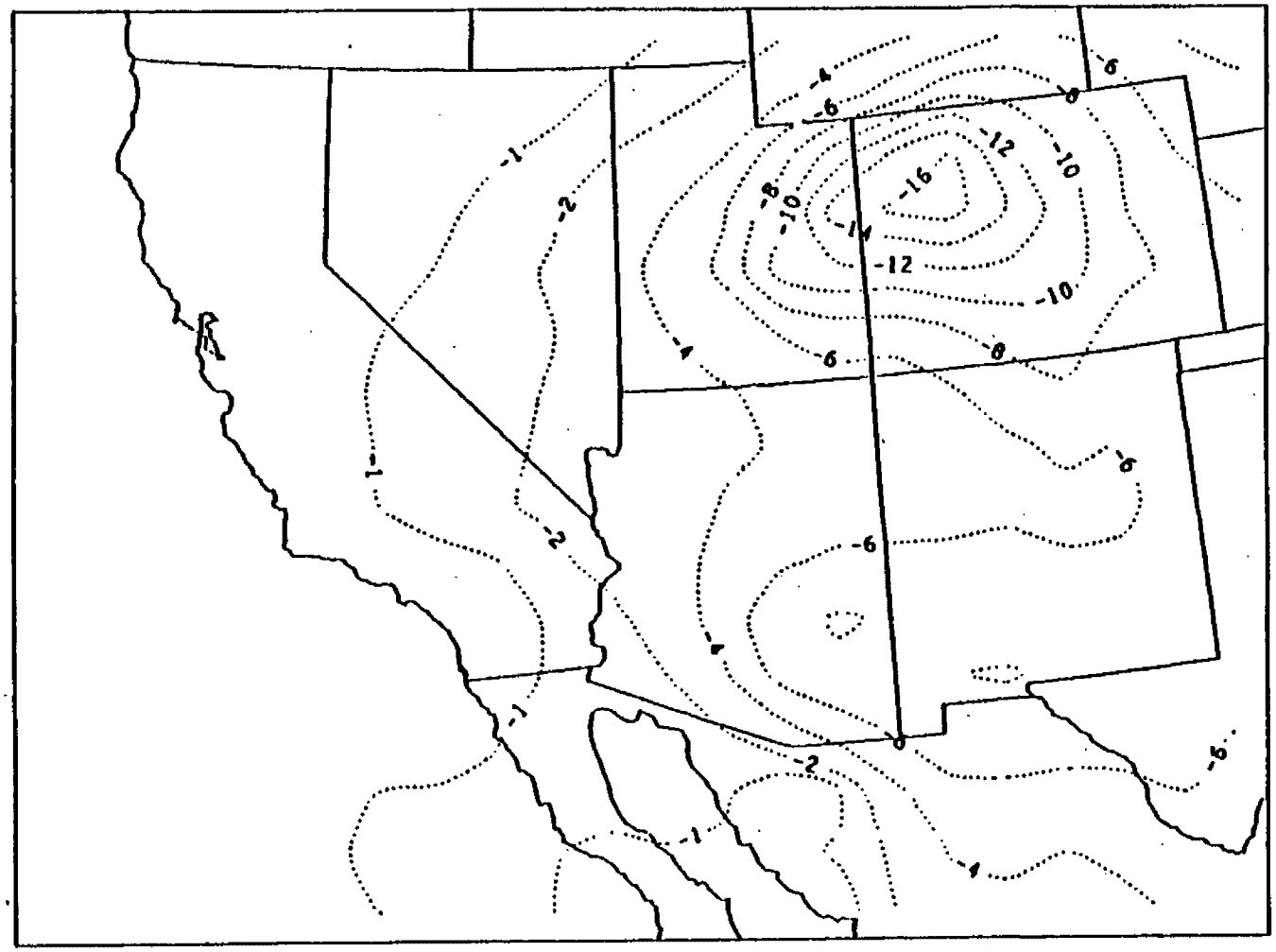

FIGURE B-5 . Percent change in annual visual range from 1995 (base) to 1995 (high emission scenario). (SAI, 1985)

On the basis of this analysis, SO2 and NOx emission controls would have the greatest potential beneficial effect on regional haze in the Southwest. Although there is concern that the projected increase in the use of diesel vehicles and wood stoves will increase local urban haze, these source categories appear to be relatively insignificant contributors to visibility impairment on a regional scale. However, more work is needed to develop and refine soot emission inventories and regional soot concentration estimates. The analysis of impacts of controlled burns and wildfires is highly uncertain; however, over the long run, burns appear to be relatively small contributors to haze compared to anthropogenic sulfate and nitrate aerosol.

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APPENDIX C. VALUE OF VISIBILITY

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APPENDIX C. VALUE OF VISIBILITY

1.0 INTRODUCTION

Regional haze can affect public welfare in essentially two areas: 1) the subjective enjoyment of the environment (aesthetics, general well being) and 2) transportation. Evidence on such effects can be drawn from studies of perception and awareness of air pollution and scenic beauty, assessment of psychological values, economic studies, and visibility requirements for air draft operation and related activities. Key examples are illustrated in Table 1. Detailed discussions prepared by task force members in each of these major areas are presented in the following sections. The available information taken together indicates that the public is concerned about visibility and is willing to pay for maintaining or improving air quality in a variety of consequences. This ability to capture this value in comprehensive and reliable quantitative terms is, however, limited.

2.0 PERCEPTION AND PSYCHOLOGICAL VALUES

2.1 Perception

A number of visibility "perception" studies have been carried out over the past 50 years. Investigators in the 1940's, 50's and 60's primarily concerned themselves with determining the contrast threshold of the human eye as a function of background illumination, target size, and time searching for the target. An important result of this research is that threshold contrast is constant over a wide range of background luminance. However, as early as 1947, Hecht reported variations in contrast threshold as a function of size and shape. They found that square objects are more easily seen than line objects. Taylor investigated the effect of target size in some detail. He found that for targets viewed in daytime and 1/2 degree or more in angular size, the threshold contrast ws 0.025 (1/3-sec. research time)(1). More recently a number of investigators have investigated in detail the threshold contrast sensitivity of the human eye brain system to a grating pattern whose brightness varies in a sinusoidal fashion. Results of this work show that the eye brain system is most sensitive to spatial frequencies of around 2 to 3 cycles per degree (2).

Whereas work discussed in the previous paragraph has emphasized detection thresholds, other researchers have concentrated their efforts in establishing the change in image appearance required to just noticeable difference (JND) in image sharpness. This work has primarily been detected toward incorporating results of basic psychophysical measurements into models which will predict the change in display modulation transfer functions (MTF) required to evoke a one JND in display image sharpness. An integral component of the JND calculation is the establishment of the image mean square luminance fluctuation, termed the image modulation depth, Henry has suggested that JND's and modulation depth may be appropriate visibility indices that incorporate all of the information content in a scenic vista (3).

TABLE 1. SUMMARY OF QUALITATIVE EVIDENCE FOR VISIBILITY RELATED VALUES

	Effect of Increased Visibility	Affected Groups	Supporting Observation
Aesthetic:			
Perception	Decreased perception of air pollution		
	a) urban settings	Substantial percentage of general population; urban areas	Perception of air pollution in Los Angeles significantly related to visibility for all averaging times (Flachburt and Phillips, 1980) Perceived visual air quality significantly related to particle scattering (Middleton et al., 1984)
	b) natural settings	Outdoor recreationists, campers, tourists	Visual air quality related to awareness of haze for Grand Canyon visitors (Ross et al., 1984) Scenic Beauty estimates related to contrast transmittance (Malm et al., 1981)
	Improved view of night sky	Amateur astronomers, other star watchers	Decrease in star brightness by fine particles (Leonard et al., 1977)
Economic Studies	Increased property values	Home owners	Property values related to perception of air pollution, hence visibility (Brookshire et al., 1979; Thay and Trijonis, 1981 Lohman, et al., 1981)
	Enhanced enjoyment (user or activity values) of environment in:		
	a) urban settings	Urban dwellers	Willingness to pay for increased visibility in several eastern and western urban areas (Brookshire et al., 1979; Tolley et al., 1984; Rae, 1984)
	b) natural settings	Outdoor recreationists, campers, residents of non-urban areas	Willingness to pay for preservation, improvement and accept compensation for degradation in national parks (Rae et al., 1980; Rae et al., 1982)
	Options values; maintaining or increasing opportunity to visit less impaired natural and urban settings	Outdoor recreationists, campers, tourists	Aggregate of activity values in iterative bidding studies suggests importance of options values (Rowe and Chestnut, 1981)
	Existence values, maintaining pristine environments	General population	Existence values may far outweigh activity or user values (Rowe and Chestnut, 1981)
Psychological Studies	Enhanced enjoyment in natural areas (user and options)	Outdoor recreationists, campers, tourists	Visual air quality attributes rank high among visitors to both Mesa Verde and Grand Canyon. Knowing park resources protected most valued psychological attribute (Ross et al., 1984)
	Less concern over perceived health effects	General population, urban areas	About 2/3 of bid for improved visibility in Los Angeles was related to concern over potential health effects (Brookshire et al., 1979)
Transportation	More efficient, lower risk operations, visual approach permitted	Airport users, operators	Visual approaches permitted when visibility >3-5 miles; airport specific (FAA, 1980a)
	Increased opportunity to operate aircraft	General aviation aircraft (non-instrument capable pilots, aircraft)	Visual flight rules permitted when visibility >3 miles (FAA, 1980b)
	Increased opportunity to conduct aircraft and weapons testing	DOD testing facilities in Desert Southwest	Basis for location of facilities in part due to high visibility

Determination of detection thresholds and JND's are statements about changes in information content in an image. However, a JND change in image sharpness is not necessarily a good indication of a change in judged image quality. For instance, a change in 10 JND's in a scene with low overall contrast may be judged to have the same change in image quality as a 10 JND change in a high contrast scene.

A just noticeable difference in the appearance of a vista will be dependent on whether haze appears as layered or uniform. Layered haze can be thought of as any confined layer of pollutants that results in a visible spectral discontinuity between that layer and its background (sky or landscape) while uniform haze exhibits itself as an overall reduction in air clarity.

Quantifications of the perceptible effect of these two types of impairment is really quite different. The eye is much more sensitive to a sharp demarcation in color or brightness than it is to a uniform change in brightness or color over a period of time. Layered haze falls into the first category in that the layer of haze is observed against some background (sky or landscape element) while uniform haze falls into the second.

Important features of layered haze are its color, size and edge sharpness. Since the eye-brain system is more sensitive to objects with certain angular or spatial frequencies and to objects with sharp edges, the calculation of a JND must incorporate these features. A JND calculation must also account for differences in threshold between when a layered haze can just be seen and when a change is taking place in a layer that is already quite visible.

Whereas the "geometry" (size, shape and color) of layered haze is important to its perceptibility, so is the "geometry" of vistas important to its sensitivity to increases in uniform haze. Visual effects of pollutants are greatest on vistas with landscape features that produce a retinal image that subtends approximately 0.3 to 0.5 degrees.(2) Therefore, the combination of scenic element size and observation's distance become important variables to integrate into a JND calculation for uniform haze.(3) Research also suggests that a JND resulting from uniform haze is a function of the vista contrast squared and atmospheric contrast transmittance squared.(4)

Some progress has been made in integrating the perceptible effects of layered haze and vista geometries into JND calculations. Models have even been proposed to combine perceptual effects of images made up of various spatial frequencies with inherent color of haze layers and landscape features.(5) Yet no formalism has emerged that comprehensively addresses all of these complex issues. The ability to quantify the amount of pollution that constitutes visibility impairment remains ripe for further research.

In recent years a number of studies have concentrated on establishing relationships between judgments of image quality of natural scenes and various atmospheric and vista parameters such as mountain/sky contrast, solar angle, extinction coefficient, sky color and percent cloud cover (6,7,8). Latimer et al. had observers judge scenic beauty (SBE) and visual air (VAQ) quality of a number of eastern and western national park vistas as they appeared under a variety of illumination and meteorological conditions (7).

The results of their study were mixed and in some cases contradictory. In an early report they conclude "To different extents for different vistas, ratings of VAQ and SBE both increase with increasing visual range. In a later study, they conclude "Ratings of SBE of a given vista were independent of visual range unless there was a dominant distant landscape feature in the landscape scenery." Since the visual range calculation "normalizes" out specific unique characteristics of vistas, these results are not surprising. These studies did conclude that changes in illumination did have a considerable effect on SBE ratings.

Middleton et al. examined relationships between VAQ and various atmospheric parameters (8). They also concluded that illumination was important to VAQ judgments, and were able to show at one site that there is a good correlation between VAQ and the natural logarithm of (b_{SCAT}) the atmospheric scattering coefficient.

Visibility parameters used in the Latimer and Stewart studies were simple indices that were unable to account for the unique viewing conditions and qualities associated with various vistas. Change in illumination manifests itself as changes in vista color and texture, while different viewing distances require observers to "look through" a greater optical depth that in turn reduces contrast of form, texture, and color.

Malm et al. examined the relationship between VAQ and contrast, a parameter that does account for variations in observer-vista distance (6,9). They used various southwestern national park scenes under a variety of illumination, meteorological and air quality conditions. Analysis of the data showed that under fixed illumination and meteorological conditions, apparent vista contrast of the most distant vista element was a good prediction of VAQ judgments. The study also showed that changes in foreground color (due to change in illumination), addition of clouds or snow cover caused the VAQ ratings to be higher, but did not cause the sensitivity of VAQ to change in vista contrast to change, i.e., slope of VAQ versus apparent vista contrast remained the same but is translated upward as foreground color increased. The study also presented a model of human perception of VAQ. The model suggests that ratings of VAQ are proportional to the sum of the fraction of each scenic element subtended by various landscape features multiplied by the atmospheric transmittance between that landscape feature and observer. It was shown that when a single landscape feature that is void of textural detail dominates the perceived change in visual air quality, the model predicts a linear relationship between VAQ and the apparent contrast of the landscape feature (contrast of form).

Although SBE and perceived VAQ (PVAQ) appear to be good indicators of image quality for uniform haze, little work has been done to examine which of many psychophysical indicators best described perceptions of layered haze much less the relationship between those indicators and air quality.

2.2 Pschyological Values in Natural Settings

Once the relationships between atmospheric haze and psychophysical indices such as JND's, SBE's and PVAQ are understood, it is still necessary to

understand the value, whether it be psychological, sociological or economic, that visitors place on a perceived change in visual air quality.

A method which has been used to assess the value of good visual air quality is recreation demand theory. Briefly, this theory professes that the demand for, or value placed on, a recreational experience is a function of demand for activities, for attributes, and for certain psychological satisfactions.(10) The satisfactions which flow from an experience are highly dependent on the activities and the presence and quality of the attributes supplied. In the context of class I areas, this means that if good visual air quality is an important attribute, and if existing visual air quality does not match what is demanded, the visitor will be less than fully satisfied with the experience.

Research conducted at Grand Canyon and Mesa Verde National Parks assessed the relative importance of visibility related attributes in comparison with other park attributes both within and between parks. It might be hypothesized that visibility attributes are of lesser importance at a park with a cultural and historical perspective such as Mesa Verde than at a nature-oriented park like Grand Canyon.

Cluster analysis ratings of relative importance of 24 attributes revealed that individual attributes collapsed into five clusters of attributes for each park. A "naturalness" cluster, which included clean, clear air was the most important attribute cluster at both parks. A view-related cluster was the second most important cluster at Grand Canyon and the third most important at Mesa Verde.(11)

The fact that the naturalness attribute cluster was the most important cluster at both parks which have different underlying themes has led to a hypothesis that "naturalness" might be a universal trait of National Parks. In the context of this study, visitors felt that "naturalness" was more important to their recreational experience than the specific attributes for which the parks are famous. The significant part of this finding, in terms of visibility protection, is that these visitors felt that clean, clear air was a part of that naturalness.

Cluster analysis of importance ratings of certain satisfactions which might accompany the recreational experience being sought at these parks showed that an "existence" cluster was rated as most important at both parks. This cluster is comprised of two satisfaction items, one of which pertains to knowing that the park resources are being protected. When combined with previous results, this indicates that visitors derive satisfaction from knowing that park resources are being protected and they feel that the naturalness of the park (which includes clean, clear air) is the most important of those resources.(12)

Before reduced visibility can have an impact on the overall recreational experience being sought, it must be salient to park visitors. That is, they must not only be able to perceive it, but they must also be aware of it as it occurs in the context of the overall recreational setting. Regression analysis between visitor awareness of haze at the Grand Canyon and a physical measure of the actual visibility at the time of the interview showed that

changes in visitor awareness of haze corresponded to actual changes in physical air quality. As visibility improved, visitors said they thought it was less hazy, and when visibility became worse, they thought it was more hazy. Furthermore, at Grand Canyon 84% of the respondents indicated they saw haze, and 82% of the respondents at Mesa Verde said it was hazy. Of special interest is that 80% of the Grand Canyon respondents and 83% of the Mesa Verde respondents who said they saw haze thought the haze occurred naturally, yet other research has shown that at least 50% of the haze is man-made.(12)

Having established that "naturalness", including clean, clear air, is most important to park visitors, and that visitors are aware of haze, it remains to be determined whether degraded visual air quality, or "hazy" air, affects the visitor's ability to enjoy park resources. Analysis was also performed to examine relationships between visitor ratings of 1) awareness of haze, 2) rating of enjoyment of the view, 3) the negative impact haze had on overall park enjoyment, and 4) satisfaction with visibility. Results of the analysis showed that as visitors say they become more aware of haze, they also say their enjoyment with the view decreases, their overall park enjoyment decreases, and their satisfaction with visibility decreases.(13)

In summary, these studies show that naturalness (which includes clean, clear air) is the most important type of attribute, knowing that park resources and values are being protected is part of the most important satisfaction cluster associated with their recreational experience, that at least 80% of the respondents said they were aware of haze, and that at least 80% of those aware of haze thought it was natural. Other research, however, has shown that 50% or more of the haze at these areas is not natural. Put more succinctly, visitors to these parks think the visibility is being protected from man-caused sources of degradation, when the fact is that at least one-half of the haze they see is man-caused. Given the above, plus the fact that more than 70% of visitors at both parks rated the views as excellent or perfect, one could speculate that the high view ratings may be due, in part, to a largely uninformed public enjoying the parks with the false impression that the park resources are being protected.

Another approach to quantification of visitor experience hypothesizes that the visitor will choose between various park attributes, including viewing of scenic vistas, in such as way as to yield the highest state of psychological and physical well-being. It is assumed that the park visitor will try to maximize personal enjoyment of park resources and will allocate accordingly the amount of time spent on various park activities. It is assumed that the visitor would not rationally choose any activity that results in increased psychological stress or greater discomfort.

The amount of time that park visitors would allocate to various activities, specifically viewing scenic vistas as a function of air pollution, can be determined through the use of a contingent ranking technique that assesses how much time a visitor is willing to give up in exchange for increases in visibility. The approach uses an ordered logit probability method similar to that used to describe consumer demand. It also inherently takes into account the frequency, spatial extent, intensity, and duration of visibility impairment.(9)

Results show that, in some cases, visitors place a high value on small changes in visual air quality. In general, the studies show that

- o Vistas containing medium distance (10-30km) highly colored landscape features are very sensitive to small increases in air pollution
- o Vistas which lack color and texture (shadowed) but with scenic elements at many varied distances show little sensitivity to changes in air quality
- o Visitors were most sensitive to changes in air quality during clean, clear winter months.
- o Vistas with distant large dominant landscape features are most sensitive to increases in air pollution
- o The value that visitors in one study placed on vistas is least during summer months. At Grand Canyon National Park visitors would spend 5.4 additional hours of driving time to see the vistas during winter months as opposed to the summer season.
- o Observer sensitivity and values could not be significantly related to socio-economic variables such as household income, education level, residence, age, etc.

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3.0 ECONOMIC BENEFITS OF VISUAL AIR QUALITY

3.1. Introduction

Air quality affects both our health and well-being. Economists have attempted to measure the value of air quality, including its aesthetic visual component, by examining data on residential property values and by asking valuation questions directly in a hypothetical or 'what if' context. Visibility values have been quantified for households engaged in day to day activities in an urban context and in the context of household visits to recreation (Class I) areas, where the clarity of scenic vistas may be an important element to the overall experience.

This section is divided into five parts: Part 3.2 describes benefit measures and the methods used by economists to quantify visual air quality benefits. Part 3.3 reviews selected studies of the benefits of visibility in urban areas. Part 3.4 reviews selected studies of visibility benefits in a recreational context for visitors to Class I areas. Finally, Part 3.5 summarizes the estimated benefits of visual air quality in urban and Class I areas and develops a range of dollar benefits that are appropriate for assessing benefits of policies to reduce emissions.

3.2 Quantification of Visual Air Quality Benefits

Economists generally perceive most things as having value. A measure of value is the well-being, or what economists call utility, derived from the consumption of a good or service. The utility derived from visibility is difficult to measure because, like other public goods, it is not traded on a market and has no explicit price. Economic benefit measures attempt to put a monetary value on changes in an individual's utility by measuring the change in income that would yield the same change in well-being as the change in visual air quality.

The benefits of a change in visual air quality can then be quantified by methods that attempt to elicit a maximum willingness to pay (WTP) an amount (forego income) or willingness to accept (WTA) compensation (receive income) to secure or avoid a change in visual air quality.* Measuring WTP requires a reference or base level of utility, and either a payment or compensation measure can be used. In evaluating visual air quality the existing level is usually taken as the reference point so that improvements are measured in terms of willingness to pay and degradations in terms of willingness to be compensated.

*In economic theory benefits are measured by consumer's surplus, which is the difference between maximum WTP and expenditures. However, since visibility is a public good supplied at zero price, expenditures are zero and maximum willingness to pay is equal to consumer's surplus.

3.2.1 Visibility Values

There are three types of visual air quality values commonly addressed: activity values, option values, and existence values. Activity value (also called user value) is the value associated with the present or future use or enjoyment of the visibility at a site, such as a residence or scenic area. The value of visibility in contributing to the enjoyment of some activity is reflected in market decisions, such as choice of housing location, and can be approached through the use of both market and non-market methods.

Option value is the value of an option to preserve some level of air quality level at a site in anticipation of potential future use or activity. This value is separate from the value of future use. WTP to insure a level of air quality for future use represents an option price that includes both a present (discounted) value of future use plus an option value. Freeman (1983) argues that for most utility functions the option value is unlikely to exceed 5 percent of activity values. Option values for visibility can be measured only by the use of non-market survey methods.

Some individuals may value the preservation or existence of a resource, such as visual air quality, even though they do not intend to use the resource themselves or to participate in an activity at the site. Such non-use values may be tied to the philanthropic goal of preserving the quality of the experience for future generations. Since by definition non-use values are not linked to market decisions, these values can only be measured by surveys of consumer behavior.

3.2.2 Methods to Measure Visibility Values

Data for estimating demand for changes in visual air quality have come from both consumer surveys and market transactions. Because air quality affects both health and welfare only surveys can separate aesthetic values, such as visibility, from other effects on human health, materials, and crops. Nevertheless, market data from housing location or property value studies have been used to attempt to estimate the total air quality value, including the value of visibility.

3.2.2.1 Contingent Valuation Survey Approaches

Most visibility benefit studies have used a contingent valuation (CV) approach. CV methods require survey respondents to reveal market information based on a hypothetical market context. The direct question method asks respondents the maximum they would be willing to pay (or the minimum they would be willing to be compensated) to change the level of an environmental good or

amenity. The contingent ranking method asks respondents to rank order alternatives that include different levels of environmental amenities and changes in household income. Estimates of the contribution of each attribute to the ranking can then be used to reveal a trade-off between income and the environmental amenity.

3.2.2.1.1 Direct Question Method

Conceptually, the direct question WTP approach is quite simple. A WTP or WTA value is obtained by asking the maximum value that respondents are willing to pay or the minimum amount they are willing to accept. This value is then used to estimate a demand curve as a function of individual or household characterstics, such as income, age, location (distance to site), etc.

A number of oral and written direct question formats have been compared, and the WTP format appears to affect the reliability and magnitude of benefits (Randall, et al., 1981). The oral bidding format uses an iterative technique that increases or decreases the asking price until a maximum WTP or minimum WTA is obtained and the respondent refuses to bid. Oral bidding has been subject to biases attributable to different starting bid levels and to the skills of different interviewers. The open end bid, administered either in oral or written form, asks for a single maximum or minimum bid. This format has been especially subject to protest behavior in the form of zero bids and refusals to bid. The payment card and checklist range formats ask the respondent to indicate a particular value or value range that approximates a maximum (or minimum) WTP. Randall et al., (1981) found that of the six formats tested the payment card elicited the highest average bids due to fewer zero bids while the checklist range yielded the lowest average bids. More recent experiments with contingent valuation formats have revealed that initial WTP bids do not yield a true maximum, and rebid mechanisms that accept or reject the maximum bid have been found to yield significant increases in WTP (Schulze, et al., 1984).

3.2.2.1.2 Contingent Ranking Method

In the contingent ranking method the benefit trade-off is measured by the change in household income that compensates for a change in visual air quality from some base condition, such as the average or median visual range. Respondents are given a set of alternatives - each specifies a visual air quality level, income gain or loss, and level of other attributes. The ranking of these alternatives from most preferred to least preferred provides a set of data from which the relative weights on visual air quality and household income can be quantified by a probability choice estimator.* Numerically, if improving average urban visual range

*A comprehensive mathematical treatment is given in Beggs, et al., 1981

from 10 to 20 miles is weighted twice as much as a $100 increase in household costs (decrease in household income), then that improvement is worth $200.

This contingent ranking method avoids many of the potential biases attributable to interviewers and the sequencing of bids. It also may be more resistant to strategic biases, since it may be less obvious how to manipulate the result. Survey design, however, requires considerable care to develop cost trade-offs that do not give rise to perfect lexicographic ordering (ranking solely on the basis of one attribute), and there is clearly a limit on the complexity of the trade-offs that respondents can manage.

The ranking method appears to provide consistent and statistically reliable estimates in comparisons of four or five alternatives composed of an environmental quality and a cost attribute. However, in more complex experiments with eight or nine alternatives and three or more attributes the ranking results have been imprecise and difficult to interpret.

3.2.2.1.3 Comparison of Contingent Valuation Methods

In general, the contingent ranking method seems to give higher estimates of benefit trade-offs than the direct question methods. For example, Desvouges, et al. (1983) found that for a change in water quality from 'boatable to swimmable' the ordered logit estimator yielded a trade-off value of about $ 50, and the direct question approach yielded a value that ranged from about $ 4-31, depending on the format. In a study of benefits of avoiding odors from diesel vehicles Rae (preliminary draft, 1984) also found that the ranking method generated larger benefits. To reduce the number of contacts with a strong diesel (truck) odor by one per week the average household was willing to pay about $ 15-18 per year in the ranking study and about $ 2-4 per year in the direct question study. It has been suggested that this difference in results is because the ranking method yields a true reservation price while the direct question method does not. This hypothesis remains to be proven, but there does appear to be an important difference in the magnitude of benefits between the two contingent valuation methods.

3.2.2.1.4 Issues in Contingent Valuation Studies of Visual Air Quality

The use of contingent valuation in estimating benefits of visual air quality necessitates developing a survey instrument. All surveys require careful attention to survey design to avoid biasing the results due to different starting points (Boyle et al., 1985), payment vehicles (Brookshire, et al., 1970), and information levels (Rowe and Chestnut, 1983). But of greatest concern in contingent valuation surveys is potential for hypothetical bias which occurs if

individuals respond differently to a survey than they would in an actual market choice situation. Results obtained by Bishop, et al. (1984) in comparing a simulated market experiment that used real cash payments with a contingent valuation survey suggest some upward bias in WTP survey bids. The average respondent indicated a WTP of $ 32-43 to obtain a deer hunting permit in a hypothetical survey, but was willing to pay only $ 19-25 when allowed to actually purchase a hunting permit for cash. Similarly, the mean WTA (sell) in a hypothetical survey was about $ 830 compared to a mean of about $ 1200 for accepting actual cash offers. The hypothesis that mean WTP survey bids were equivalent to cash transactions was rejected at the .10 level of significance in all but the sealed bid experiment. In a follow-up experiment (Bishop, et al., forthcoming 1985) using an accept or reject format, the researchers found a mean WTP survey bid of $ 25 and an actual mean payment of $ 31. In this experiment the null hypothesis of no significant difference was accepted. A tentative explanation for the different results may be due to the larger uncertainty in the first experiment. Only four permits were available to be bought and sold, and the authors suggest that this may have caused sellers to overstate WTA in the hopes of a windfall and buyers to understate bids in hopes of a bargain. The more recent experiment was conducted with many more permits, and respondents were confronted with take it or leave it offers so that uncertainty was not a major problem. Thus, there is mixed evidence on whether hypothetical bias is an important problem in CV survey research. More apparent is the large difference in magnitudes between willingness to pay and willingness to accept compensation, and until markets for environmental goods are better understood the income-limited WTP measure appears less prone to error.

Valuing visibility requires the use of some visual materials and descriptors in order to illustrate the changes being considered. Several studies have referred to a slide or photograph as an average, median, or typical condition and asked respondents to value large changes in visual range -- on the order of 50 to 200 percent. Visibility, however, is a distribution of daily, even hourly, events, and describing visibility by reference to a mean or median condition may oversimplify the problem, especially in urban areas where respondents are familiar with the range of visibility conditions. Two studies (Loehman, et al. 1981 and Rae/CRA, EPRI draft, 1984) have described these distributions in terms of the number or percentage of days with different visibility levels and found that respondents were able to value relatively small changes in the number of days of clear or hazy visibility that were equivalent to a change in mean visual range of less than 15 percent.

Contingent valuation surveys require a payment vehicle, such as a utility bill or entrance fee, and the time period of these hypothetical payments may affect the results. Payments can be specified on a one time, annual, or monthly basis. Advertisers know that many buyers are more easily persuaded by "low monthly payments" of $ 10 compared to a larger lump sum or annual payment

of $ 120. There may be a hidden upward bias in payment vehicles that require larger numbers of smaller payments. On the other hand, respondents with cash flow constraints may bid less when asked their WTP in large annual or lump sum payments.

A final concern is that surveys that value one environmental good, say visual air quality, may be capturing more generalized values for all air quality, or even all environmental quality. Two studies evaluated the effects of presenting visibility in the context of other competing claims on scarce household resources. Randall, et al. (1981) found that the value of preserving visibility at the Grand Canyon as a single environmental good was significantly larger than when visibility at the Grand Canyon was included with visibility improvement in the Chicago area and the eastern United States. When valued as a single good preserving visibility at Grand Canyon was worth about $ 90 per household per year compared to $ 15 per household per year when valued as the third component of a three good visibility package. Similarly, Rae/CRA (EPRI draft, 1984) found that preserving visual air quality in the Smokies was worth an average of about $ 60 per household annually when presented as single good, but average household WTP declined to about $ 20 when presented in a competing context with 10 other 'good causes' Rae attributed much of this reduced WTP to a change in value for the non-use component of total benefits, but more research is needed to evaluate the effects of benefit estimation in a multiple good context.

3.2.2.2 Hedonic Property Value Approach

Property value studies have been generally preferred by economists for valuing environmental goods because they are based on real market preferences. Despite their limitations in measuring the aesthetic or visual air quality component, property value studies do provide a measure of willingness to pay for a given change in overall air quality and therefore provide an upper bound to estimates of visual air quality benefits from contingent valuation studies.

Hedonic price theory, as developed by Griliches (1971) and Rosen (1974), suggests that consumers select the particular bundle of attributes they desire when purchasing a differentiated market good, such as housing and that consumers derive utility from these attributes. The amounts of the different attributes in a composite good determine the prices that consumers are willing to pay for that good. The value of each attribute can then be estimated by regressing property value against housing characteristics to obtain a hedonic or implicit price function. The hedonic price function enables the analyst statistically to hold all attributes constant and to answer the question of how differences in air quality or other attributes would affect prices of property if each residence were identical in every other respect.

The regression coefficients represent the household's marginal implicit price, MIP, or willingness to pay for a unit change in air quality. However, public policy questions typically require estimation of the household's willingness to pay for non-marginal changes in air quality. This requires a second step in the hedonic approach, which is to estimate the demand or willingness to pay (WTP) function for air quality at the residence. This is the relationship between the marginal implicit price of air quality and the level of air quality at which the household will choose to locate. It must also account for the effects of household income, household size, and other household characteristics and property attributes that influence the household's demand for air quality.

The application of the hedonic property value technique has encountered a number of practical and theoretical problems. Among the practical problems are the requirements for detailed data on large numbers of properties and the costs of collecting these data. In addition, three important theoretical problems have emerged in applying the hedonic method to property values: instability of results across specifications, multicollinearity among variables, and endogeneity of the marginal implicit price of air quality. In empirical applications minor changes in variables specified or number of observations in the data set have caused key air quality variables to become insignificant (Brookshire et al. 1979). Multicollinearity among variables has also made it quite difficult to separate the effects of different pollutants from each other and from other variables that affect property values. Principal components analysis has been used to separate correlated variables, but the resulting coefficients are not easily interpreted (Thayer and Trijonis, 1984). Finally, the MIP function appears to be endogenous to the model, and thus estimation is possible only by assuming an underlying functional form (Mendelsohn, 1980).

3.3 Economic Benefit Studies of Visual Air Quality in Urban Areas

As of January 1985 there exist six studies of visibility benefits in urban areas, although three remain in draft form. Three studies have quantified the benefits of improving visibility in eastern cities using a contingent valuation approach. Three other studies in California urban areas provide estimates of visibility and air quality benefits using both the contingent valuation and property value methods. Below we review these studies to estimate a value for visibility improvement in the eastern United States.

3.3.1 Chicago Urban Visibility Study*

The Chicago visibility experiment (Randall, et al., 1981) evaluated household willingness to pay for visibility improvement and willingness to pay to avoid visibility degradation in the Chicago urban area. A contingent valuation survey was designed to compare six oral and written direct question formats. The survey was conducted in the summer of 1981, and usable information was obtained from 273 repondents. A composite set of photographs of three Chicago urban vistas was used to portray poor, median, and good visibility conditions. A non-specific payment vehicle was then used to elicit a maximum monthly willingness to pay (WTP) per household to achieve an improvement in visual air quality or to avoid a reduction in visibility. The five scenarios are listed below:

a. WTP (degradation) 9 to 4 miles - Chicago area
b. WTP (improvement) 9 to 18 miles - Chicago area
c. WTP (improvement) 9 to 30 miles - Chicago area
d. WTP (improvement) 9 to 18 miles - Chicago plus eastern U.S.
e. WTP (improvement) 9 to 18 miles - Chicago plus eastern U.S. plus preventing a decline in visibility at Grand Canyon**

The six different formats generated a wide range of benefit estimates, as shown in Table 1. Formats using a payment card generated the fewest zero bids and protest bids and the largest dollar benefits. The written checklist format yielded less than half the magnitude of benefits obtained by the expanded payment card (C2) that included information on typical expenditures for public and private goods. For the three urban visibility increments the results can be summarized as follows:

Measure	Visibility (miles)	WTP ($/year)	WTP ($/mile)
WTP-degradation	9 to 4	$ 121-283	$ 24-57
WTP-improvement	9 to 18	$ 109-324	$ 12-36
WTP-improvement	9 to 30	$ 152-456	$ 7-22

Note: These bids are all based on solid core data (1981 dollars).

*This study is included as an appendix to the later Six Cities study
**Results of this scenario will be discussed later in Section 4, Visibility Benefits in Class I Areas.

The average household willingness to pay for all respondents (all six formats) to avoid a 5 mile reduction in visibility from 9 to 4 miles was $ 227 using only the "solid core" sample of 221 respondents. Improvement from 9 to 18 miles in visual range yielded an annual average bid of $ 218 per household, and improvement from 9 to 30 miles resulted in an annual average bid of $ 271 per household.

In evaluating these benefit results it should be remembered that visual air quality was the only component of air quality valued, and it is possible that these visibility benefits include some measure of health or other air quality concerns. Nor was there a test for the effects of other competing claims for scarce household resources on household WTP for urban visibility. The authors did test for this effect in comparing values for preserving visibility in Grand Canyon from a previous CV study and found a substantial decline in household WTP. It should also be noted that the authors did not test for order effects in the bids, which proceeded in order of increasing visual range. Evidence from other studies (Rowe and Chestnut, 1983) suggests that benefit magnitudes may be affected by the starting point and the direction of bidding.

Despite these criticisms, several important conclusions can be drawn from this study. First, respondents were willing to pay significant amounts of annual income to improve typical visibility from 9 to 18 miles and from 9 to 30 miles. Second, the WTP benefit is very much dependent on the choice of CV format. Third, the WTP to avoid a reduction in visibility is significantly larger than the WTP to improve visibility. The estimates of WTP for the two scenarios to improve visibility appear fairly consistent and suggest a nonlinear WTP curve with decreasing marginal benefits as visual range increases.

3.3.2 Six Cities Study

The Six Cities study (Tolley, et al., EPA draft, 1984, 1985) was a major effort to apply the results of the Chicago urban visibility study to six other eastern cities. The WTP survey utilized an expanded payment card and a rebid mechanism to value changes in visual air quality. A total of 792 respondents were surveyed in 1982 in six eastern cities -- Washington, D.C., Atlanta, Mobile, Boston, Miami, and Cincinnati,-- and 528 complete surveys were used in the analysis.

Visual air quality was portrayed with sets of photographs of three different urban scenes that showed poor, median, and good visibility conditions. The same set of generic urban visibility photographs was shown to all respondents, regardless of city. Monthly bids were elicited for five scenarios:

a. WTP (degradation) 10 to 5 miles
b. WTP (improvement) 10 to 20 miles
c. WTP (improvement) 10 to 30 miles
d. WTP (improvement) 10 miles eastern United States
e. WTP (improvement) 10 miles eastern and western United States

Visibility in the east was portrayed by photographs of poor, median, and good visibility in the Smoky Mountains, and visibility in the west was portrayed by photographs of poor, median, and good visibility in the Grand Canyon.

The average household bids varied greatly across the six cities, as shown in Table 2. Average annual household bids to avoid a five mile reduction in typical visibility ranged from $ 57 in Cincinnati to $ 232 in Washington, D.C. To improve from 10 to 20 miles average bids ranged from $ 57 in Cincinnati to $ 238 in Washington, D.C. A larger improvement from 10 to 30 miles elicited average bids that ranged from $ 64 in Cincinnati to $ 303 in Washington, D.C. For the eastern and total U.S. scenarios average annual household bids ranged from $ 74-358 and $ 80-422, respectively.

A number of linear and non-linear specifications relating visual range to WTP values were tested, and visual range was found to be highly significant in explaining differences in WTP. The linear specification found that for a 1 mile improvement in urban visual range the average household was willing to pay $ 14.20 per year. The researchers found that the best non-linear specification was a negative exponential of the form

$$BID_j = A[1-\exp(-B)(VR)],$$

where VR is visual range rescaled so that the existing level is zero, and A and B are parameters to be estimated. The function passes through the origin, increases monotonically, and implies reduced WTP as VR increases. The parameter, B, determines how rapidly the maximum WTP is approached and is estimated as the sum of socio-economic characteristics of respondents and city-specific effects. The parameter, A, is a rotational constant, or shift parameter, that determines the position of the function and the magnitude of the bid. In this case the effects of non-local (eastern and western) visibility are included as independent (dummy variable) terms in the rotational constant.*

Empirical estimation found that differences in socio-economic and city effects explained away much of the difference in the raw WTP bids. For a 1 mile improvement in local visual range from the base

*Alternatively, dummy variables for non-local visibility could have been specified independent of the rotational constant. Tests of significance could then be applied to determine the appropriateness of the specifications.

(10 miles) average household WTP varied from $ 12.78 per year in Cincinnati to $ 15.90 per year in Washington, D.C. Similarly, annual household WTP for a 10 mile improvement in local visual range varied from about $ 115 in Cincinnati to $ 139 in Washington, D.C. Non-local household WTP bids varied from $ 68 to 82 per year for a 10 mile improvement in eastern visual range and about $ 32 to 39 for a 10 mile improvement in western visual range.

The reliability of the data depends on the adequacy of survey procedures. One concern is that the photographs used were of generic urban scenes, and the failure to provide site-specific photographs may be a source of bias (probably downwards) in estimates of WTP for improvements in visual range in each city. Similarly, the photographs of the Great Smokies and Grand Canyon do not accurately portray typical vistas in the east and the west, and as a consequence the values for visibility improvement in the east and west may be biased upwards. In addition, the appropriateness of including non-local visibility effects, much of which are probably non-use values, in the shift parameter, remains to be demonstrated.

These surveys in six eastern cities provide the largest amount of data on household WTP for improved visual air quality. In addition, the authors have succeeded in demonstrating that large variations in the raw data bids are mostly explained by socio-economic and city-specific differences so that the resulting effect of changes in visual range on WTP bids is fairly consistent across the six city sample. Finally, the non-linear specification captures the effect of diminishing WTP for increases in visual range.

3.3.3 Cincinnati Visibility Study

The Electric Power Research Institute (EPRI) commissioned a benefits study of visual air quality in Cincinnati using the contingent ranking and the direct question methodologies. (Rae/ Charles River Associates, 1984). A survey pre-test was conducted on 147 respondents in March 1982, and a final survey collected data from 314 respondents in June 1982. The report has undergone several drafts to refine the estimates and evaluate the methodology, the most recent being August 1984.

The contingent valuation survey presented respondents with a choice of alternatives that included different levels of household fuel costs and visual air pollution. Changes in visibility were linked with changes in home heating costs by suggesting that coal-derived synthetic gas and oil would soon be available for use in home heating systems. Lower heating costs were associated with fuel that contained pollutants, especially sulfur. Higher heating costs were associated with clean fuel. A heating cost increase represented a WTP measure for an improvement in visual range, and a reduction (or saving) in heating cost represented a WTA measure (with compensation limited by the annual cost of fuel) for a reduction in visual range.

Visual air quality was portrayed by slides of Cincinnati that depicted haze, median, and clear conditions. The pre-test used an older set of 35 mm. slides with visual ranges of about 3, 8, and 25 miles. An updated set of 50 mm. slides with visual ranges of about 3, 11.5, and 16.5 miles was used in the final survey. The three visibility slides were projected simultaneously on one screen. Changes in visual range were presented using two different descriptors: one where visibility conditions were stated to occur 'most of the time' and a second where information was provided to indicate the annual percentage of days typical of each of the three visibility conditions. The results of the survey pre-test and the final survey are compared in Table 3.

Using the first descriptor, an improvement in visual range from median to clear 'most of the time' yielded an annual household WTP (increase in fuel costs) of $ 381-544 in the pre-test and $ 343-516 in the final survey. For a degradation from median to haze 'most of the time' WTA compensation (saving in fuel costs) amounted to $ 387-635 in the pre-test and $ 884-1324 in the final survey. The range of benefits is attributable to different specifications. On a per mile basis the WTP estimate is higher in the final survey while the WTA measure yields fairly similar per mile estimates in both surveys.

Measure	Pre-test ($/mile)	Final Survey ($/mile)
WTP	$ 22-32	$ 71-108
WTA	$ 81-132	$ 103-154

Note: These estimates are in 1982 dollars.

Using the probability distribution descriptor, respondents in the pre-test evaluated a simple two attribute trade-off between visibility and fuel costs and obtained fairly precise estimates. Annual household WTP amounted to $ 217 to improve from an existing distribution (27 percent clear) to a distribution with 80 percent clear days. To improve from a distribution with 27 percent clear to 40 percent clear was worth $ 142. Annual compensation of $ 106 and $ 268 was required to accept a reduction in visibility to distributions of 15 and 8 percent clear days.

The final survey added health effects as a third attribute. Health effects proved highly significant, but the reliability and significance of the visibility attributes were eroded.* On a per mile basis visibility benefit estimates from the pre-test were generally less than in the final survey, where the range is quite wide and the results reflect considerable uncertainty.

*The best specifications evaluated the likelihood of the ordering on only the first three out of a total of nine alternatives ranked.

Measure	Pre-test	Final Survey
WTP: Existing to Best	$ 23	$ 35-102
Existing to Good	$ 59	$ 36-204
WTA: Existing to Poor	$ 38	$ 169-227
Existing to Worst	$ 57	$ 123-184

Note: Estimates are in 1982 dollars.

Respondents also registered a direct question bid (checklist format) for a change from median to clear visibility 'most of the time'. In the pre-test repondents were willing to pay an average of about $ 85 per household per year for an improvement of about 8 to 25 miles while in the final survey they were willing to pay about $ 143 for an improvement of about 11.5 to 16.5 miles. For a one mile improvement in visual range these benefits equal about $ 5 (pre-test) and $ 30 (final survey) and are considerably smaller than the benefit estimates obtained from the ranking method.

The Cincinnati study generally confirmed that visibility is an important component of the air quality good and that respondents were willing to pay significant amounts of income in fuel costs to obtain better visual air quality. A significant household WTP for visual air quality was demonstrated in both contingent ranking and direct question surveys. The magnitude and significance of these benefit estimates were affected by the use of different sets of slides, different visibility descriptors and the inclusion of health effects, and some results tended to be unstable across specifications.

3.3.4 Review of California Visibility/Air Quality Studies

There have been three other major studies that have attempted to value changes in urban visual air quality. Two studies compared the CV and property value approaches in the Los Angeles and San Francisco areas. In addition, a more recent study reestimated air quality benefits from property value data using the extinction coefficient as a measure of air quality.

3.3.4.1 South Coast Air Basin Study

This study (Brookshire, et al., 1979, 1980) used data from 1977/78 property values and a 1978 direct question oral bidding survey of residents to estimate benefits of improved air quality. In both analyses homes were grouped into poor, fair, and good air quality. Empirical estimates of the hedonic price function found that a 0.01 ppm decrease in annual average NOx was associated with a $ 2010 per unit increase in residential property values (1977/78 dollars), and that a 1 ug/cubic meter decrease in annual average TSP

was associated with about a $ 300 (1977/78 dollars) increase in property values. Estimates of household willingness to pay yielded annual (discounted) benefits of about $ 600 (1977 dollars) to improve from poor to fair (about 20 percent) and about $ 440 (NOx) to $ 580 (TSP) to improve from fair to good (about 25 percent).*

In the contingent valuation survey a total of 345 respondents were asked how much they would be willing to pay for air quality improvement, including an aesthetic visibility component and a chronic and acute health component. An iterative oral bidding format was used to elicit willingness to pay as an extra charge on their monthly electric bills. The authors reported an average household WTP of $26 per month ($ 312 per year) for bids to improve visual air quality from poor to fair (2 to 12 mile visual range) and fair to good (12 to 28 mile visual range). Results, however, varied with different payment vehicles, time of compliance, and order of questions. For example, aesthetic visibility improvement accounted for 34 percent of the total benefit or about $ 105 per year over all bidding sequences, but it ranged from under 10 percent when valued as the last benefit element to over 70 percent when valued as the first. The annual benefit estimate of $ 312 per household represents an improvement in visual range of 10-16 miles so that benefits per mile vary from about $ 6.50 to $ 10.50 per household (1978 dollars).

3.3.4.2 The San Francisco Bay Area (SFBA) Study

Loehman, Boldt, and Chaikin (1981) also compared the results of a property value study and a contingent valuation survey that quantified benefits of air quality changes in the San Francisco Bay area (SFBA). The property value study (1978 data) utilized household level data and found significant negative effects for increases in ozone and a Pollution Standards Index (PSI), a composite measure of pollution that captures both concentration levels and frequency of occurrence. Non-linear specifications yielded the best results, and marginal willingness to pay was found to increase with increases in pollution and with income. Average annual household willingness to pay (1978 dollars) amounted to $ 45-98 to reduce ozone 30 percent and $ 86 to reduce the PSI 30 percent. These annual average household WTP benefits, which include the effects of health, visibility, and other air quality components, are considerably lower than the estimates obtained in the SCAB study, but this could be partially due to the lower pollution levels in the San Francisco area.

*A reanalysis (Brookshire, et al. 1980) using a slightly reduced number of properties (634 instead of 719) and a different form of the hedonic price function generated a similar range in annual benefits.

A contingent valuation survey of 412 respondents was conducted in the San Francisco area in early summer 1980 and obtained WTP bids for improved air quality using a written checklist format * This SFBA study pioneered the use of distributions as descriptors for both visibility and health variables The visual aesthetic component of air quality was characterized by the number of non-polluted days (over 10 miles visual range), moderate days (6 to 10 miles visual range), and poor days (0 to 5 miles visual range). Willingness to pay to improve from a mean visual range of 16.3 to 18.6 miles amounted to about $ 71 per year (1980 dollars).** Visibility accounted for about 43-64 percent of the total health and aesthetic air quality values. For a 30 percent improvement in air quality the CV survey yielded an annual average household WTP of about $ 51 compared to $ 45-98 for the property value study. However, comparison of benefits for households in each air quality locale revealed considerable differences between the CV and property value results.

3.3.4.3 California Property Value Visibility Study

Thayer and Trijonis (draft, 1984) used disaggregate data from 7871 homes sold in 1973/74 and 1978/79 and measures of light extinction to assess the effect of air pollution in the Los Angeles and San Francisco areas. In all specifications light extinction had a significant negative association with property value, but the size of the coefficient varied considerably with the definition of extinction - with and without sea haze.

Important differences were also implied in the separate WTP functions. In the San Francisco area, where median visibility is about 17 miles, marginal WTP was found to increase as the level of pollution (as measured by light extinction) increased. In the more polluted Los Angeles area, however, marginal WTP was found to decrease with increases in pollution. A 10 percent improvement in visibility yielded average annual household benefits (1978/79 dollars) of $ 57-153 in Los Angeles and $ 115-128 in San Francisco with the range of estimates attributable to different forms of the hedonic price function. In San Francisco ozone, which accounts for most of the air pollution effects on health, is independent of extinction, and the authors were able to estimate separate coefficients for both air pollutant variables. They found that a 10 percent reduction in ozone increased housing values by 1.03-1.3 percent compared to 1.4-2.5 percent for a 10 percent reduction in extinction. In San Francisco extinction accounts for mostly aesthetic effects so that visibility accounts for up to 57-66 percent of total air quality values.

*The authors call it a payment card, but it appears equivalent to the checklist used by Randall, et al. in Chicago.

**Mean visibility was calculated by assuming visual ranges of 3, 8, and 20 miles for the three air quality conditions

3.3.4.4 Conclusions from California Visibility Studies

The three California studies reviewed above all found that there was a significant WTP for improved air quality in Los Angeles and San Francisco and that the aesthetic visual component of air quality accounted for about one-third to two-thirds of the total benefit. This relationship is used to compute estimates of the visibility benefits, which are summarized in Table 4.

The annual household WTP benefits (1984 dollars) per mile improvement in visual range from the California studies are not dissimilar to the estimates obtained from the visibility studies conducted in eastern urban areas. The contingent valuation results range from about $ 10-16 per mile improvement in the SCAB study to about $ 40 per mile in the SFBA study. When converted to 1984 dollars, the property value studies yield annual household visibility benefits in a wide range of about $ 23-165 per mile improvement. The recent work by Thayer and Trijonis yields a large annual household WTP value for aesthetic air quality benefits in San Francisco that ranges from about $ 112-122 per mile improvement in visual range.

3.4 Value of Visual Air Quality in Class I Areas

Visibility in class I areas results from both regional haze and discrete plumes. Early attempts to quantify the economic value of visibility were in response to aesthetic and environmental insults (plumes) attributable primarily to existing and proposed power plants (see Rowe and Chestnut, 1983). More recent economic benefit studies have focused on the problems of regional haze.

Several studies have employed contingent valuation surveys to quantify the value of visual air quality in Class I areas. Schulze, et al. (September 1983) conducted a contingent valuation oral bidding survey at four urban locations to measure willingness to pay for visibility at Grand Canyon and other Southwest Parks. MacFarland, Malm, and Molenar (1982) used a contingent valuation oral bidding format to quantify user (visitor) values of improved visibility at Grand Canyon, Mesa Verde, and Zion National Parks. Rae (1982a,b) used contingent ranking and direct question written checklist methods to measure visitor willingness to pay for improved visibility at Mesa Verde and Great Smoky Mountain National Parks. In addition, the Six Cities study, which was discussed in Section 3, evaluated WTP bids for improved visual air quality in both eastern and western areas of the United States. A detailed review of these studies is presented in the following sections.

3.4.1 Grand Canyon/Southwest Parks Study

The authors (Schulze, et al., 1983) designed and implemented a WTP survey with an oral bidding format to measure user and non-user

benefits of visual air quality. Regional visibility at Grand Canyon was portrayed by a panel of photographs that included three vistas and five different air quality conditions. Similarly, visibility at Southwest Parks was portrayed by a regional composite that included vistas from Grand Canyon, Mesa Verde and Zion National Parks, each with five different air quality conditions. These photographs were evaluated in terms of frequency of occurrence and grouped from A (about 7th percentile) to C (median) to E (99th percentile). Bids to improve visibility for users were elicited in terms of an increase in entrance fee ($ 2.00 per vehicle), and bids by non-users to preserve visibility were elicited in terms of an increase in monthly electric bills.

A total of 450 questionnaires were completed in 1980 in Albuquerque (115), Los Angeles (127), Denver (110), and Chicago (98). Respondents who indicated past or expected future visits to Grand Canyon numbered 166 and were categorized as users. User WTP for improved visibility on the day of a visit ranged from $ 1.68 per household visit for an improvement from A to B (about 78 to 105 mile visual range)* to $ 5.15 per household visit for an improvement from A to E (about 78 to 258 miles visual range), as shown in Table 5. For the entire Southwest Region users were willing to pay $ 4.29 per household visit to avoid a reduction from C to B (about 120 to 99 miles visual range).

All 450 respondents were asked their WTP to avoid a deterioration in visibility from C to B both at Grand Canyon and for all Southwest Parks. The average respondent household was willing to pay an additional $ 5.38 per month in electricity costs to avoid a reduction in visibility from about 125 to 105 miles at Grand Canyon and an additional increment of $ 4.58 per month to avoid a similar reduction in visibility (about 120 to 99 miles) at all Southwest Parks.

Non-use values are quite large and overwhelm user values in significance. In fact, the average user visits Grand Canyon 0.28 days per year so that an improvement in visibility from B to C (about 105 to 125 miles) is worth about $ 0.30 per household per year. In contrast, the preservation value of avoiding that same reduction in Grand Canyon visibility amounts to about $ 65 per household per year. Avoiding a similar reduction (about 120 to 99 miles) at all Southwest Parks is valued at about $ 120 per household per year.

The magnitude of the estimates of user benefits are consistent with other studies, but the validity of the preservation benefit estimates has been challenged by the results of other studies.

*Visual ranges were calculated from data in Schulze, et al., Table 3 (p. 18) and averaged across the three vistas.

Randall, Hoehn, and Tolley (1981) found that WTP for preserving Grand Canyon visibility was significantly reduced when the Grand Canyon component was valued as the third element in an air quality program. In 1980 they found that for Chicago respondents the value of preserving visibility at Grand Canyon as the sole program was about $ 90 per household per year, but in a 1981 survey that value declined to about $ 15 per household per year when Grand Canyon visibility was evaluated third in a program that included improving visibility in Chicago and the eastern United States. Rae/CRA (EPRI draft, 1984) obtained similar results when visual air quality in the Smokies was compared in a single and multiple good context.

In follow-up research Schulze et al. (1984) tested the sensitivity of their findings in the Grand Canyon/Southwest Parks study to the single/multiple good context. Four different experiments were designed to introduce budget constraints and to include other competing local and regional air quality programs. The authors found no significant difference in bids to preserve Grand Canyon visibility for four different contexts. Nevertheless, Schulze, et al. did not duplicate the Chicago procedure. Whereas Randall, et al. asked for total WTP for an expanded air quality program, Schulze, et al. asked whether under new circumstances the Grand Canyon bid would change. The oral nature of the questioning is likely to affect the response, since respondents may be reluctant to change their bid for the sake of maintaining consistency. More theoretical and empirical research is needed to verify the bits and pieces of knowledge so far available.

The Grand Canyon/Southwest Parks study attempted to quantify use and non-use benefits of visual air quality in Class I areas. User WTP was measured in terms of increases in entrance fees and yielded a value at Grand Canyon of up to $ 5.15 per household visit to improve visibility from a 7th percentile day (about 105 miles) to a 99th percentile day (about 258 miles). The non-use benefits amounted to about $ 65 per household per year to preserve median visibility (about 125 miles) at Grand Canyon and about $ 120 per household per year to preserve median visibility (about 120 miles) at all Southwest Parks. Subsequent studies have raised questions about the accuracy and reliability of these non-use benefit estimates, but this study does suggest that such benefits could be important in valuing visual air quality in Class I areas.

3.4.2 National Park Service Study

The National Park Service conducted a survey at Grand Canyon and Mesa Verde National Parks to assess the effect of visual air quality on visitor enjoyment (MacFarland, Malm, and Molenar, 1982). The study included an economic valuation component that employed an oral bidding format to measure willingness to pay for improved visibility. Approximately 1000 respondents were surveyed at each site during the summer of 1981.

Visitors to Grand Canyon NP were asked about their WTP for visibility improvement at Grand Canyon and their WTP for visibility improvement over the Southwest Region. A Grand Canyon composite depicted three different vistas under five different air quality conditions. A Southwest Region composite included vistas of Grand Canyon, Mesa Verde, and Zion National Parks under five different air quality conditions. At Mesa Verde NP visitors were shown vistas of Mesa Verde, Zion, and Grand Canyon, one park at a time, and asked their WTP for five levels of improved visibility. The five air quality levels in each survey represented visual range conditions of about 110, 160, 210, 270, and 350 kilometers (66, 96, 126, 162, and 210 miles).

Respondents were shown all five slides simultaneously; then they were asked to compare the worst visibility with the next worst and to indicate their maximum WTP in increased entrance fees to visit the park under the improved air quality condition. At Grand Canyon NP respondents were willing to pay an average of about $ 1 per household visit over the $ 2.00 entrance fee to improve visibility from 110 to 160 km. visual range. To improve from 110 to 210 km. was valued at about $ 1.70, from 110 to 270 km. at about $ 2.10, and from 110 to 350 km. at about $ 2.70 by Grand Canyon respondents. The regional composite of Grand Canyon, Zion, and Mesa Verde was valued slightly less than the slides of Grand Canyon alone, which suggests that Grand Canyon WTP bids may be a proxy for general regional visibility improvement.

The survey of respondents at Mesa Verde elicited independent bids for improved visual air quality at all three parks. As expected, for comparable improvements in visual air quality respondents were willing to pay the most for Grand Canyon; visual air quality at Zion was valued slightly more that at Mesa Verde. Mesa Verde NP respondents valued Grand Canyon visibility about the same as respondents at Grand Canyon NP: an improvement from 110 to 160 km. was valued at about $ 1 per household visit while a larger improvement from 110 to 350 km. was valued at about $ 2.75. For similar visibility improvements household WTP in increased entrance fees to visit Mesa Verde was about 10 to 20 cents less than to visit Grand Canyon. Visual air quality at Zion valued slightly higher than at Mesa Verde.

The authors found that socioeconomic variables had no important effect on WTP for visual air quality. The most important variable was length of stay, and visitors were willing to pay more the longer their intended stay in the park. Overall, this study found that visitors (users) were willing to pay several dollars per household in increased entry fees to visit the parks in the Southwest on days of good visibility.

3.4.3 EPRI Parks Study

The Electric Power Research Institute sponsored a contingent valuation study of benefits of improving visibility at Mesa Verde and Great Smoky Mountains National Parks (Rae/CRA, draft 1982).* A survey was given to about 200 visitors at each park in the summer of 1981. Both contingent ranking and direct question (checklist format) were used in eliciting WTP for visibility improvement as an increase in park entrance fees.

Four different visibility slides were shown to respondents at each site. Slides were projected simultaneously so that respondents could study and compare the differences in visual air quality. The Mesa Verde vista showed Hogback Ridge under three visual ranges: 119, 156, and 256 km. (71, 94, and 154 miles) and an intense plume that obscured the view of the ridge. The slides of Great Smoky portrayed regional haze conditions with visual ranges of 10, 20 50, and 100 km (about 6, 12, 30, and 60 miles).

The survey design asked respondents to compare these visibility conditions under two assumptions. In one case the visibility condition on the day of a visit was known with certainty. In the second case visibility was not known and was described as a probability distribution with each possible condition occurring a specified percentage of time. The results of this second ranking were not consistent across all specifications. Consequently, the value of visibility as a probability distribution is difficult to interpret and is not reported here.

When visibility conditions were presented as certain, the rankings of visitors to Mesa Verde indicated a value of about $ 3.40 per household per visit to improve from a hazy condition of 119-156 km. (71-94 miles) to a clear condition of 256 km. (154 miles). In this case the intense haze and the median condition could not be separated statistically, and the two conditions were subsequently treated as visually equivalent. At Great Smoky visitors rankings indicated a WTP trade-off of about $ 10 per household visit to improve visibility from 50 to 100 km. (about 30 to 60 miles). To improve visibility from 10-20 km. (6-12 miles) to 100 km. (60 miles) was valued at about $ 15 per household visit.

Respondents were also asked to indicate in a direct question written checklist format their WTP to insure a clear day on their next visit. At Mesa Verde this value amounted to about $ 4.20 per household to insure a clear (256 km.) condition relative to a median (156 km.) condition (about 154 to 94 miles) on a future visit. Given a stated probability of a future visit of .456, negligible option value, and zero discount rate, the average use value amounts

*A paper on this research was presented at the National Park Service's Visibility Values Workshop, May 1982.

to about $ 9 per household visit.** At Great Smoky, this bid to insure clear visibility on a future visit amounted about to $ 6 per household. Given a .769 probability of a return visit, negligible option value, and a zero discount rate, this amounts to a use value of about $ 7.75 per household to insure a clear (100 km.) condition relative to a median (about 30 km.) condition (about 60 to 18 miles). However, in the case of the Smokies the $ 10 limit on the checklist may have biased bids downwards, despite the opportunity to write in a higher bid.

This study found that visitors to Mesa Verde and Great Smoky were willing to pay about $ 3 to 15 per household per visit for a major improvement in visual range. The direct question checklist bid appeared to yield values of similar magnitude to the contingent ranking method, although the results were not confirmed on independent samples. Visual air quality appeared to yield higher values per visit at Great Smoky than at Mesa Verde, but correcting for the average length of visitor stay (about three days at Great Smoky compared to one day at Mesa Verde) yields fairly similar benefits per household.

3.4.4 Six Cities Study

The survey design in the Six Cities study, reported above, included WTP bids (expanded payment card and rebid) for a 10 mile improvement in visual range in the eastern and western United States. These bids represent both future use and non-use values for visual air quality outside the immediate urban area. Annual average household WTP for each of the six eastern cities ranged from about $68 to 83 for the eastern scenario and about $ 34 to 39 for the western scenario. The survey employed vistas of the Smokies and Grand Canyon to portray eastern and western visibility, but these vistas are probably not typical of the whole area included in the bid. Nor were these bids presented in a wider multiple good context of competing claims on household resources. Nevertheless, these results provide further evidence that there may be an important non-use component in valuing non-local visibility, especially in Class I areas.

3.5 Comparison of Benefits of Visual Air Quality in Urban and Class I Areas

This report has reviewed visibility benefits research from nine different urban areas and three National Parks. Contingent

**A positive discount rate would increase this user value while the likelihood of more than one future visit would reduce it.

valuation studies, including both direct question and contingent ranking methods, were conducted in all nine cities and the three national parks Property value studies were conducted in Los Angeles and San Francisco and permit a useful comparison between the survey-based CV and market-based hedonic methodologies.

3.5.1 Theoretical and Empirical Considerations

Many concerns about visibility benefit studies have been summarized by Ruud (1985) for the Utilities Air Regulatory Group. The UARG report concludes that the evidence of economic benefits associated with improved visibility is insufficient for policy prescriptions except to assert that the benefits could range from zero to a very large value. The principal criticisms are summarized below:

1. The hypothetical nature of the surveys and the presentation of visibility in a single good context causes respondents to overvalue the benefits of visibility improvement.

2. The expanded payment card CV format and the method of adjusting and removing high and low bids lead to an upward bias in benefit results.

3. There is a wide variation in bids across individuals and across CV formats that implies a very wide confidence interval.

4. The median serves as a better indicator of average benefits than the mean, which in small samples is more easily influenced by outliers, especially high bids.

As discussed in Section 2.2.1.4., the hypothetical nature of contingent valuation surveys has two components: unfamiliarity with the market and the possibility of inaccurate bids because no money is actually exchanged. Lack of familiarity with the market is certainly a concern, but it may lead either to overvaluing or undervaluing a good. The lack of a money payment is a more serious concern, since economists are always more comfortable with direct market evidence. However, as reported above, the results of comparing CV results from a hypothetical survey with the results of a simulated market experiment in buying and selling hunting permits are mixed. In one study Bishop, et al. (1984) found that a hypothetical mean WTP exceeded the actual (real money) mean payment and that the difference was statistically significant. However, preliminary results of data collected in 1984 found no significant difference between the results obtained from the hypothetical survey and the actual cash payment in a simulated market. Thus, hypothetical bias may not be as significant as once feared, and pending further research there is no empirical basis for adjusting results from contingent valuation surveys to account for hypothetical biases.

The issue of competing claims on respondents' incomes is another source of potential upward bias. The Cincinnati and Chicago studies suggest that this problem is clearly of concern in valuing non-use benefits in Class I areas, but its applicability to user benefits is unclear. A comparison of user WTP, with and without budget constraint information, to avoid contact with diesel odors indicates no important differences in results. A survey (Rae, 1983) in Boston (79 individuals) without a budget constraint yielded annual benefits of about $ 2.50 and $ 10 (1983 dollars) to avoid increased weekly contacts with low and high intensity odors. Preliminary results of a similar study in Philadelphia (Lareau and Rae, forthcoming) that included WTP for other competing environmental and charitable goods yielded higher benefit values, about $ 3 and $ 16 (1984 dollars), respectively The expanded payment card format that contains budget information may also serve to remind respondents of their budget constraint. This problem of competing claims on scarce income is by no means settled, but again there is mixed evidence as to whether it is an important concern in measuring user values associated with urban visibility improvement.

The criteria for portraying and interpreting visual materials is the subject of considerable research. There is concern that survey respondents may view visibility, a good with which they have little market familiarity, in a qualitative manner. That is, there may be consistency in an individual's valuations of median to good, but that an individual may be relatively indifferent to photos of 25 or 40 mile visual range relative to a median 10 mile visual range. Consequently, comparing values of improved visual range across studies requires great care. However, there is no obvious bias associated with this problem. Respondents may react to a 25 mile visual range or a 35 mile visual range as both typical of some wider visibility range with a 30 mile mean.

Some direct question formats have encountered problems with protest bids, and Ruud suggests that the procedures used in both the Six City and Chicago studies may bias the results upwards. These studies identified zero, protest, and high bids and further questioned respondents to determine the accuracy of the stated bid. Protest bids were eliminated, and some very high bids were adjusted downwards. These corrections appear to have been somewhat ad hoc; nevertheless the direction of the change is to depress the mean of the "solid core" data relative to the raw data. A more rigorous approach to outlyers would have been preferable, but it is not apparent that such an approach would yield significantly different benefit estimates than were reported in the "solid core" data.

Tolley, et al. justified using the expanded payment card (C2) format in the Six Cities study on the basis of a greater percentage of "solid core" data (mainly attributable to fewer zero and protest bids), which results in higher WTP. The UARG study points out that this criterion creates potential upward biases due to format selection. However, a strong downward bias is also at work in the

Six Cities study in that the photographs depicted generic backgrounds. These two biases appear to cancel each other. Average WTP bids in the Six Cities study using the C2 format and generic photos are about the same as the six formats in the Chicago study that employed photos of the Chicago urban area.

The UARG report points out that individual visibility bid data exhibit a wide confidence interval for a given format. However, econometric evidence suggests a fairly precise relationship between visual range and WTP for visibility improvement in the Six Cities data. A linear specification yielded a coefficient on visual range (miles) of $14.2 with a standard error of $ .60. Thus for a 20 mile improvement the 95 percent confidence interval (two standard errors or $ 14.20±$1.20) would be $ 260 to $ 308, which is actually a very tight confidence interval. Further econometric analysis using an aggregate model has provided non-linear specifications with similarly tight confidence bands.

That different formats yield different bid results is clear from the Chicago study. If variation across formats is included, Ruud demonstrates that the confidence interval increases significantly. This calculation assumes that choice of format is a random element in the survey design. The development of different survey formats has been motivated by the need to avoid certain types of biasing influences and to capture a full measure of WTP. The fact that these formats yield different results is to be expected. It is certainly fair to suggest that the expanded payment card format used in the Six Cities study has some potential biases and to suggest that some other format is more accurate. However, it is not correct to ignore all the literature on CV format development and to assert that all formats ever used in previous studies are part of a distribution that should be treated as a random element in estimating benefits.

Another important issue is whether the mean or the median of a sample represents a more accurate measure for computing aggregate benefits. It should be pointed out that the mean of the population is the correct measure, but in small samples the mean is easily biased by extreme values. The appropriate question is at what sample size is the mean of the sample more accurate than the median. This question applies primarily to the direct question studies (Six Cities and Chicago), since the ordered logit estimator used in the Cincinnati study approximates a median estimate (Hanneman, 1984). Table 2 shows that for the Six Cities study with over 500 observations the median amounted to about 72-80 percent of the mean local visibility bids. However, the standard errors of the means of the three bids indicate a reasonable level of precision in the estimate of the mean. For the 10 to 30 mile improvement we can say with 95 percent confidence that the mean lies between 170.36 and 212.04. The median value in this case lies outside the range of even four standard errors. Thus, in the Six Cities study with a sample size over 500 the sample mean is a better approximation of the true mean of the population than is the sample median.

3.5.2 Comparison of Visibility Benefits in Urban Areas

The three eastern urban visibility studies are most appropriate for estimating WTP benefits for improvements in urban visibility. Table 5 compares in 1984 dollars the WTP benefit estimates for a one mile improvement in median visual range from the three visibility studies in the eastern United States.

The direct question WTP method generated annual average WTP benefit estimates (1984 dollars) per household that ranged from about $ 5-41 for different cities and across different formats. The Chicago study tested WTP direct question formats and obtained annual average household benefits of $ 14-41 per mile improvement in typical visual range. The highest WTP benefit, $ 41 per mile, was achieved with the expanded payment card format. Using an expanded payment card plus a rebid mechanism, the Six Cities study yielded average annual household WTP benefit values for each city that ranged from $ 6-26 per mile improvement in typical visual range. Estimation of a non-linear visibility value function reduced that range to about $14-17.50 per mile. The Cincinnati study used a checklist format and obtained annual average WTP benefits of about $5 per mile improvement in the pre-test and about $ 33 per mile in the final survey.

The contingent ranking method was used only in Cincinnati. A pre-test generated an annual average household WTP (1984 dollars) of $ 24-34 per mile improvement in visual range for a change in visibility occurring 'most of the time'. In contrast, the comparable benefits from the final contingent ranking survey, which used smaller visual range increments, were much higher, $ 78-119. The range of estimates for each survey is due to specifications that used different choice sets. When visibility was described as a distribution of visibility conditions, the contingent ranking method yielded larger WTP benefits on a per mile basis. The pre-test yielded a benefit of $ 25 per mile for a large (84 percent) change in average visual range and $ 65 per mile for a small (21 percent) change in average visual range. The final survey resulted in substantially higher benefits, but inconsistencies across specifications yielded considerable uncertainty in the estimates.

Benefit estimates from the California studies, both contingent valuation and property value, tend to lie in a wide range of about $10-127 per mile for improvements in visual range. The two California contingent valuation studies were in the same range as eastern CV visibility studies. Annual average household WTP for a one mile improvement in median visual range was about $ 10-16 in the SCAB study and about $ 40 in the SFBA study. Using 34-50 percent as the visibility component of total benefits, WTP values for the three property value studies ranged from $ 23 to $ 127 per mile improvement in visual range. A one mile improvement in visual range in the South Coast Air Basin was valued at $ 23-54 per household. In the San Francisco Bay Area study a one mile improvement in visual

range was valued at $ 49-72 per household. A more recent hedonic property value study in Los Angeles and San Francisco that used the extinction coefficient as a measure of air quality yielded somewhat higher household WTP benefit estimates for a one mile improvement in visual range: $ 37-127 in Los Angeles and $ 38-61 in San Francisco. The wide ranges for these property value estimates reflect differences in WTP benefits for the different functional forms estimated.

The WTP benefit values generated by the direct question formats used in the Chicago, Six Cities, Cincinnati, and California contingent valuation studies fall into a range of about $ 5 to $ 41 per mile for 50 to 100 percent increases in typical visual range The results of the Cincinnati contingent ranking pre-test also lie within this range. The annual household benefit values from the property value studies conducted in California range from $ 23-127 per mile, which is wider than the range implied in the contingent valuation results The property value benefit results depend on the percentage of visibility benefits, and thus the CV results in the range of $ 5-41 per mile appear more defensible at this time. It should be noted, however, that several studies found benefits per mile improvement in visual range that were in excess of $ 50 per household, and the $ 5-41 range of benefits may be considered relatively conservative.

3.5.2.1 Derivation of Urban Visibility Benefits Estimates

There is no one study that can withstand all the relevant criticisms. Rather, it is necessary to choose among the existing studies, recognizing their limitations. The University of Chicago studies of Chicago and an additional six eastern cities appear to offer the most broad-based data set for estimating the value of improved visibility in eastern areas. Annual household bids (1984 dollars) for the expanded payment card format yielded an average estimate (seven cities) of about $ 18 for a one mile improvement in visual range. The simplicity of the linear functional form is appealing, but a non-linear specification is indicated by the data. A non-linear function was estimated on data for six cities using the negative exponential specification presented below:

$$\text{Bid } (\$\ 1982) = 519.7206[1-\exp(-0.02708^{*}\ VR)]$$

r-squared = 0.469

where VR is visual range rescaled so that the mean VR = 0.

This relationship yields a significant parameter for visual range and explains a high percentage of the variance in the estimates. It also explains much of the difference in the raw bids in terms of differences between individuals and cities. In 1984 dollars (constant term becomes 571.6926) it predicts that for an average

household (in Boston or Mobile) a 1 mile increase from the mean (about 10 miles) would be worth about $15 and an increase from 19 to 20 miles visual range would be worth about $12. Thus, a best estimate of urban visibility benefits can be obtained by applying the relationship below to changes in visual range:

$$\text{Bid (1984 \$)} = 571.6926[1-\exp(-0.02708*VR)]$$

3.5.2.2 Low and High Estimates

Results from other studies provide a basis for low and high estimates. A comparison of the average of the five other formats in the Chicago study suggests that the expanded payment card generated average bids that were about 50 to 100 percent higher. It seems appropriate to use this variation as a basis for a low estimate. The constant term from the Six Cities study is adjusted to one-half of the value used in the best estimate, and a 1 mile improvement from the average visual range is worth about $7.50:

The high estimate is based on the upper bound estimate from the initial Chicago study, the San Fransisco Bay Area study, and the pretest results from the Cincinnati study. The Chicago upper bound estimate was $41/mile, while the CV portion of the San Fransisco estimate was $40/mile. A value of $45/mile is derived from the Cincinnati contingent ranking pre-test data using a semi-log specification to relate bids to changes in visual range. Thus, there is evidence from three studies that visibility could be valued as high as $40/mile, which serves as the high estimate. This benefit is captured in a higher constant term in the negative exponential function:

$$\text{Bid (1984 \$)} = 1497[1-\exp(-0.02708*VR)]$$

These predictors are all based on a mean visual range of 9 to 10 miles, which must be rescaled to zero. This allows changes from the mean visual range to enter the equation directly as VR. The resulting benefit estimates are in 1984 dollars.

3.5.3 Comparison of Class I Area Visibility Studies

Class I areas include many unique National Parks and Wilderness areas. Consequently, it is to be expected that visibility benefits will differ at different sites. Yet, the user values reported in these three studies are quite similar after correcting for inflation, visual range improvement, and time of visit. These studies have elicited user values for large increases in visual range, and Table 6 presents user values in 1984 dollars for a 100 mile visibility improvement at Grand Canyon, Mesa Verde, and Great Smoky Mountains National Parks. At Grand Canyon these benefit estimates vary from about $ 2.40 to 7.80 per household-day. At Mesa Verde all but one of the benefit estimates lie in the range of about $ 2.20 to 5.50 per household-day. At Great Smoky Mountains the benefit estimates

range from about $ 7.75 (probably biased downwards) to $12.80 per household-day. The remaining differences in visibility values between eastern and western Class I areas may be explained by differences in mean visual range. Mean visual range in the rural west is about 60 miles compared to about 20 miles in the rural east. There are not sufficient studies to estimate a non-linear visibility value function for Class I areas, but it appears reasonable to apply the following user benefit estimates (1984 dollars per household-day) to any 100 mile improvement in visual range at class I areas:

User Benefits Per 100 Mile Increase in Mean Visual Range
(1984 Dollars/Household-Day)

	West	East
Low	$ 2.50	$ 8.00
Medium	4.00	11.00
High	7.50	13.00

In addition, there is evidence to suggest that households are willing to forego some income in order to preserve or improve visual air quality at certain vistas for the use of others. Estimates for the Grand Canyon ranged from about $ 15 to 90 per household per year, and estimates for the Smokies ranged from about $ 20 to 60 per household per year. The differences in these estimates were due to the bidding context: a multiple good context generated the low estimates and a single good context generated the high estimates. Using photographs of Grand Canyon and the Smokies to portray western and eastern visibility, respectively, it was also found that urban households in the east were willing to pay $ 34 to 39 per year for a 10 mile improvement in western visibility and $ 68 to 83 per year for a 10 mile improvment in eastern visual range. These values were in addition to bids for local visibility improvement, but did not consider competing claims of other non-visibility goods.

That Americans are willing to pay significant sums of money to preserve the important features of our natural and historical heritage is evidenced by the large number of dollars contributed to different funds, especially the current Save the Statue of Liberty campaign. However, what is not clear is whether that amount of money would be forthcoming every year and what other charities or other volunteer causes are receiving less as a result. Until the answers to these questions are known it is impossible to estimate a non-use value for visibility in non-local or Class I areas. It should also be noted that for some areas non-use values are likely to be quite significant in the magnitude of benefits for improvements in visual air quality.

Table 1

Average Annual Household Willingness to Pay for Visibility Change in Chicago
(Solid Core Bids - 1981 dollars)

WTP Format	Observations	Change in Typical Visual Range 9 to 4	9 to 18	9 to 30
Single Bid (A1) (Oral)	37	$ 250 (51)	$ 236 (50)	$ 362 (50)
Accept/Reject (A2) (Oral)	35	156 (30)	147 (22)	171 (24)
Oral Iterative (A3) Bid	31	222 (37)	210 (38)	240 (39)
Checklist (B)	34	121 (25)	109 (22)	152 (29)
Payment Card (C1) (Public Goods)	42	210 (44)	186 (35)	234 (53)
Payment Card (C2) (Public and Private Goods)	42	283 (57)	324 (72)	456 (115)
Total Sample	221	227 (20)	218 (20)	271 (28)

Notes: Numbers in parenthese are standard errors of the mean.

Source: Randall, A., Hoehn, J., and Tolley, G., "The Structure of Contingent Markets: Results of a Recent Experiment," a paper presented at the American Economic Association Meetings, December 1981.

Table 2

Average Annual Household Willingness to Pay for Visibility Change in Six Cities
(City Average in 1982 dollars)

City	Change in Typical Visual Range				
	10 to 5 (miles)	10 to 20 (miles)	10 to 30 (miles)	+10 East (miles)	+10 U.S. (miles)
Atlanta	$ -196	$ 188	$ 286	$ 281	$ 353
Boston	-145	139	171	189	224
Cincinnati	- 57	57	64	74	80
Miami	- 99	88	104	116	118
Mobile	-156	168	197	215	238
Washington	-232	238	303	358	422
Total Observations	-525	533	535		
Sample Mean	-150 (181)	150 (182)	191 (241)	205 (NA)	239 (NA)
Sample Median	-120	108	144	NA	NA

Notes:
1) Negative values represent WTP to avoid a reduction in visual range; positive bids represent WTP to achieve an improvement in visual range.
2) City values are mean bids for each city.
3) Mean and median values are presented for the entire sample. Numbers in parentheses are standard deviations from the mean.

Source: Tolley, G., et al., Establishing and Valuing the Effects of Improved Visibility in Eastern United States, draft report for U.S. Environmental Protection Agency, Office of Research and Development, March 1984.

Table 3

Average Annual Household Benefits of Changes in Visibility in Cincinnati
(1982 dollars)

Method	Basic Specification (Pre-test)	Basic Specification (Final Survey)
First Contingent Ranking		
WTP: median to clear ('most of the time')	$ 381-544 (38-97)	$ 343-516 (50-66)
WTA: median to haze ('most of the time')	$ 387-635 (85-120)	$ 884-1324 (102-153)
Observations:	140	296
Second Contingent Ranking		
WTP: Existing (27 Percent Clear) to Best (80 Percent Clear)	$ 217 (36)	$ 122-358 (73-40)
Existing (27 Percent Clear) to Good (40 Percent Clear)	$ 142 (25)	$ 32-184 (49-45)
WTA: Existing (27 Percent Clear) to Degraded (15 Percent Clear)	$ 106 (24)	$ 288-386 (61-93)
Existing (27 Percent Clear) to Very Degraded (8 Percent Clear)	$ 268 (35)	$ 417-625 (72-113)
No Health Effects to 2 days lung and eye irritation	--	$ 323-498 (73-127)
No Health Effects to 8 days lung and eye irritation	--	$ 530-906 (84-182)
Observations:	82	296
Direct Question - Checklist Bid		
WTP: median to clear	$ 85 (10)	$ 143 (12)
Observations:	147	314

Notes: 1) The range of estimates is based on specifications with different choice sets.
2) Numbers in parenthese are standard errors of estimate associated with the bottom and top of the range.

Source: Rae, D.,/Charles River Associates, Benefits of Visual Air Quality In Cincinnati Results of a Contingent Ranking Survey, draft report, Electric Power Research Institute, Project #1742, August, 1984

Table 4

Summary of California Visibility Studies
(Average Annual Willingness to Pay Per Household)

Study	WTP for Change in Air Quality ($ Current)	WTP for Change in Air Quality ($ 1984)	WTP for VR Change (34-65%)	VR Change (miles)	($ 1984)
Brookshire, et al. South Coast Air Basin					
Property Value 30 % reduction in TSP - 1977/78	$ 558	$ 1073	$ 365-697	2 to 12 12 to 28	$ 23-70
Contingent Valuation 30 % reduction in ambient pollution 1978 survey	312	477	162	2 to 12 12 to 28	10-16
Loehman, et al. San Francisco Bay Area					
Property Value 30% reduction in PSI Index - 1978/79	86	143	49-93	16.3-21.2	10-19
Contingent Valuation 14% improvement in visibility - 1980	71	90	90	16.3-18.6	40
Thayer and Trijonis					
Los Angeles Property Value 10% reduction in extinction - 1978/79	57-153	95-254	32-165	10-11	32-165
San Francisco Property Value 10% reduction in extinction independent of ozone	115-125	191-208	191-208	17-18.7	112-122

Note: Rate of inflation for residential properties in California is 9.7 % per year. For households values are inflated by the Department of Labor's Implicit Price Deflator for Personal Consumption Expenditures, which rose from 149.2 in 1978 to about 228 in 1984.

Source: Brookshire, D., d'Arge, R., Schulze, W., and Thayer, M., 1979 Experiments in Valuing Non-Market Goods: Alternative Benefit Measures of Air Pollution in the South Coast Air Basin of Southern California, EPA-600/6-79-0016; Loehman, E., Boldt, D., and Chaikin, K., 1981, Measuring the Benefits of Air Quality Improvements in the San Fancisco Bay Area, SRI 8962; and Thayer, M., and Trijonis, J., February 1984, Visibility Benefits Analysis, draft report for California Air Resources Board.

Table 5

Comparison of Willingness to Pay Benefit Estimates for Visibility Changes in the Eastern United States
(dollars per mile)

Study	Benefit Estimates ($/mile)	(1984 $/mile)
CHICAGO: Six Direct Question Formats (Solid Core Bids - 1981 Dollars)		
9 to 4 miles	24-57	27-64
9 to 18 miles	12-36	14-41
9 to 30 miles	7-22	8-25
SIX CITIES: Payment Card and Rebid Format (1982 Dollars)		
10 to 5 miles	11-46	13-51
10 to 20 miles	6-24	6-26
10 to 30 miles	3-15	4-17
CINCINNATI: Pre-Test (1982 Dollars)		
WTP: Contingent Ranking		
7.8 to 25.2 miles (most of time)	22-31	24-34
11.4 to 21.0 miles (distribution)	23	25
11.4 to 13.8 miles (distribution)	59	65
WTP: Direct Question - Checklist Bid		
7.8 to 25.2 miles (most of time)	5	5
CINCINNATI: Final Survey (1982 Dollars)		
WTP: Contingent Ranking		
11.6 to 16.4 miles (most of time)	71-108	79-118
10.9 to 14.4 miles (distribution)	35-102	43-127
10.9 to 11.8 miles (distribution)	36-204	39-225
WTP: Direct Question - Checklist Bid		
11.4 to 16.4 miles (most of time)	30	33

Source: G. Tolley, et al., 1984, Establishing and Valuing the Effects of Improved Visibility in Eastern United States, Office of Research and Development, Environmental Protection Agency, March 1984; D. Rae/Charles River Associates, Benefits of Visual Air Quality In Cincinnati Results of a Contingent Ranking Survey, draft report, Electric Power Research Institute, Project #1742, August.

Table 6

WTP Benefits of Visual Air Quality in Class I Areas
(dollars per household visit)

Study	Observations	Visibility (miles)	Vista (Current)	Benefits ($) (1984/100 miles/day)	
Grand Canyon 1980	166	78 to 105	G.C.	$ 1.68	$ 7.80
	166	78 to 125	G.C.	2.76	7.40
	166	78 to 179	G.C.	3.90	4.85
	166	78 to 258	G.C.	5.15	3.60
National Park Service 1980	1000	66 to 96	G.C.	0.97-0.98	4.10
	1000	66 to 126	G.C.	1.35-1.60	2.80-3.40
	1000	66 to 162	G.C.	1.92-2.10	2.50-2.75
	1000	66 to 210	G.C.	2.75	2.40
	800	66 to 96	M.V.	0.85	3.55
	800	66 to 126	M.V.	1.15	2.40
	800	66 to 162	M.V.	1.75	2.30
	800	66 to 210	M.V.	2.55	2.20
EPRI - Parks 1981	196	71-94 to 154	M.V.	3.40	5.50
	193	94 to 154	M.V.	9.14	17.70
	202	6-12 to 60	G.S.M.	14.94	11.10
	202	30 to 60	G.S.M.	9.91	12.80
	201	18 to 60	G.S.M.	7.75	7.15

Notes: 1) The National Park Service Study evaluated visibility at Grand Canyon in surveys undertaken at both Grand Canyon and Mesa Verde National Parks. The benefit range presented above reflects the small differences between the two surveys.

2) Benefits in current dollars per visit are converted to 1984 dollars per household-day. The Consumer Price Index is used to inflate 1980 and 1981 values to 1984 dollars. The average visitor length of stay is used to convert the benefits per visit to benefits per household-day. This value is about 3 days at Great Smoky Mountain and 1 day at Mesa Verde. Data for Grand Canyon were not available and this calculation assumes 1 day.

Source: Schulze, W., Brookshire, D., Walther, E., Kelley, K., Thayer, M., Whitworth, R., Ben-David, S., Malm, W., and Molenar, J., September 1983, Methods Development for Environmental Control Benefits Assessment, Volume III, The Benefits of Preserving Visibility in the National Parklands of the Southwest, U.S. EPA, Office of Policy Analysis, Office of Policy and Resource Management, EPA-230-07-83-009, Washington, D.C.; Rae, Douglas A., "The Value to Visitors of Improving Visibility at Mesa Verde and Great Smoky Mountains National Parks," and MacFarland, Karen K., Malm, W., and Molenar, J., " An Examination of Methodologies for Assessing the Value of Visibility," in Rowe,R. and Chestnut, L. (eds.), 1983, Managing Air Quality and Scenic Resources at National Parks and Wilderness Areas, Westview Press, Boulder, Co.

3.6 Quantification of Dollar Benefits of Improvements in Visual Range

An estimate of the benefits of policies that improve visual air quality requires two pieces of information: the change in visual range caused by reduced emissions and the valuation of specific visibility increments. The preceding sections developed a visibility value function that can be used to value specific increments in urban visual range. The contractor study (SAI, 1984) described in Appendix B provides estimates of changes in visual range in the eastern United States for various sulfur reduction scenarios.

The SAI analysis yields a prediction of visual range for 80 regions in 30 eastern states for several different emission reduction scenarios. A visibility value function was then applied to these changes to yield a benefit value per household in each state.* Total state benefits were computed by summing over the number of households. Similarly, total benefits for the eastern United States were computed by summing over all 30 states. A summary of these results is provided below for three acid rain abatement proposals by applying the low, best, and high visibility benefits estimates derived above to the changes in visibility predicted by SAI:

Visibility Benefits of Acid Deposition Abatement in the Eastern United States

Reduction Scenario (SO2)	VR Change (%)	Benefits ($ million) Low	Midpoint	High
10 State	4.5	$ 250	$ 500	$ 1300
8 million tons	11.1	500	1100	2900
12 million tons	15.8	800	1600	4100

Note: These benefits are in 1984 dollars.

Research from perception studies has demonstrated that the human eye can perceive a change in contrast of 2-5 percent which translates into a change in visual range of about 5-15 percent. This peception threshold applies to evaluating specific slides or photographs that represent median or typical conditions. In urban areas, however, studies have shown that respondents do value small changes in distributions of good, median, and bad days that may change the mean visibility by less than 5-15 percent. Consequently, it is likely that this concept of a 5-15 percent threshold of perception is more applicable to visits to Class I areas than to changes in local visibility. Nevertheless, a medium estimate of benefits is provided below with perception thresholds of 0, 5, and 15 percent.

*The SAI report used a semi-log visibility value function while this report uses a negative exponential visibility value function taken from the Six Cities study described above.

Benefits of Improvements in Visual Range
(Medium Benefit Scenario)

Reduction Scenario	VC Change (%)	Benefits ($ millions) Thresholds 0 %	5 %	15 %
10 State	4.5	$ 500	$ 400	$ 0
8 million tons	11.1	1100	1100	400
12 million tons	15.8	1600	1600	1300

Note: These benefits are in 1984 dollars.

A report by the Utilities Air Regulatory Group (AeroVironment, 1985) found much smaller benefits for improving visibility in the eastern United States. In addition to applying different scientific and modeling parameters this analysis employed an economic benefit function based on the Six Cities data whose origin was shifted to account for a 15 percent threshold of perception. This function then assumed zero benefits at a 15 percent threshold level and fitted both linear and non-linear curves from this point of origin. This shift of the origin is inappropriate, since it does not fit the Six Cities WTP data, which are best fit by a non-linear function through the origin and which lies significantly above zero at the threshold point.

The development of similar benefit estimates for visual range improvement in western urban areas is also possible. However, no comprehensive modeling analysis is yet available to translate regional emission reductions into changes in visual range.

A similar valuation analysis could be applied to visitors to Class I areas. As mentioned above, for short duration visits the concept of a threshold of perception is applicable. An improvement in visual range of less than 5-15 percent on a given day would have no value to visitors. However, even a sub-threshold improvement in mean visual range could cause some days to improve by more than 5-15 percent, but this value could be estimated only if a highly detailed modeling analysis were available to predict the full distribution of daily visibility events.

In the case of Great Smoky Mountains National Park, which lies on the border between North Carolina and Tennessee, a 12 million ton reduction scenario yields an estimated improvement in mean visual range of 13.9 to 20.7 percent, or about 1.5 to 2.3 miles. If we assume this increase in mean visibility occurs each day of the year, we can estimate the benefit to visitors to Great Smoky Mountains National Park. The Park records about 9 million visitor days per year, or about 3 million household days. The value of visibility in eastern Class I areas was estimated in dollars per household-day per 100 mile increase in visual range and ranged from about $ 8-13.

Thus, a 1.5 to 2.3 mile increase in mean visual range at Great Smoky Mountains National Park would have a user value of about $ 400,000 to 900,000 per year.

Other eastern Class I areas have to be evaluated individually. A 12 million ton reduction scenario would yield a 23.6 percent improvement in visual range at Shenandoah NP in Virginia, but only a 5.0 percent improvement at Acadia NP in Maine. The total benefits at the former can easily be calculated from visitation data. Total benefits at Shenandoah NP are less than at the Great Smoky Mountains NP because Shenandoah receives substantially fewer visitors per year. At Acadia the visibility change is not great enough to exceed the threshold value so that benefits are probably negligible. As is evident, the range of benefits per Class I area is fairly small and summing over the relatively small number of Class I areas in the east is expected to yield annual dollar benefits for users that is unlikely to exceed $ 10 million. This level of benefits is small relative to the magnitude of benefits for local visibility improvement. However, it should be noted that there is some evidence that non-use benefits for visual air quality improvement in Class I areas could be significant, but at this point in time there is not enough agreement on the level of these benefits to include them in this summation.

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4.0 VISIBILITY EFFECTS ON AIRCRAFT AND RELATED OPERATIONS

4.1 Significant and Major Visibility Reductions

Any analysis of the effect of visibility on aircraft operations must necessarily distinguish between significant and severe reductions in visibility. For the purposes of this discussion, a severe reduction in visibility is one which reduces visible range below 3 miles, or below one mile within about 1000 feet of the surface. Federal Aviation Regulations allow VFR (Visual Flight Rules) operation when visibility is greater than 3 miles, or greater than one mile within 700 or 1200 feet of the surface. In general, the 700-foot figure will apply in the vicinity of airports or in areas of congestion. Visibility reductions which prohibit VFR operation are considered severe in this context.

Again for the purposes of this discussion, a significant reduction in visibility must be defined, but without benefit of specific aviation regulation defining a visibility limitation. By popular consensus, visibility in the West would be considered significantly reduced when visibility drops below about 25 miles, but in the East 25 miles is considered excellent visibility. 25 mile visibility is great enough that it is very unlikely to affect aircraft operations. 25 miles represents a travel time of 1/4 hour in a small private plane. Below 10,000 feet, speeds are restricted so that 25 miles represents a travel time of at least 5 minutes in even the fastest aircraft. This travel time would give more than ample time for accident avoidance and visual navigation, and so is considered to be equivalent to unrestricted visibility. Instead, a lower visibility will be selected as a "significant reduction." This visibility will be selected for its effect on aircraft visual operations rather than on an aesthetic perception. For these purposes, a visibility of five to ten miles is selected based on the operations of student pilots in cross-country flights. A five to ten mile visibility is considered adequate depending on the student's capabilities as determined by the instructor while a lesser visible range is considered insufficient for cross-country operations by student pilots. This is because the student will have difficulty in locating his destination airport and in avoiding other aircraft when visibility is more restricted but still above VFR limits.

4.2 Effects of Visibility Reductions on Safety

Most pilots and non-pilots assume that reduced visibility degrades the level of safety of flight operations. This assumption is based on the fact that there is more difficulty in maintaining visual contact with other aircraft during reduced-visibility conditions. In addition, the load on air traffic controllers would increase, especially below 3 miles visibility, as "special VFR" operations increase reliance on air traffic control to maintain aircraft separation.

Examination of accident records does not produce immediate evidence of a direct correlation of reduced visibility conditions with increased accidents, although impaired visibility is frequently listed as a contributing factor in accident reports. Apparently, pilots are more vigilant in reduced visibility situations and greater use is made of other-than-visual means

of maintaining aircraft separation. Reduced visibility appears to transfer the responsibility for collision avoidance from the pilot to the air traffic controller. This transfer does not seem to have an immediate effect on safety but may restrict some flight operations and would certainly increase controller workload.

4.3 Major Visibility Reductions

The effect of major reductions in visibility is to cause a change from Visual Flight Rules to Instrument Flight Rules. This change eliminates all operations by pilots who are not instrument rated and restricts operations by rated pilots to necessary flights between airports. (Sightseeing or aerial photography would be precluded). Thus major visibility reductions would tend to change the make-up of the air traffic and would eliminate most or all pleasure flying.

Airport data reported in the 1982 EPA Sulfur Oxides and Particulate Matter Criteria Document indicate major reductions ($\leq$ 3 miles) are not likely to be caused by haze, except in the summer. In 1971-75 haze apparently caused visibility in the eastern U.S. to be less than 3 miles 2 to 12% of the time during the summer (% occurrences with no fog, precipitation, or blowing materials). The frequency of these episodic reductions slightly decreased in the ensuing pentade (76-80). In other seasons, it is usually fog or precipitation related events that produce major reductions less than 3 miles.

4.4 Significant Visibility Reductions

The effect of significant visibility reductions are somewhat more subtle than those of major reductions. VFR operations are possible and are common under significantly reduced visibility, and accidents do not appear to be more common under these conditions. However, activities which depend on long visual range will not occur. These activities include military activities where visual contact with a "target" are necessary. Officials at Edwards Air Force Base and the China Lake Naval Weapons Center, both located in the Mohave Desert, have expressed concern over haze intrusions that increasingly limit their activities; these include aviation and defense related research, development, testing, and evaluation and all require maintenance of excellent visibility. Aerial photography would also be greatly curtailed or eliminated since picture quality would be degraded. Finally, student pilot and pleasure flying would be reduced due to the need for greater visibility for these operations.

Significant visibility reductions are frequently the result of urban haze. Humidity is often a contributing factor, but the haze would not be characterized as fog. This range of visibility reduction is often due to air pollution rather than natural phenomena.

APPENDIX D. ALTERNATIVE CONTROL STRATEGIES FOR REGIONAL HAZE

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APPENDIX D. ALTERNATIVE CONTROL STRATEGIES FOR REGIONAL HAZE

1.0 INTRODUCTION

In considering potential long-term regulatory strategies for regional haze, it is useful to treat the regional haze phenomena in the East and West separately. Regional haze characteristics, intensity, sources, and associated air quality problems are sufficiently different between West and East that distinct control program goals and approaches should be considered within each region. It may also be useful to consider tailoring specific control approaches for certain source categories, sub-regions, or urban areas in both East and West.

Given the complexity and variability of regional haze, both from a pollution and public perception standpoint, it is questionable whether any single regulatory approach will have the flexibility needed to provide efficient and effective control of regional haze. Rather a combination of approaches - - some designed specifically to protect visibility, some implemented to meet other air quality objectives - - may be more appropriate.

The task force examined a number of alternatives for limiting or reducing emissions of precursors of regional haze. These alternatives included both strategies (master plans for control) and tactics (detailed elements needed to implement strategy) that address this visibility problem. The various approaches can be categorized into three classes:

1. Those capable of being implemented using the existing legislative authorities in the Clean Air Act.

2. Modifications to existing legislative authorities that might enhance (or diminish) their effectiveness for control regional haze.

3. Those that rely on addition of new legislative and regulatory authorities.

The approaches also can be categorized according to environmental goals: 1) reduction of regional haze as a primary objective, 2) regional haze control as a partial or supplemental objective, or 3) reduction of some other adverse effect. The degree to which haze reduction is used to justify regulatory action, then, forms a second conceptualizing dimension.

These two categorizations are used to organize alternative strategies in Table 1. To the extent possible, each of the approaches listed within the matrix has undergone a preliminary qualitative examination with respect to appropriate criteria including cost-effectiveness, equity, ease of understanding, enforceability, flexibility, compatibility with existing air pollution control programs, and acceptability to affected parties. That examination is summarized in the next section of this appendix. The evaluations are highly subjective and represent the opinions of individuals based on a qualitative understanding of general approaches. More detailed specifications and quantitative analyses are needed for deciding on the potential usefulness of particular variants. Two major approaches - various SO_2 rollbacks and

TABLE D-1. MATRIX OF REGULATORY OPTIONS

AUTHORITY	GOAL		
	I. Haze Principally	II. Haze Secondarily	III. Other Objective
A. Existing	1) Secondary NAAQS - fine particles, sulfates, extinction, other 2) "Phase II" visibility programs-class I areas	1) PSD Requirements 2) Interstate Pollution Control 3) International Air Pollution 4) NSPS, BACT/LAER major source categories	1) Primary NAAQS PM, SO_2 2) Motor Vehicle Emissions Standards
B. Modified Existing	1) Codify integral vistas 2) Modifications to 169A 3) Modify PSD 4) State based programs	1) Modify Interstate Pollution Control 2) Regional Secondary NAAQS; NAAQS "Criteria" 3) Episode Control 4) Revised NSPS requirements 5) Requirements for "Nontraditional" Sources	1) Emissions trading 2) "Reasonable Effort" for SNAAQS 3) Modify PSD
C. New	1) Visibility Standards	1) SO_2 Rollback 2) Age Based Controls	1) Acid Rain

targeted acid deposition scenarios have been examined more quantitatively in the contractor analyses (See Appendix B). In addition, Section 3 of this appendix provides observations on the major alternatives that deserve further consideration in policy analysis and discusses outstanding issues in current visibility regulations that could affect haze control programs in the future.

2.0 EXAMINATION OF CONTROL STRATEGY ALTERNATIVES MATRIX

2.1 Approaches Based on Current Legislative and Regulatory Authorities

2.1.1 Haze as Principal Objective

a) Secondary National Ambient Air Quality Standards (SNAAQS)

Section 109(a)(1)(B) of the Act requires the EPA to prescribe secondary national ambient air quality standards that specify a level of air quality which once attained and maintained will "protect the public welfare from any known or anticipated adverse effects." Under Section 110(a)(2)(A)(ii), the States are required to submit plans to the EPA that show attainment and maintenance of SNAAQS in a "reasonable time."

Specific haze-based approaches include developing SNAAQS for fine particles (<2.5um); components of fine particles such as sulfate; visibility important precursors such as sulfur dioxide, nitrogen oxides and reactive hydrocarbons; or atmospheric optical parameters such as extinction or scattering coefficient. Different limits could be set for the above parameters and could apply to ground-level, point or area-wide concentrations; worst-case short-term events; or monthly, seasonal or annual averages.

Effectiveness:

This approach can be effective depending on the regulatory goals of the program and the specific area or region of interest. The secondary standard could be effective in protecting currently good or excellent visibility, preventing undesirable visibility impairment or improving existing visibility in those regions where it is currently impaired. However, a single nationally applicable welfare standard could not be effective at achieving all such goals in all areas of the country such as western and eastern urban areas or pristine class I areas. The extent of visibility impairment and the value people place on visibility vary widely with affected populations, regions of the country and settings within each region. A single SNAAQS could not reasonably address all facets of the visibility problem equally. In particular a SNAAQS that would maintain current visibility levels in the rural West might require lower than natural background levels in the East. The level of any SNAAQS might best be directed at establishing desirable visibility goals for those regions in the East affected by large scale regional haze of multistate origin and those major western urban centers affected by haze predominately of local origin. The visibility in pristine class I areas would have to be protected via some other mechanism, e.g., the PSD program, Section 169A, etc.

Simplicity:

The SNAAQS approach is relatively simple conceptually and understandable to the regulators, industry, environmentalists and the general public, but would be complext to implement. The decision on selecting an acceptable national level could be difficult. A SNAAQS based on PM-2.5 or atmospheric optical conditions would require a national visibility or fine particle/secondary aerosol monitoring network and corresponding modeling capability.

Cost:

The cost of design, implementation and enforcement of this approach would depend on the standard level. In any event, monitoring network implementation and development of modeling capability may be initially costly. To the extent substantial additional controls are required, control strategy design, implementation and enforcement are likely to be costly.

Enforceability:

The enforceability would depend on the implementation alternatives chosen. The traditional approach of predictive modeling and monitoring would be significantly hampered by available tools and the long range transport problem.

Flexibility:

This approach is a relatively inflexible one in that it cannot address all problems and differences between geographic areas and vistas within a given area. Modifications to the Act (See 2.2.2.b and 2.2.3.b) could add flexibility, but at a cost to simplicity.

Compatibility:

Regulating regional haze with a SNAAQS would very compatible with existing approaches for regulating air quality.

Acceptability:

The acceptability of this approach is problematic and depends greatly on the nature of the standard, its goal, relation to other approaches, and implementation alternatives. A single national level cannot be expected to deal with both eastern and western visibility.

b) Visibility Protection for Class I Federal Areas (Phase II)

Section 169A of the Clean Air Act establishes the national goal of remedying existing and preventing future impairment of visibility in class I federal areas resulting from man-made air pollution. The mechanisms within the Section 169A program include 1) the requirement for certain existing sources to reduce their contribution to existing visibility impairment by installing the Best Available Retrofit Technology (BART), 2) the long-term strategy that States must develop to make progress in meeting the national goal, 3) the review of new sources' impacts on visibility in federal class I areas, and 4) integral vistas, which encompass selective protection of visibility beyond class I area boundaries.

EPA promulgated regulations under Section 169A in December 1980. These requirements dealt with plumes and other pollution that were "reasonably attributable" to specific sources. (These requirements were referred to as the "Phase I" requirements.) In October 1984, EPA proposed to implement parts of these regulations (monitoring and new source review) in those States that do not adopt their own implementation procedures.

Action on "Phase II" (regional haze) visibility protection was originally deferred to permit development of improved scientific and technical bases for action. The provisions of this section could, with appropriate regulatory development and technical guidance, be applied to visibility impairment in class I areas caused by regional haze in the West. It would be more difficult to justify the use of this authority as a principal means for addressing haze in the East.

Effectiveness:

The effectiveness of this approach relies heavily on how well visibility research programs can reduce the uncertainties in areas such as predicting the formation of secondary aerosols under varying meteorological conditions; the estimation of transport and dispersion parameters in areas of complex terrain; the predicition of the impact of single or multiple sources on a regional scale; the determinations of whether incremental changes in contrast or color will be perceptible; and visibility monitoring.

The application of BART will be restricted to those major sources for which there is good evidence linking them to noticable visibility-impacts, which meet the age requirement (began operation during the period from August 1962 to August 1977) and the control of which can be expected to result in a significant improvement in visibility. The application of BART in phase I will therefore have little effect on regional haze. Even if applied to regional haze, the number of sources affected would be limited. BART would not be applicable to source categories such as agricultural activities, prescription fires, copper smelters, and most urban pollution (motor vehicle emissions, space, heating, etc.)

The requirement for a "long-term (10-15 years) strategy for making reasonable progress toward meeting the national visibility goal may provide additional authority to implement regional haze presursor control, particularly, in the West where a large number of class I areas are located. Specific mechanisms for such application are not specified in the Clean Air Act, and substantial regulatory guidance would be required. In its development of a long-term strategy, the State can consider additional measures for remedying existing visibility impairment in mandatory class I areas, such as adopting additional emission limitations and schedules for compliance for uncontrolled or poorly controlled sources not covered by BART.

The review of new sources' impacts on visibility in federal class I areas can provide a mechanism for controlling a new source's contribution to regional haze. However, the capability for predicting visibility impacts over regional scales must be developed adequately.

Selective integral vistas protection would provide for greater geographical coverage of the Phase II regional haze rules and may provide protection for some areas between class I areas.

Simplicity:

The Phase II approach, if it builds on ongoing SIP programs, could be relatively understandable to the regulators and affected parties. Given the complexity of the regional scale phenomena, however, multistate coordination will be required. Improved predictive modeling and monitoring capability would greatly enhance the effectiveness of such an approach.

Cost:

The cost of the design and implementation of this program would be relatively high. Monitoring network implementation and development of modeling capability can be costly especially in an enforcement mode. An individual source's contribution to the visibility problem and the predicted effectiveness of control options must be analyzed prior to enforcement. Such tasks may be resource intensive.

Enforceability:

The enforceability would depend on the effectiveness of the modeling approaches adopted and the extent and reliability of the monitoring data.

Flexibility:

This approach is relatively flexible for class I area visibility impairment problems. Many but not all visibility impairing sources would be regulated under this approach. The long-term strategy is a flexible mechanism that can adapt to difficult impairment problems. Urban areas with haze problems, but which do not impact class I areas would not be subject to control under Phase II.

Compatibility:

Phase II rules could be made compatible with the Phase I visibility program and the State Implementation Plan but would represent a substantial expansion of concerns and coverage. Section 3.3 discusses Phase I issues that should be addressed prior to a Phase II program.

Acceptability:

The acceptability of this approach would depend on the general acceptability of the monitoring data and regional haze modeling approaches. Source/receptor relationships must be better understood and documented.

2.1.2 Haze as Partial Objective

a) PSD - Sections 160-169 CAA

The PSD program is designed to protect and preserve clean areas of the United States and its territories by controlling the amount of air quality deterioration allowed in these clean areas. This strategy is implemented primarily via a preconstruction permit program for major and modified sources of air pollution and a clean air area classification system which places clean air areas into one of three classes, each with progressively more stringent levels of allowable air quality deterioration. The key provisions within the PSD program that are of interest to the regional haze problem are: 1) the PSD sulfur dioxide (SO_2) and particulate matter increments for the three classes of areas; 2) the requirement that PSD sources reduce air pollutant emissions by the application of the Best Available Control Technology (BACT); 3) the PSD provision that allows States to redesignate areas to class I, the most protective area classification; and 4) the provisions giving the Federal Land Managers (FLMs) the responsibility and role in the PSD program to protect the air quality related values (AQRVs), including visibility, of certain class I federal areas. The net effect of the PSD program, including the present visibility review requirements, is to limit regional emission increases for certain major emission source categories.

Effectiveness:

This approach is only partially effective but it does have the potential for improvement with respect to protecting and enhancing visual air quality. In order to make the PSD program more effective in protecting visibility, stronger emphasis must be placed on class I area air quality protection as a major goal of the program with appropriate, supporting policy guidance and regulatory structure. Several aspects of the PSD program could be improved through this interpretation of the goals of PSD. These aspects generally fall into two categories: procedural and regualtory.

The procedural aspects to be considered include: 1) better implementation of the existing requirements to notify affected FLMs; 2) additional notification requirements which will involve the FLMs earlier in the permit review process; and 3) a mechanism to ensure interstate cooperation in regard to notifying and encouraging participation by State air quality officials and FLMs in States impacted by PSD permit activities in antoher State. Suggested additional requirements for FLM notification might involve: 1) advance notification whenever the permitting authority receives such advance notice, such as the scheduling of a preapplication meeting with the applicant; 2) consultation with the affected FLMs on the completeness of the permit application as it relates to impacts on class I areas; and 3) development of impact/source size/distance criteria to guide the determination of which FLMs to notify.

The regulatory aspects to be considered include: 1) requiring a cumulative visibility impact analysis in permit applications that incorporate all existing and permitted sources of visibility impairing pollutants (or presursors to those pollutants); 2) develop PSD increments for other pollutants for which NAAQS exist and which are visibility impairing pollutants or precursors to those pollutants; and 3) explicitly requiring visual air quality monitoring by PSD applicants.

Simplicity:

Historically, the PSD program is viewed as quite complex. However, given the experience gained over the life of the program, it has become more understandable to the regulatory agencies, industry, and public interest groups. It would be somewhat more simple matter to incorporate these additional visibility aspects into the existing program, than to create a parallel visibility review program.

Cost:

The additional costs involved could be incremental to the existing costs of implementing the PSD program, requiring additional monitoring and modeling.

Enforceability:

Enforceability would be comparable to that under the existing PSD program. It will depend upon the legal interpretation of the goals of the PSD program, the construction of any new regulatory language, the proper implementation of the program, and establishment of enforceable permit conditions.

Flexibility:

This approach is flexible in that all PSD determinations are made on a case-by-case basis. New increments, however, would not be flexible.

Compatibility:

This approach is compatible with the existing PSD program; the new permitting procedures could be handled under current frameworks.

Acceptability:

Acceptability will depend to some extent upon the development of approved analysis techniques for predicting and monitoring visibility. The procedural aspects may be reluctantly acceptable due to the increased administrative burden placed on permitting agencies.

b) Interstate Air Pollution Control

Subsection 110(a)(2)(E)(i)(II) of the Act prohibits one State from "interfering" with visibility protection plans of another State. Section 126 requires that nearby States be notified of all new, modified and existing major sources which could so "interfere." Subsection 165(d) (concerning air quality values, including visibility) also requires that Federal Land Managers be informed of plans for new sources which could affect their Class I areas. Section 126 further provides for States to petition the Administrator to disallow a new source or modification which would "interfere" or to require a SIP revision where an existing source "interferes." This portion of the Act as currently written would be most effectively considered in the context of implementing a SNAAQS or Phase I class I area visibility protection program.

Effectiveness:

This approach is currently constrained in its effectiveness to protect visibility by both legal and technical considerations. This is demonstrated at least in part by an Environmental Protection Agency decision in 1984 on interstate air pollution petitions which were filed in 1980 and 1981 under the provisions of Section 126. Based on the decision reached in consideration of these petitions, it appears that States must have approved visibility protection plans for regional haze before Section 110 and 126 can be used as vehicles for addressing haze problems. Transboundary pollutants which may be responsibile for causing regional haze impacts appaently can only be controlled through the petition mechanism of this time if these pollutants are "interfering" with other requirements contained in State plans, such as compliance with PSD increments or NAAQS.

Even absent the legal question, there is still a lack of technical tools and thorough understanding of the transformation and transport processes responsible for regional haze. In order to effectively analyze and mitigate regional haze impacts utilizing the interstate air pollution control provisions of the Clean Air Act, more research and development will be needed to address these problems.

Simplicity:

This approach would not be simple to implement. Exercising the provisions of Section 110 and 126 with respect to the "interference" clauses requires the affected State(s) to assume a significant burden of proof in demonstrating the prohibited impacts coming from the accused State(s). Such an approach is, by its nature, reacting to an existing problem and not preventative. It could also be adversarial and might involve arbitration or court settlement to reach a decision. The notification provision under Section 165 is a simple procedural permitting activity which is ongoing. Some improvements to simplify this section are offered in a subsequent section.

Cost:

This approach is likely to be costly in terms of money, time, and agency resources regarding activities under Sections 110 and 126.

Enforceability:

It would be hard to enforce this approach pursuant to Section 110 and 126 due to potential legal recource and the technical uncertainties that currently exist. It is also hard to track the compliance with Federal Land Manager notification procedures under Section 165.

Flexibility:

The approach under Sections 110 and 126 as written appears to depend on source/receptor specificity that is not likely to be achieved in the near future. In that sense, it is not flexible for dealing with regional scale transport.

Compatibility:

As applied to regional haze, this approach would not be compatible with existing air quality programs.

Acceptability:

This approach is partially acceptable in that it provides a mechanism for affected parties to seek corrective action under Sections 110 and 126 and for Federal Land Managers to be apprised of impending permit actions. Its overall acceptibility is, however, adversely affected because of its inherent limitations.

c) International Air Pollution

Section 115 of the Act provides authority to call for States to control U.S. pollution that may endanger health and welfare in a foreign country, when that country has reciprocal legislation with respect to the U.S. The complexity of source receptor relationships may limit the usefulness of this authority for transboundry transport of haze between the U.S. annd Canada, but use of this aauthority or other bilateral discussions regarding impacts of emissions from several smelters near the U.S.-Mexico border may be more tractable.

Effectiveness:

Partially effective as discussed above. The potential exists for greater effectiveness given future advances in the understanding of source receptor relationships and improvements predictive and analytical technology.

Cost:

Low to moderate, depending upon the level of interest given to any particular international air pollution problem.

Enforceability:

Difficult to enforce, givern the tenuous nature of international agreements and jurisdictional aspects which would complicate any definitive action.

Flexibility:

This approach is extremely flexible, perhaps at the expense of being effective.

Compatibility:

This approach should be compatible with existing air pollution control programs, but permits regulations of effects for which no other standards exist.

Acceptability:

Provided there are benefits to all international parties engaging in problem resolution, this approach should be acceptable. It is likely that the affected localities may find the apprach the least acceptable.

d) New Source Performance Standards (NSPS), Motor Vehicle Emission Standards (MVES)

NSPS for new stationary sources and MVES for vehicles apply to new emission sources and are generically called "technology related." Such emission standards are selected on the basis of technology availability and cost-effectiveness and apply nationwide. NSPS must be reviewed every four years and revised if superior technology has become available. NSPS requirements are supplemented by BACT determinations under PSD and Lowest Achievable Emission Reductions (LAER) under new source review where NAAQS are violated.

In the long term, NSPS and MVES are the principal means presently used to control regional air pollution, like haze. The retirement/replacement process that ultimately reduces emissions operates over the long run. This may be fairly rapid (10 years for vehicles), intermediate (20 years for smaller boilers and many processes) or quite slow (up to 60 years for utility boilers). Given that NSPS will eventually limit haze precursors, the key policy issues related to the intermediate time domain are: Will NSPS/MVES operate with acceptable speed, and if not, how could their operation be hastened or supplemented?

Effectiveness:

These approaches are effective over the long term as older, minimally controlled sources are replaced by newer, better controlled sources. However, the degree of effectiveness will depend upon several factors such as the respective rates of existing source retirements/replacements and new source growth, the siting locations of new stationary sources, and the recognition and control of those emissions which are ultimately responsibile for haze formation. The effectiveness of this approach can be improved if emissions control requirements are considered with visibility protection as a goal. On the other hand, the effectiveness may be limited by the inability of this approach to prevent eventual increases in total visibility-reducing emissions within a particular region or area. In such situations, PSD (BACT) and LAER decisions can be used to tailor requirements for specific areas.

Simplicity:

This approach is simple to implement in that both the NSPS and MVES programs are ongoing and fromilar. Any new requirements could simply be added to the existing regulations.

Cost:

In terms of program costs to the administering agencies, there should be little additional costs since these are existing programs. Some additional costs would be incurred by the regulated industry and the general public, however, if NSPS are developed for currently unregulated industry or pollutants and if stricter MVES are adopted. Also, front-end costs would be necessary to determine the effectiveness of implementing new control requirements to achieve public health and welfare goals.

Enforceability:

This approach would be enforced through existing compliance mechanisms. These include: 1) requiring stationary sources to install, operate, and maintain control technology to minimize emissions of the affected pollutants; 2) requiring these same sources to install, operate, and maintain continuous emissions monitoring systems and to report the monitoring data; 3) performing compliance testing of these sources to verify industry reports of compliance to the control agencies; and 4) implementation of vehicle inspection and maintenance programs for compliance of any MVES.

Flexibility:

This approach is flexible to the extent that it allows sources subject to NSPS to employ any control technology they choose in order to meet the required emission limits. Vehicle manufacturors may have fewer options under strict MVES.

Compatibility:

This approach is compatible with existing regulatory programs.

Acceptability:

This approach would be acceptable to the implementing agencies due to the familiarity with the programs and the simplicity of their implementation. It is likely to be less acceptable to the affected industries due to stricter regulation and associated increase in control costs.

2.1.3 Control of Haze Precursors to Meet Other Objectives

a) Primary National Ambient Air Quality Standards (PNAAQS)

Sections 109(a)(1)(B) and (b)(1) of the Act require the EPA to prescribe national primary ambient air quality standards "the attainment and maintenance of which ... are requisite to protect the public health." PNAAQS protect the public health by limiting the ambient concentrations of SO_2, NO_2, O_3, particulate matter and lead. Control programs designed to attain and maintain these ambient concentration levels may also have an impact on reducing the frequency and intensity of haze. If, in the future, a PNAAQS for fine particles (e.g., PM-2.5) or sulfates is supported by health data, reductions in regional haze might be substantial. A more stringent primary SO_2 standard could also result in haze reductions.

Effectiveness

The past fifteen years have been marked by significant reductions in emissions of particulate matter, SO_2, NO_2, VOC and reductions in ambient O_3 concentrations resulting from the continuing effort at achieving and maintaining the primary national ambient air quality standards. In the absence of such progress the frequency, intensity, and extent of regional haze would surely be significanly greater than it is at present.

The existing set of PNAAQS do not effectively control important visibility precursors and secondary aerosals such as fine particulate matter (PM-2.5) and sulfates, nor address the long range transport of visibility precursors from polluted urban areas to more pristine ones.

A primary NAAQS for a visibility important precursor, if justifiable on health grounds, would be more effective at reducing haze problems in western urban areas; the northwest; and the east. Control programs developed in response to such PNAAQS would be effective because they would utimately result in lower ambient levels of visibility impairing precursors. A major issue of this approach would be whether sufficient information is available to justify a health related standard and when such standard setting could occur. EPA is currently in the process of making revisions to the primary and secondary NAAQS for PM. During March 1984, EPA proposed to replace the TSP PNAAQS with a standard based on PM-10. With this revision process as of yet unfinished, it appears premature to expect any initiative to create a health based PM-2.5 NAAQS within the next five years. The review of the SO_2 PNAAQS is, however, not yet completed.

Any standard established for ground-level concentrations may not protect against all regional or layered hazes. An elevated haze layer could be readily perceptible and yet ground-level fine particulate concentrations could be near zero.

Simplicity:

This approach is simple and easy to understand and is identical or similar to existing ambient air quality standards and proposed PM-10 standards. PNAAQS for PM-2.5 and/or sulfates would require specialized monitoring and modeling capabilities and implementation.

Cost:

Standard setting process, establishment and implementation of a monitoring network and the development of a modeling capability may be fairly costly.

Enforceability:

The enforceability would depend on the effectiveness of the modeling approaches and the extend and reliability of the monitoring data.

Flexibility:

The PNAAQS strategy is a relatively inflexible one because it cannot be adapted to all problems, differences between geographic areas and vistas within a given area.

Compatibility:

This approach would be compatible with existing air quality standards and proposed PM-10 fine particle standards.

Acceptablility:

Concerns about the adequacy of modeling and monitoring science or the justifiability of a health based standard for PM-2.5 or sulfates could affect the acceptability of this approach.

2.2.0 Modifications of Existing Authorities

2.2.1 Haze as Principal Objective

a) Codification of Integral Vistas

The Act, in 1977, established a national goal of protecting certain national parks and other areas of national significance from visibility impairment resulting from industrial pollution. Section 169A of the Act required EPA to promulgate regulations as guidelines to the States for implementing a visibility protection program. The agency published these regulations in December 1980. These regulations give the States the discretion of extending the visibility protection to views perceived from within certain national parks and other federal areas of specific landmarks or panoramas located outside the boundary of the area. These views are called "integral vistas". Although it is the State that determines how much protection (if any) to afford these integral vistas, it is the Federal Land Manager that must identify and list them for the State's consideration.

The concept of integral vistas has been the subject of legal challenge. This regulatory uncertainty could be eliminated by Congress including provisions for the listing and State-selective protection of integral vistas in amendments to the Clean Air Act.

Effectiveness:

Congressional action to incorporate integral vistas into the Clean Air Act would eliminate the uncertainty of this mechanism and encourage its implementation. Unless authorized differently by Congress, the integral vistas could be applied selectively to prevent or remedy visibility impairment that was reasonably attributable to a source or group of sources. Under this Phase I approach, regional haze would not be regulated. If regional haze impairment of integral vistas were to be considered, this mechanism would provide the means of States to balance the need for correcting or preventing the vista haze problems with other factor such as economics and energy considerations. Such protection would not be automatic and would not be applicable to all lands external to class I areas, only those areas included within the integral vistas. Certain important State lands not designated as class I, where visibility nonetheless is an important value, may not receive protection under this approach unless the State incorporates special protection provisions in its own rulemaking. Given the greater density of class I areas and potential integral vistas in the West, and because regional haze tends to occur on large geographical scales, this approach would be more effective at protecting the intervening spaces between class I areas in the West rather than the East. It is questionable this approach should be considered in remedying or preventing urban haze caused by urban area emissions. Opting for the protection of an integral

vista, with the resulting economic and social costs of further reductions in emissions in urban areas, may be a very difficult decision for a State to make and enforce.

Simplicity:

This integral vista approach is simple in principle. In practice, it may be very difficult to regulate haze in this manner because of the difficulty States may experience in performing the benefits/cost analysis needed to justify how much (if any) protection is afforded integral vistas. Ambient monitoring as well as source monitoring will be required to determine the origin of the haze.

Cost:

The cost of the design and implementation of this approach would be relatively low. However, the monitoring and modeling support required by this approach may be costly.

Enforceability:

The enforceability would depend on the effectiveness of the modeling approaches, the extent and reliability of the monitoring data and the States resolve to balance the need for industrial growth with that of resource protection.

Flexibility:

Class I areas with sensitive vistas could be addressed with this approach, and states are given substantial flexibility.

Compatibility:

This approach would be compatible with existing air quality regulations and standards.

Acceptability:

Protection of integral vistas would probably be accepted eventually providing that such protection is not mandated but rather part of a process that evaluates alternative goals or objectives for the lands included in these vistas.

b) Modification of Section 169A

Section of 169A of the Act could be strengthened or weakened with respect to regional haze. As noted above, the 1980 EPA regulations implementing Section 169A distinguished between identifiable plumes and regional haze. The decision to include regional haze type visibility impairment in the Section 169A visibility protection program was deferred until a later Phase II. Phase II would be proposed and promulgated when improvements in monitoring techniques provide more data on source-specific levels of visibility impairment, regional scale models become refined, and our scientific knowledge about the relationships between emitted air pollutants and visibility impairment improves. Section 169A could be modified by Congress to encourage the application of the program to regional and urban haze; to exclude haze from Section 169A and address it elsewhere; or could be left in its present form.

Effectiveness:

As noted, left in its present form, 169A could be an effective approach for addressing western visibility. Exclusion of haze from 169A and addressing haze with acid deposition might be useful in the East, but of questionable effectiveness in the West. A reauthorization by Congress could be a very effective means for accelerating the development of programs for addressing the haze problems,in the West. For example, Congress could establish a firm date for the implementation of Phase II visibility protection. Such a statutory deadline would create a high priority for haze research and would encourage research monies to be directed in the areas of improving the science of regional visibility modeling and monitoring. Other modifications that would be of use are (1) increasing the subset of existing sources subject to BART, such as pre-1962 sources, (2) addressing the role of smoke management in preventing of remedying haze problems caused by prescription burns and other land management practices, (3) requiring regional haze to be analyzed in the new source review PSD process, (4) specifically subjecting urban haze impairment to control and remedy via this section, and (5) broading the geographical scope of this section to encompass more than the federal class I areas.

Simplicity:

The concept of such an approach could be straightforward and understandable to regulators, environmentalists, industry and the general public. Implementation, however, must still address complex multi-source regional problems.

Cost:

The cost of design, implementation and enforcement be relatively high. Determining the major contributions to the haze would require expensive monitoring and modeling. Enforcement would be expensive if smelters or urban areas were the major contributions especially if such sources were located hundreds of kilometers from the geographical areas with the haze problems.

Enforceability:

Enforceability would be difficult for urban area sources and older existing sources that could not afford retrofit controls.

Flexibility:

The current Section 169A approach is very flexible one that provides a consistent framework to evaluate different types of visibility impairment, in different regions, and caused by a variety of sources. A modified approach might reduce flexibility, but increase effectiveness.

Compatibility:

If this approach expands to cover class II areas, it would be inconsistant with existing approaches for regulating air quality and visibility impairment.

Acceptability:

Those urban areas or industries affected by this approach would probably not find the controls required acceptable and challange such rules in court. Public comments from environmentalists and industry question both the desirablility of expanding to class II areas and the need to reauthorize 169A to deal with haze.

c) Modify the PSD Program

A separate task force is examining the PSD program and is discussing modifications motivated by objectives other than haze. These should be examined for haze implications. The PSD program could be modified to increase its effectiveness at addressing regional haze problems.. Such modifications could include:

1) Replacing the PSD increments with new ones based on PM-2.5 (instead of TSP).

2) Mandating short-term PSD increments for other pollutants that affect visibility;

3) Allowing BACT determination to consider mitigating regional haze and impacts on AQRVs in addition to economics, and energy impacts;

4) Providing specific language enabling regional haze effects to be addressed in class I and class II areas;

5) Requiring States and Federal Land Managers to set state wide, regional or local visibility objectives or goals wich would be implemented through PSD;

6) Including review and control of "minor" air pollution sources which emit pollutants that affect visibility.

Effectiveness:

The overall effectiveness in reducing or preventing regional haze would be enhanced if the above modifications were made to the PSD program.

Fine particles are commonly defined as particulate matter which is smaller than 2.5 micrometers in diameter, and referred to as PM-2.5. Relatively high concentrations of fine particles are primarily responsible for regional haze in the West. Lowering the magnitude of the PSD particulate increments and redefining them to be based on PM-2.5 rather than total suspended particulates would focus more control on the amounts of both those fine particulates that are directly emitted and those that are formed in the atmosphere (e.g., sulfates from precursor pollutants) (e.g., sulfur dioxide). Exceedances of these PM-2.5 increments would be addressed via the PSD permit process or through a revision of the State's SIP which could require reductions in emissions from existing sources.

Promulgating short-term PSD increments for other pollutants that affect visibility and haze would, like the PM-2.5 approach above, provide a direct means for regulating haze producing emissions in areas where PSD is applicable.

Increment could be established for pollutants such as sulfates or optical air quality indicators such as contrast.

Allowing the determinations of BACT to consider environmental impacts such as regional haze and impacts on class I area air quality related values, could increase the stringency of control technology requirements for PSD sources and encourage additional reduction of haze producing pollutants. Presently, BACT represents the maximum degree of emission reduction achievable taking into account energy, environmental and economic impacts and other costs.

Language could be added to the PSD statute that would enable regional haze effects on class I and II areas to be addressed. Such added emphasis on regional haze would encourage better analyses of haze to be performed during the PSD permit review.

A fifth modification of PSD would allow the State and/or Federal Land Managers to set state-wide, regional or local visibility objectives or goals which would be implemented through the PSD program. A visibility analysis for a proposed new source would consider whether the new source impact is consistent with the applicable objectives or goals with respect to haze, perceptible plumes or atmospheric discoloration. If the visibility analysis indicates an unacceptable impact relative to the objectives, the permit could be denied; the source could relocate to more acceptable locations where meteorology and terrain are more favorable; the source could improve the emission controls; or the source could scale down the size of the project to reduce emissions.

Lastly, the effectiveness of the PSD program at addressing haze could be improved by broadening the coverage of PSD review to other source categories which emit pollutants that affect visibility. Certain "minor" sources, general urban development and smaller populations centers near class I areas that are created in response to major industry could be reviewed under the PSD program.

Simplicity:

These modifications represent major extensions to the existing PSD program which has been in effect for over a decade. They would probably add to the complexity of program.

Cost:

The cost of design, implementation and enforcement of PSD will increase if these modifications are made. Establishing new increments, developing visibility goals and objectives and the PSD review of additional sources are all resource intensive activities.

Enforceability:

These modifications would be as enforceable as the existing PSD provisions provided tht adequate modeling and monitoring tools are available to characterize the haze source/receptor relationships.

Flexibility:

This approach would not be flexible enough to address the significant haze problems associated with many urban nonattainment areas. The modifications are better suited for managing visibility problems of class I and class II attainment areas where the PSD provisions are applicable.

Compatibility:

Modifying the PSD program to better regulate regional haze would create a new program that would be compatible with the existing PSD approach.

Acceptability:

Modifications such as establishment of new or revised increments, visibility objectives, more stringent BACT determinations, would probably not be very well accepted by industry and would be the subject of legal and technical challenge.

d) State Based Programs: Six Rocky Mountain States Cooperative Study

States would have the opportunity to develop a visibility protection program, choose quantitative visibility parameters and standards, designate specific areas or vistas requiring protection, and choose the most cost-effective strategy in the absence of national program requirements. The States of Colorado, Idaho, Montana, New Mexico, Utah and Wyoming cooperated on a study with the National Park Service and U.S. Forest Service to examine such an approach. It was the intent of these States to consider the feasibility and desirability of a consistent region-wide approach to visibility protection.

Effectiveness:

This approach has the potential to be effective depending upon the degree to which individual states develop and adopt visibility standards. Without specific national requirements for adoption of state plans, however, it is doubtful that all western states would adopt a program to control regional haze. Overall effectiveness would be enhanced if there is comprehensive coverage of visibility control programs.

Simplicity:

The concept of establishing and implementing a standard is easy to understand but the establishment of an aesthetic visibility standard may not be a simple task. Implementation of this standard may also be difficult due to the need for acceptable modeling techniques and monitoring methods.

Cost:

The cost of this approach would be less than that of a national program. Much of the costs would be incurred during the planning and development stages of standard setting. Control costs may also be significant for both existing sources which must reduce emissions to make progress toward attaining a standard and for new sources which may affect areas subject to a standard.

Enforceability:

The enforcement of applicable standards will depend upon several factors. These factors include: 1) the degree to which states cooperate on adopting a consistant form of the standard; 2) the degree to which interstate cooperation on visibility impacts occurs; and 3) the adequacy and acceptablity of modeling techniques and monitoring methods. The lack of nationally applicable, federally enforceable standards may also hamper strict enforcement, especially with regard to interstate impacts.

Flexibility:

This approach is flexibile in that it allows for consideration of regional, area and vista-specific goals in standard setting.

Compatibility:

Standard adoption and implementation should be compatible with existing air quality protection programs.

Acceptability:

Acceptablity of this approach will be greater if ample opportunity is allowed for public participation and review during the standard setting process. Further development of acceptable models and monitoring methods will also increase the acceptability of this approach.

2.2.2 Haze as Partial Objective

a) Interstate Air Pollution Control

"Regional" or "transported" air pollutants include fine PM, ozone (and other oxidants), and acidifying agents (SO_x, NO_x). Regional air pollution occurs over large (interstate) areas and is difficult to attribute to specific sources except in a statistical sense. Modifications to Section 126 could increase the flexibility to deal with interstate transport when it is not possible to pinpoint impacts of specific sources. This could enhance the implementation of a number of air quality management approaches in dealing with regional transport, including NAAQS, 169A, PSD, International Air Pollution, as well as modifications to these authorities.

Effectiveness:

The modifications under discussion here include:

1) retain 126 as is for identifiable sources and tight clusters of sources,

2) replace "interfere with" and "prevent" in 110(a)(2)(E) with "substantially interfere with",

3) add a new subject addressing long range transport (>50 km) from multiple sources
   a) acknowledge problems with specific source attribution, but empower limits on emissions from a state or a large portion thereof,
   b) provide authority to impose reasonable conditions on SIP acceptibility to mitigate or prevent regional pollution,
   c) provide a mechanism for prior consultation between EPA and states involved, and
   d) define or provide for defining "substantial interferences."

Such modifications could provide an effective tool for implementing regional haze and other air quality management approaches by recognizing difficulties in source-receptor relationships permitting reasonable actions, and providing mechanisms for conflict resolution.

Simplicity:

As with any air quality management based approach, this would not be simple to implement.

Cost:

The cost of this supplemental approach depends on the air quality management approach it is used to implement.

Enforceability:

As with other air quality based approaches, enforceability is limited by the availability of technical tools to support this kind of regulatory action.

Flexibility:

This approach is flexible in that it allows for "reasonable" measures and prior states involvement.

Compatibility:

This approach could affect compatibility between regional programs and existing air quality programs.

Acceptability:

This approach is partially acceptable in that it provides an improved mechanism for affected States to seek correcitve action for a problem over which they would otherwise have no direct control. Its overall acceptability depends on the program it is used to implement.

b) <u>Variable Secondary National Ambient Air Quality Standards (SNAAQS)</u>

Visibility is better in arid climates than in humid ones. A small addition of pollution-derived fine particlues produces a greater effect in an area with naturally high visual ranges than in an area with lower visual ranges. A single nationally applicable SNAAQS for haze that would maintain currently good western visibility could be unnecessarily stringent for the eastern

United States where the natural background of fine particles may exceed current loadings in the West. A similar imbalance could result if a SNAAQS for ozone or SO_2 were based on crop protection where sensitive crops were region-specific rather than ubiquitous. A more effective approach could be revision of Section 109 (b)(2) of the Act to allow the welfare related Standards to be region specific or even variable within a region. A second possible NAAQS change would permit cost/benefit considerations to be considered in establishing SNAAQS.

Effectiveness:

The regional standard approach could be more effective than the single nationally applicable SNAAQS. The regulatory goals of such a program could more realistically reflect the diverse nature of haze problems in the United States. The variable SNAAQS could be designed to protect currently good or excellent visibility in the southwest, for example, or prevent undesirable visibility impairment, or improve existing visibility in those regions where it is currently impaired.

The existence of regional specific SNAAQS could facilitate haze control being incorporated in urban air quality management. This approach would be useful in addressing important haze issues in areas other than class I designated areas and in multistate areas. Use of costs to establish SNAAQS would put great weight on uncertain benefits and costs estimates with the possibility of standard levels becoming more stringent as lower cost controls were developed. To the extent that national uniform standards are used, the "balance" could be suboptional. Such an approach could, however, permit establishing practical goals and more aggressive implementation.

Simplicity:

A variable SNAAQS approach would be more difficult and complicated to establish than setting of a single SNAAQS. Division of the nation into potentially numerous regions would be particularly difficult. In effect, the standard setting process would have to be duplicated in each region.

The development and articulation of regional and area visibility goals, objectives and numerical limits would demand the participation of industry Federal Land Management agencies, State and federal agencies, and environmental groups. The federal government would have the responsibility for promulgating these regional standards. States may argue that such a task is best accomplished by the State rulemaking process, especially if the region in question is totally situated within one State. Interstate haze issues could be dealt with better at the federal level.

Cost:

Resources for setting variable SNAAQS would be greater in than in getting a single standard. Once promulgated, the standards would require resources for implementation and enforcement that would be of the same order of magnitude as other strategies analyzed. The cost of monitoring and modeling for the purposes of establishing the sources' contributions to haze and the degree of improvement that would result from implementing source emissions controls would be relatively expensive and resource intensive. Use of cost/balancing approaches in standard

setting could lower costs of control, but it is not clear that it offers substantial benefits in this regard over considering costs in implementation.

Enforceability:

The enforceability would depend on the adequacy and acceptability of the modeling methodology and monitoring data.

Flexibility:

This approach is relatively flexible because of the ability to tailor the standards on a regional or subregional basis. Protection of specific vistas in class I areas is probably best handled with other mechanisms. Use of national cost/benefit balancing could decrease flexibility of implementing SNAAQS, but increase flexibility in standard setting.

Compatibility:

Variable SNAAQS would be compatible with the existing air quality management programs for the existing primary and secondary NAAQS.

Acceptability:

Given sufficient opportunity for participation and review during the standard setting process, those regulated may find the resulting standards acceptable. The acceptability will depend strongly on the adequacy of the monitoring and modeling tools. It may be argued, however, that this approach departs from the traditional thrust of the Act, which encourages uniform national standards, and discourages development of "havens" allowing poorer air quality. Use of cost-benefit in standard setting would be controversial.

c) Episode Related Control

Haze, and other air pollution, varies substantially with weather and season. Control of high pollution episodes could be more efficiently accomplished if weather or seasonally variable emission control could be practiced. However, Section 123 specifically prohibits SIP credit for weather variable controls. The "reasonable progress, time, and/or measures" approach to SNAAQS attainment is conducive to the use of efficient but imprecise measures such as weather variable control.

Therefore, alteration of Section 123 may be useful for the control of haze or other welfare related air pollution.

Effectiveness:

This approach may be partially effective, has limitations over the long-term. The traditional approach of controlling during periodic episodes would require coordination and communication among hundreds of sources and short response times. Moreover, benefits would be limited to reducing haze on the worst days, not making average conditions good or good conditions better. With the possible exception of health, associated benefits (acidic deposition, materials damage)

would also be limited. Episodic control might have some application in the West, but only if understanding of transport patterns improves. Possibly more effective would be seasonal control approaches, with an emphasis on reducing summertime emissions.

Simplicity:

This approach would not be simple to implement. To make this alternative viable, it would be necessary to estimate haze formation based on a number of factors. These include variable meteorological conditions, transport and dispersion parameters in areas of complex terrain, formation of secondary aerosols, emissions from single or multiple sources on a regional scale, and the resulting perceptibility of the haze itself.

Cost:

Unless a fairly accurate and simplified methodology could be developed for predicting haze episodes, this approach would be costly to operate, and not clearly less expensive than continuous control. Extensive monitoring and research would be required to develop any useful predictive techniques initially and to verify the effectiveness of the program as it is implemented. The practicality of major fuel shifts or periodic curtailment of operation on a large scale needs further assessment.

Enforceability:

This approach would be difficult to enforce without the use of costly continuous monitoring devices and/or frequent inspections of operation records.

Flexibility:

This approach is flexible, permitting the possibility of improved visibility that might not be reasonably affordable with fulltime control.

Compatibility:

This approach could have compatibility problems with the usual air pollution control procedures; such systems have however been used on individual sources (e.g. smelters) on an interim basis.

Acceptability:

Because of its non-traditional character and enforcement burden, this approach might not be well received by state and local programs. Sources might or might not prefer such approaches depending on their costs and effects on reliability as compared to those for alternatives that might be required.

d) Revised New Source Performance Standard Requirements

One possible revision to New Source Preformance Standards that has been suggested concerns the percent reduction requirement of Section 111(a)(1)(A)(ii) which in effect prevents the use of low sulfur coal as the sole means of achieving NSPS for fossil fuel fired stationary sources. Removal of this provision has been proposed by same, and if implemented, SO_2 emissions in the West would

increase because flue gas desulfurization technology would not be routinely applied to power plants using low sulfur coal. A related provision would permit NSPS "bubbles", i.e., the reduction of emissions from existing sources that offset new source growth (see "emissions trading" below).

Effectiveness:

The overall effectiveness in reducing or preventing visibility degradation, would be limited, to the eastern U.S., where it could accelerate reductions in the near term. Eliminating the percent removal requirement could, however, increase future western SO_2 emissions.

Simplicity:

Such an approach would be relatively simple and understandable to regulators, affected industries, environmentalists and the public.

Cost:

The cost of development of revised NSPS under the current or modified provision would be comparable. Control costs would decrease.

Enforceability:

Emission standards are generally easier to enforce than ambient air quality standards, and nationally applicable standards facilitate enforcement.

Flexibility:

This is a relatively inflexible approach that, of itself, cannot effectively consider regional, area or vista-specific differences.

Compatibility:

Revised NSPS would be compatible with the existing statutory and regulatory programs.

Acceptability:

Eliminating the percent removal requirement for the power plant NSPS would be very controversial, and objected to by those whose livelihood depends on high sulfur coal, and by those concerned about long-term emissions growth in the West.

e) Requirements for Forest, Range, Agricultural and Other Land Management Practices

Congress could give generic guidance for developing regulations to control the use of prescribed and agricultural burning, soil cultivation and construction and maintenance of unpaved roads under NAAQS, PSD, and the visibility program. Regulation of these "non-traditional" sources in a consistent, effective manner has proven to be a difficult challenge under current authorities.

Effectiveness:

This approach should be effective in controlling land management practices that can contribute significantly to visibility impairment on a broad scale. Seasonal impacts of these various activities could be minimized through substitute activities or by specifying alternative methods.

Simplicity:

This approach would be complex to implement, but the mandate could make it easier than at present. Some aspects may, however, not be readily acceptable to land management agencies. The ease with which this approach is carried out will depend upon the degree of authority delegated to the regulating agencies.

Cost:

The cost of this approach is difficult to determine. It would vary by region and depend upon feasibility of measures that could be imposed. Program design and enforcement activities would require additional resources to implement.

Enforceability:

Successful enforcement of this approach also depends upon the authority granted to the regulating agencies.

Flexibility:

This approach should be flexibile to the extent that different control measures would be necessary for the various land management activities in different regions. A combination of measures could be implemented to minimize impacts of these activities on regional haze.

Compatibility:

Although control measures under this approach have not been utilized to a large extent, historically, this approach should be compatible with existing control programs.

Acceptability:

Efforts to control burning, and other temporary area sources have met with resistance in the past; the number of "sources" of various sites make it likely that some will resist regulation. Nevertheless, land managers and sources recognize the need for consensus guidelines.

2.2.3 Modifications Based on Other Objectives

a) Emissions Trading

Another option that could be considered in conjunction with the emissions and technology based approaches discussed in this report is to amend the Clean Air Act to permit emissions trading (bubbles) involving new as well as existing sources. Such a measure would substantially expand currently allowable emissions

trades and may be well suited to regional pollution where source location is relatively less important. An emission trade would create an imaginary "bubble" within which a source of air pollution could increase its emissions above the legally allowable limits, if another source(s) within the bubble would agree to reduce its emissions by an equal or greater amount. The effect of the combined emission increases and decreases would be to create a net improvement in air quality. A factor linking emission trading to haze is that power plant smelter trades in some regions of the West might improve visibility because smelter emissions are richer in directly emitted sulfates and other fine particles that produce haze. It is best considered as a cost minimizing approach used in combination with an overall emissions reductions strategy e.g., age based control, or more stringent NSPS.

Effectiveness:

The effectiveness of such a strategy must be examined very carefully to insure that any benefits realized by reducing haze on a regional scale would not be offset by degradation of air quality on the local scale near the air pollution sources.

EPA contracted with Systems Applications, Inc. (SAI) to perform a preliminary analysis of the net regional air quality impacts resulting from a scenario in which the SO_2 emissions from power plants were allowed to increase in a trade that provided for decreases in emissions at smelters. In particular, increases in emissions at 11 power plants and decreases in emissions at 7 copper smelters in the southwestern United States were analyzed. The results of this modeling analysis indicated that there would be areas of improved air quality near copper smelters and degraded air quality near the power plants. However, for sulfate concentrations and visibility impacts, that are caused by fine particulate sulfate, areas of relative improvement and degradation were less localized. Visibility and sulfate air quality were predicted to improve slightly in most areas in the southwest. In the small number of areas where degradation was predicted, the precentage degradation was very small. Sulfate air quality and visibility was predicted not to change significantly as a result of emission trading. These results should be viewed with caution, however, due to model based limitations.

The SAI report also indicated a potential problem resulting from this proposed emission trading in that increased SO_2 emissions at many power plant sites may not be possible because of constraints imposed by PSD class I and II increment consumption. These constraints would be most severe in areas of complex terrain and areas in the vicinity of national parks and wilderness areas. This report also assumed that the copper smelters would meet the SIP emission limits. If the smelter industry were unable to meet the SIP emission limits without emission trading with electric utilities, much more significant improvements in regional haze and air quality could result from an emission trade.

Approved emission trades with new sources could circumvent the application and installation of BACT on all new sources which has been a long-standing national policy and requirement of the Clean Air Act.

The overall effectiveness in reducing or preventing visibility degradation could be very limited because it would not prevent large increases in visibility

reducing emissions within a particular area. This approach also does not have any direct relationship to ambient air quality or visual air quality. Without continuous monitoring and extensive regional modeling the effectiveness of this approach would only be known after the fact and possibly too late to effectively address visibility problems. Under this approach, area specific visibility problems of specific class I areas and other visually sensitive federal and non-federal areas and vistas would not be addressed. However, the interstate nature of haze could be considered with such emission trades. By itself, it would be insufficient to assure effective visibility protection. Alternative approaches should be examined more carefully before steps are taken toward developing such an initative.

Simplicity:

Emissions trading is a simple and understandable concept, but one that would be complex in its implementation. Extensive regional modeling analyses would be required both to isolate those existing and new sources with a significant potential to reduce haze by participating in a trade, and to calculate the contribution to improvement or worsening of air and visual quality of each source.

Cost:

The cost of this approach would be relatively high in dollars, time and personnel on the part of the agency evaluating and implementing an emission trend.

Enforceability:

The emission trade concept is enforceable only as long as the emission limitations of the participating sources are enforceable.

Flexibility:

Emission trades would provide added flexibility in designing and modifying other pollution control strategies.

Compatibility:

This approach would be compatible with the existing bubble policies and regulations of the EPA and various State governments. Generally, the bubble approach has been applied to existing sources located in nonattainment areas. At present, the State of North Dakota is conducting a study of the feasibility of an emission trading program to assist in the management of air quality class I and II increment consumption.

Acceptability:

Emission trading for new sources would be expected to be very controversial. The smelter industry has indicated in its comments to the task force that it sees little to be gained from such trading.

b) Reasonable Effort to Attain SNAAQS

Section 110(a)(2)(A)(ii) of the Act specifies that a State plan implementing a secondary National Ambient Air Quality Standard specify a "reasonable time" at which such standard will be attained. A possible alternative would be to require a "reasonable effort" at attaining the SNAAQS. The latter is more amenable to regulatory interpretation via demonstrated, cost-effective control methods. Such an amendment might be appropriate if SNAAQS were the vehicle by which haze (or any other welfare effect) was to be addressed.

Effectiveness:

This amendment would facilitate the regulatory implementation of the SNAAQS by encouraging technology/cost based procedures, e.g., RACT.

Simplicity:

The requirement for a "reasonable effort" appears to be a relatively simple one to understand, but must be well defined in EPA guidelines.

Cost:

This measure would probably increase the cost-effectivenss of an approach to control haze based on the SNAAQS by providing for a more efficient implementation.

Enforceability:

Determining whether a reasonable effort has been made could be very difficult which in turn, would make enforcement difficult.

Flexibility:

As discussed above, the SNAAQS approach does not provide a very flexiable framework to attack diverse visibility problems. Incorporating the requirement that a reasonable effort be made to attain the SNAAQS could increase the approach's flexibility, if visibility aspects could be considered in the determination of reasonable effort.

Compatibility:

This amendment would not be incompatible with current approaches for regulating air quality and visibility impairment, or other goals and responsibilities of federal and State governments.

Acceptability:

The acceptability would be related the nature of guidance issued.

2.3.0 New Clean Air Act Authorities

2.3.1 Haze as Principal Objective

a) Visibility Standards

Under this approach, a regional, area specific or local visibility standard based on some quantitative measure of visibility (e.g., visual range, contrast, etc.) would be promulgated by the Federal or State government. A deadline for attaining the standard would be established and the States would be required to develop plans for attaining the visibility standards by controlling existing and new emissions of visibility-related pollutants.

Effectiveness:

This approach could be very effective in preventing and improving regional visibility degradation. Provided that the attainment of any such standard could be achieved through control of any and all sources contributing to visibility-reducing emissions, this approach would be comprehensive in scope. The key to the effectiveness of this approach is in the establishment and enforcement of a standard level which is acceptable to the public in any given area of applicability.

Simplicity:

This approach would be implemented in the same fashion as other ambient air quality standards, but accounting for non-pollutant influences on visibility (fog, rain, illumination, clouds) would add complexity.

Cost:

The cost of this approach could be significant. Many states would have to develop emission control strategies which may place increased control costs on certain existing and new sources. Additional federal and State resoruces may be necessary to develop and implement the standard.

Enforceability:

The enforceability would depend on the effectiveness of modeling approaches, the extent and reliability of monitoring data, and authorities granted to control interstate air pollution.

Flexibility:

Any new mandate for a standard to protect visibility should be flexibile. It should allow the application of a standard in such a way that will meet the goals of class I protection and provide for reasonable progress in other areas of the nations.

Compatibility:

This approach would be compatible with existing approaches to protecting the public welfare.

Acceptability:

This complexity of this approach may cause disagreement among air quality control agencies, industry, and the interested public.

2.3.2 Haze as Partial Objective

a) SO_2 Rollback

The SO_2 rollback proposals are usually advocated in the name of "acid rain" control. When the SO_2 rollback proposals are viewed as general air pollution control, haze reduction is one of the potentially major benefits that can be legitimately cited. Some examples are examined in detail in Appendix B.

Effectiveness:

Since regional visibility impairment has been associated with regional sulfur oxides emissions, particularly in the east, this approach could be at least partially effective at reducing existing impairment. If a cap on SO_2 emissions is established as a provision of any required rollbacks, then this approch might be effective in controlling any future increases of SO_2 from new sources as well. The effectiveness could also be enhanced by making SO_2 rollback provisions applicalbe to all sources regardless of emission potential. This approach would not address the visibility impairment problems caused by other pollutants such as primary fine particles, nitrogen oxides, and volatile organics.

Simplicity:

This approach would be reltively simple to implement once equitable scenarios are developed.

Cost:

The cost of the design of this approach could be relatively low. However, implementation and enforcement could be costly.

Enforceability:

This approach should be relatively easy to enforce if source specific SO_2 emissions levels are specified.

Flexibility:

Such approach can be flexibile, within the limits of the overall mandated reductions. Control strategies could be designed to require emissions reductions either on a national, regiona, or more localized scale or by some other criteria such as one which might consider source characteristics.

Compatibility:

This approach could have aspects of air quality management (SIP based emission limits) compatible and technology based programs.

Acceptability:

Industry affected by this approach may not readily accept regulation based solely on visibility concerns, but the other public health and welfare benefits associated with SO_2 reductions may lend more support to this strategy. A congressional mandate offers strong advantages in this area.

b) Age Based Control (existing powerplants)

An alternative to SO_2 rollback, suggested by Congressmen Broyhill and Madigan, would be to require existing powerplants to control at age X (or retire) emissions to level y (e.g., x = 40 years, y =2 lb/10^6 BTU). The effect would be similar to SO_2 rollback, but would occur over a 20-30 year period rather than all at once in the mid 1990's.

Effectiveness:

This approach would probably as effective than a general SO_2 rollback strategy in the long-run. Its chief drawback is improvements would occur 10 to 20 years later than rollbacks in 1995-2000.

Simplicity:

This approach is simple and easy to understand.

Cost:

The costs are comparable to rollback but are incurred 10 to 20 years later for many power plants significantly reducing present value of the costs. The stream of costs would be similar to the stream of cost savings associated with new existing source emissions trading. Preliminary analyses by DOE indicates that a combination of those measures could break even or even yield a net savings relative to current programs.

Enforceability:

Once the affected sources are identified and control schedules developed, this strategy should be relatively easy to enforce.

Flexibility:

This approach would not be very flexibile. Its purpose is to address the problem of long-lived power plants directly. When combined with emissions trading, the overall approach is quite flexible.

Compatiblity:

This approach is supplementary to and compatible with current technology based programs (NSPS, BACT, LAER).

Acceptability:

The approach would be more acceptable than roll back to industry but less acceptable to those who would prefer to see continued visibility improvements in the next 10 to 20 years. The acceptability of any further SO_2 control is, however, contingent on a societal decision that such control is necessary and beneficial.

2.3.3 New Authorities for Haze Precursors to Meet Other Objectives

a) "Acid Rain"

"Acid rain" control is the subject of major new legislative proposals whose side effect could be haze reduction. The primary focus of this legislation is to reduce the impacts of acid deposition in the eastern United States with little benefit for western areas of the nation. A comprehensive national acid rain control program has the potential for significantly reducing total emissions of pollutants that are primarily responsible for acid deposition and visibility degradation, i.e., sulfur dioxide and nitrogen oxides.

If NO_x is shown to be the principal cause of forest effects and spring snowmelt-related acidification of aquatic areas, then SO_2 reduction could be deemphasized and eastern haze reduction potential diminished.

Effectiveness:

This approach has the potential for greatly reducing the need for any separate major visibility protection program for regional haze. As indicated in Appendix B, very targeted acid deposition strategies may produce little haze related benefits. The effectiveness in reducing western regional haze will depend upon the extent and degree of required emissions reductions which impact haze in the West. The need for further emissions reduction to protect visibility could be determined after implementation of any acid rain control program, but this would delay the timing of regional haze benefits.

Simplicity:

This approach can be simple or complex depending on the final program design by Congress. Emissions reductions could be specified by State, region, or nationwide and could apply across the board to all sources by categories, size, or other source characteristics.

Cost:

The cost could be substantial. Control technology costs would be high as well as control agency costs to implement and enforce the program.

Enforceability:

Once emission reduction plans and compliance schedules are developed, enforcement of this approach should be reltively easy.

Flexibility:

The design of the program by Congress will determine how much flexibility is allowed in implementing this approach. A national program could prove to be less flexible and adaptable to the needs of individual states and the problems of individual sources.

Compatibility:

This approach should be compatible with existing air pollution control programs.

Acceptability:

Uniform national requirements for acid rain control may be more acceptable to all concerned, when compared to individual state or regional approaches that would operate without Congressional backing.

3.0 MAJOR APPROACHES FOR FURTHER EXAMINATION

The available projections in Appendix B suggest that regional visibility in both the East and West is likely to be stable for the next decade - the East experiencing continued episodic regional haze and the West maintaining relatively good current conditions. Smaller areas within these regions may, however, experience visibility degradation depending upon local emissions and meteorology. Based on its examination of strategies as they might be applied to these somewhat distinct problems in these regions, the following findings are offered.

3.1 Eastern Haze Strategies

Maintaining current regulatory programs will likely result in approximately the present level of episodic regional haze in the East through about 2030, with potential improvement thereafter. More rapid improvements would require regional reductions of SO_2 emissions. The major approaches for accelerating such reductions are ranked in order of effectiveness.

1. The analyses of SO_2 control strategies (Appendices B,C) suggest that the benefits of improved visibility estimated for SO_2 roll backs are uncertain, but might be substantial. Even at the higher end of the uncertainty range, however, they are unlikely to equal or exceed control costs by themselves. Some of the more targeted strategies designed to control acid-deposition produce visibility improvements that are limited in extent and magnitude. If accelerated reductions of SO_2 emissions are judged appropriate, the most effective long-term regulatory approach would be to develop cost-effective regional strategies designed to maximize all of the known and anticipated multiple environmental benefits of SO_2 control, including haze reduction. Implementation of such a strategy is best accomplished with new legislation.

2. Although less timely and more difficult to implement than a mandated control strategy, if it is decided that accelerated reduction of eastern haze is warranted, consideration should be given to developing a fine particle SNAAQS. Outside groups may attempt to force action on such a standard in any case, and in the absence of new legislation mandating regional SO_2 reduction, a standard could guide long-term sulfur oxides and other control programs by establishing an acceptable target. Some modifications to current Clean Air Act authorities might improve the design and implementation of SNAAQS for fine particles, especially if haze control is the major objective.

3. A supplemental (or alternative) long-term strategy for reducing SO_2 is control of sources based after a defined source life-time. This could act-

to ensure and accelerate reductions projected from retirement (or control) of higher emitting existing sources and their replacement with cleaner new facilities.

3.2 Western Haze Strategies

Protection of western visibility may be effected well enough without new legislation. Assuming implementation of current regulatory programs, the western analyses suggests that delaying development of new regional haze programs for five years while awaiting improved source-receptor information would not result in unacceptable or irreversible degradation. As new research results improve our ability to predict regional impacts of emission source limitations, "phase II" regulations can be developed under the existing section 169A. Protecting visibility in class I areas while implementing existing NAAQS, PSD, and mobile source controls will provide substantial protection against impairment from haze throughout the West. Interim adjustments to existing 169A implementation procedures can facilitate the transition to a phase II program. Alternatives for doing this are discussed in the following section.

3.3 Issues Associated With Current Visibility Regulations

On December 2, 1980, at 45 FR 80084, EPA established requirements for States to consider visibility in mandatory Class I Federal areas as part of the State implementation plan (SIP) to meet Clean Air Act goals. At the time of promulgation of these requirements, technical limitations prevented consideration of control strategies for regional haze. However, the basic structure of the requirements did allow for documentation and consideration of regional haze impairment at the Class I areas. It also anticipated future EPA action, called Phase II, which would address control strategies for regional visibility impairment. Through this report, EPA now is looking at control strategies which will address regional haze, although the scope is not limited to mandatory Federal Class I areas.

It is important to note that the framework of Phase I visibility regulations is not yet in place. Only in 1984 did EPA begin to seriously encourage States to develop their own plans, and begin to act for those States with deficient SIP's. Therefore, any consideration of control for regional haze must also consider important issues yet unresolved from Phase I.

3.3.1 Immediate Issues

The EPA is in the process of implementing changes to the SIP's to incorporate rules promulgated under Section 165 (new source review) and Section 169A (visibility protection in mandatory Class I Federal areas). Certain key issues should be resolved so as to provide a reasonable basis for any future action on regional haze. The most immediate actions will take place in June 1985, with promulgation of a Federal monitoring strategy and new source review requirements. Certain issues EPA will address in this rulemaking that may have consequences on regional haze control are discussed below.

1. Documentation of Impairment

In addition to allowing Federal Land Managers (FLM's) to establish integral vistas, the Phase I rules also allow FLM's to identify impairment in the Class I areas, as well as any named integral vistas. This identification process is not only for the types of impairment that can be controlled under Phase I, but also covers regional haze type impairment. The intent of the regulations is to assess all visiblity impairment that affects the Class I areas. Such identification by the FLM's is then subject to further review as to whether the impairment is significant, and then even further review to see if such significant impairment can be considered reasonably attributable and therefore controlled under Phase I. In implementation of Phase I and in development of strategies for Phase II, EPA should stress the fact that a documented record of regional haze impairments that exist at Class I areas is called for by the current regulatory framework and should be part of the SIP's when the Phase I rules are implemented.

2. Monitoring Strategy and the Proposed Network

Because EPA is now implementing the Phase I rules for most States, it has proposed a national network for collection of visual air quality data important to carrying out the review and permitting of sources near Class I areas. This network will be used, in part, as a source of information on background levels of visibility impairment for the purpose of determining a potential source's contribution to that impairment. In collecting this information, the monitors will also create a record of impairment resulting from long range transport from distant sources or regional haze. This information should be utilized in any national strategy for regional haze control. Therefore, careful planning of collection and storage of the information is needed to assure access to Phase II programs.

Better criteria for measurement of impairment and its relative levels would also aid in assessing progress toward the national goal which is required in the long-term strategy review under Phase I. The most direct means of standardization is a EPA reference method. Work on a reference method is scheduled for FY 86 and should be completed quickly to aid Phase I implementation by the States and pave the way for Phase II considerations.

3.3.2 Long-Term Strategies Under Phase I

In the near future, EPA will be developing Federal plans to incorporate consideration of integral vistas, review of existing source impairments, and long-term strategies for control of visibility impairment. Certain general guidance should be issued, especially for review of SIP's for a long-term strategy. For example: Los Angeles currently has a long-term strategy for ozone control which encourages residential development and other growth into the desert to relieve ozone concentrations in the western part of the valley. This clearly is in direct opposition to a policy to protect visibility in Class I areas of the desert that are immediately east of Los Angeles. EPA should take firm stands on several issues before completing development of this Federal promulgation or acting on State submittals. These issues are:

1. Cumulative Impacts of New Sources

The current review of new sources for visibility impacts is essentially tied to the prevention of significant deterioration program (PSD) and new source review promgram (NSR) in nonattainment areas. While it is common practice to add a permitted sources' emissions to background levels before reviewing the next permit, neither the visibility rules nor the PSD/NSR rules are explicit in dealing with situations when many sources are applying for permits in the same general location at the same time. This is commonly referred to as the "cumulative effect" of permit processing. In a situation where several owner/operators apply for permits in one area (such as an oil field development), each permit would be reviewed based on that owner/operator's contribution to background. Because the background information used to judge impacts would reflect conditions as they exist now, the effect of all sources once built would be underestimated. An explicit policy on permit processing in this situation, either as part of PSD or visibility review, should be set. This policy could continue the individual permit process or require simultaneous permits applications for different source owner/ operators to be considered as one action. Combining the impacts of many minor sources that if reviewed together would trigger a permit review action should also be considered. This issue will affect all types of visibility impairment, both plume and regional haze. However, it may be more important in the case of regional haze, since there are almost always multiple sources involved. As an example: a major mineral development project involving many companies acting independently could create a regional problem, with none of the individual permits causing an adverse impairment on its own.

2. Integral Vistas

Integral vistas are views from a Class I area of panoramas or landmarks that lie outside the statutory boundary of the area. The EPA recognizes that there are important views from Class I areas to lands surrounding them. Also the establishment by Congress of certain Class I areas was substantiated on spectacular views from these areas, which encompass great distances. In consideration of the importance of such views, the provision for protection of integral vistas was included in the existing regulations. However, the existing rule allows the balanacing between protection of integral vistas and economic and other social factors when issuing permits or for developing strategies to meet the national goal. This is less stringent than the requirement that a permit be denied if an FLM proclaims adverse impairment to visibility within a class I area.

Several petitions for reconsideration of the rules requested EPA to remove integral vista protection from the rules. Although not responding to these petitions, EPA is now implementing these rules by a court ordered settlement agreement and will, at the appropriate time, incorporate consideration for integral vistas named by the FLM's according to the December 1980 rule. However, EPA's delay in implementation of the rules, and in lack of response to the petitions for reconsideration, have caused some problems. The December 1980 rules only give the FLM's until December 31, 1985, to name any integral vistas. As yet, only one set for one Class I area has been named. The FLM's have, in addition to other internal considerations, been waiting for EPA's response to the petitions and for court action before devoting resources to naming integral vistas.

Before consideration of any regional haze program, EPA should take action on the petitions for reconsideration with respect to this issue. Such action quickly would resolve the question of EPA support or nonsupport for integral vistas and end FLM debate on establishing integal vistas. If integral vistas are kept, they should become part of a regional haze control strategy. If not, EPA need not consider such a specialized program.

3. Definitions and Guidance on Long Term Strategy Review

Phase I rules only trigger control strategies for impairment attributable to one source or a group of sources: however, better guidance on defining significant and adverse impairment for all types of visibility degradation events needs to be developed. Although many subjective components will determine actions taken under the Phase I program, some review and compilation of different actions by EPA and the States in handling impairment could become a case-by-case guideline. This would also point to areas of needed research and regulatory investigation for areas where visibility improvement or maintenance is not seen. This would be useful also in a Phase II program for class I areas as envisioned, based on the success of control decisions.

4. Prescribed Burning

In certain areas, particularly the Pacific Northwest, control of wildfires and underbrush growth is accomplished through man-made fires. These activities are sometimes the major cause of visual impairment in mandatory Federal Class I areas. While these operations can cover large expanses of land in and near Class I areas, controlling precribed burning activities can be handled now as a "reasonably attributable" source issue.

During the development of the Phase I rules, discussions on factoring visibility impacts into decisions on when, where, and how often to use presribed burning in and near Class I areas were begun. The Forest Service continually updates its manuals and guidance on proper techniques for prescribed buring. This guidance does consider visibility impacts when deciding on burn days and amount of land to be burned. During implementation of Phase I rules, EPA and the States should specifically address prescribed buring during development of the long-term strategies. In some cases, existing Forest Service guidance will be sufficient to limit visibility impacts to a reasonable level; in other cases, additional restrictions may have to be considered. This issue is best resolved in a case-by-case review during Phase I rulemaking.

APPENDIX E. RESEARCH NEEDS

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APPENDIX E. RESEARCH NEEDS

The first major examination of interagency visibility strategies and information needs was presented in the 1979 EPA Report to Congress. Progress has been made since that time, but significant opportunities were lost by the reduction of EPA's visibility research program. The Park Service, Department of Defense and industry groups have all mounted visibility programs, but all cite the need to restore EPA to a leadership role in visibility research. The reduction of uncertainties in a number of key areas, particularly in source receptor relationships, perception and values, is the highest priority for the development and implementation of credible long-term strategies for regional haze. The task force recognizes that visibility will not be the highest research priority, and that EPA will not be able to fund the full extent of research needed.

The discussion in this Appendix focuses on general needs to be addressed by the collective visibility research community. Continued and expanded coordination is needed to agree upon priorities in these areas. Near-term research priorities for EPA budget planning are documented in the separate interim needs statement (March 1984) and have already been factored into FY85 and FY86 budget planning.

1.0 HUMAN PERCEPTION

Studies of perception to date have yielded information that is pertinent to understanding the response of the human eye-brain system to changes in scenic quality resulting from changes in atmospheric aerosol concentration.

There are a number of needs that remain unanswered and in some cases have not ever been addressed. Specifically:

1. Does a just perceptible change in image information content constitute visibility impairment or is a just noticeable difference in judgments of image quality the more pertinent approach?

2. What features of a scenic landscape that are perceptible are sensitive to changes in air quality (color, texture, form etc)?

3. How much of a change in air quality constitutes visibility impairment of a scenic vista, as a function of vista characteristics (vista size, textural content, color etc.)?

4. How does the size, shape, edge sharpness, and color of layered haze relate to visibility impairment (just-noticeable difference)?

5. How much of a change in optical characteristics of a visible layered haze is noticeable, as a function of its size, shape and edge sharpness?

6. How does the passage of time affect perception of differences in visual air quality?

7. How does perception vary in the population?

Additional research into methods for quantifying information content and quality of landscape features will be required to address these research questions. Of primary interest is the quantification of scenic textural content and scene color. Because conclusions derived from studies of visibility values are often highly sensitive to assumptions about perception, strong linkages should be established among researchers in the fields of perception and value.

2.0 MONITORING TECHNIQUES

Introduction

There are several techniques in use at present for monitoring visibility and other related parameters. Some techniques have serious deficiencies which limit their utility. Even those without inherent flaws are presently limited by a lack of standardized guidance for their use and the use of data they generate. This section discusses the desired characteristics and possible directions for new technology plus the requirements for guidance in the use of existing methods.

Monitoring of visibility and related parameters is performed to obtain three distinct types of information. The characteristics of a scene viewed at a distance are monitored to document the scene-specific visibility. Optical properties of the atmosphere are monitored for a scene-independent measure of visual air quality. Aerosol characteristics are determined to associate atmospheric optical properties with the responsible pollutants. Monitoring techniques development for each of these informational requirements is discussed separately below. Though most of the following discussion concerns monitoring regionally uniform visibility, monitoring techniques for plumes and layered hazes are also covered.

2.1 View Monitoring

View monitoring requires the development of well-tested equipment and procedures to allow the brightness, color, and spatial detail of the viewed scene to be accurately recorded and subsequently used. The photographic method is most commonly used for monitoring vistas. The availability of adequate equipment, supplies and services to support this method make it the obvious choice for qualitative documentation purposes. However, the present lack of standardized procedures for its use in visibility monitoring make quantitative analysis much less certain. Among the items which need to be addressed are the choice of films and processing, camera exposure and lenses, methods to calibrate or document system gamma functions, archiving, and quality assurance procedures.

Promising new techniques which may be applied to view monitoring include digital photography and video tape or disk archiving of images. The cost and inherent difficulties associated with the use of film for long-term routine monitoring make the non-film approaches very attractive. Prior to their use

for visibility monitoring, these new techniques must be evaluated and standardized procedures for their use developed.

Some of the objectives of view monitoring are the collection of data which can be used to study perception, to evaluate visibility trends and to assess the sensitivity of a view to changes in air quality. To accommodate these objectives, equipment and procedures to extract quantitive measures of brightness, color and spatial detail from photographs (film or digital medium) must be developed. Several methods to accomplish this are presently in use. These include film spot densitometry and several techniques to measure radiance of projected images. Such techniques need to be evaluated, improved where possible and standardized. New approaches, including methods to process digitally recorded images, should also be developed and characterized.

Another objective of view monitoring is to make possible the determination of frequency, persistence and intensity of plumes and elevated hazes associated with local sources. Time lapse photography has been used for this purpose. Operations, quality assurance and information processing procedures are required to promote comparability of data collected by different investigators.

2.2 Monitoring Atmospheric Optical Properties

For scene-independent measurements of visual air quality, the goal is to develop techniques to routinely monitor the atmospheric extinction coefficient. Measurement of the scattering phase function is also of interest where the objective is to associate optical properties to view impacts. There are two methods in common use for monitoring the atmospheric extinction coefficient. Both have deficiencies which limit their use, thus new techniques are being investigated. Scattering phase function is not routinely measured for visibility research.

The extinction monitoring methods in common use are long path measurements of target/sky contrast by teleradiometer (or other radiance monitoring method) and scattering coefficient measurements by integrating nephelometer. The deficiencies of the contrast measurement technique primarily involve non-uniform lighting conditions and inherent contrast (target/sky contrasts at the target) uncertainty. For nephelometer measurements of scattering, the primary deficiencies are inadvertent sample modification (aerosol size distribution changes), and the need for separately measured or assumed absorption coefficient information. With the possible exception of the nephelometer sample modification, these deficiencies are inherent to the techniques. Until new techniques are available for routine use, standardized guidance for the use of existing methods must be developed to minimize the inherent deficiencies, quantify the uncertainties, and promote some degree of uniformity in the quality of data collected. Standardized measurement specification (precision, accuracy, sensitivity, spectral characteristics, etc.) by instrument type should be established. Guidance for instrument selection and siting and minimum acceptable monitoring and quality assurance procedures should be developed. Determining target/sky contrast from photographs is supported by many investigators as a reasonable alternative to use of teleradiometers. This approach requires additional characterization and comparability tests and procedures development prior to its routine use. Also required for all methods is the development of data handling and editing procedures, including methods used to estimate

inherent contrasts. In addition, absorption coefficient measurement techniques require additional development, testing and standardization.

Several new techniques are being developed and tested in hopes of providing methods without the deficiencies described above. The techniques being investigated are transmission measurements and radiance measurements with configurations beyond the commonly used target/sky contrast. Both techniques will likely operate over an intermediate path length (1 to 10 km), though some of the radiance measurement methods may be made over long paths if artificial targets are not required. Other desired instruments include a next generation integrating nephelometer (open air or other design to eliminate sample modification), a continuous absorption coefficient monitor, and a field worthy polar nephelometer or other device for continuous phase function monitoring. Any new method must be fully characterized, field tested and have operation and quality control procedures developed prior to its routine use.

Monitoring optical characteristics of plumes and layered hazes is done remotely, using radiance measurements through and outside of the plume and in situ, typically with airborne measurements of scattering coefficients (nephelometer) occasionally supplemented with absorption coefficient measurements. In spite of the infrequent use of monitoring for this objective, guidance concerning operation and quality control procedures is needed to promote comparability among investigations.

2.3 Monitoring Aerosol Characteristics

To understand the causes of visibility impairment, it is necessary to monitor particle characteristics in conjuction with optical monitoring. The two approaches are to develop and employ techniques which provide optically important aerosol information, and information which will aid in source identification. The most common method employed to meet these goals is size-segregated aerosol sampling and subsequent sample analysis for physical and chemical characteristics. There is a need to establish guidance for sampler and analysis selection, and minimum acceptable sampling, analysis, and data handling procedures based upon desired overall precision, accuracy and sensitivity by particle characteristic (mass, species, etc., in each size range).

Improved sampling technology is required to minimize sampling artifacts associated with volatile aerosol components (e.g., volatile organics and nitrates). If the volatile aerosol component contributions to visibility impairment are shown to be significant, the need for routine methods to sample them will be critical. Other desired sampling characteristics include the ability to sample in many size ranges with substrates and sample amounts consistent with full compositional analysis, and samplers that are field worthy for remote, low-power, routine service.

More work should be done on the development and testing of non-traditional sampling methods of characterizing aerosols and their optical properties. One such approach, which has resulted in several prototype instruments, involves systematically modifying aerosol size distributions by physical or chemical processes prior to measuring the scattering coefficient with an integrating

nephelometer. In this way, an association between chemical/physical properties and the scattering of aerosols can be inferred. In the long term, such methods may prove a cost-effective supplement or alternative to the sampling and analysis approach.

Methods for aerosol characterization within plumes or elevated layers have many of the same requirements as those discussed above. They have the additional requirements usually associated with airborne monitoring including low power and rapid response ot sample time. Instrument and procedures development for aerosol plume characterization is required for comparability of data collected.

SUMMARY OF RESEARCH RECOMMENDATIONS

1. Current view monitoring techniques standardization and guidance
2. New view nitoring methods development, testing, and standardization
3. Equipment and procedures development to obtain quantitative view data
4. View monitoring techniques development and standardization for plumes
5. Current extinction measurement techniques standardization and guidance
6. New extinction measurement techniques development testing and standardization
7. Fieldworthy measure of phase function development, testing, and standardization
8. Optical monitoring of plumes-development, testing and standardization
9. Current aerosol monitoring techniques-standardization and guidance
10. New aerosol monitoring techniques development, testing, and standardization
11. Nontraditional aerosol characterization-techniques development and testing
12. Aerosol monitoring of plumes development, testing and standardization

3.0 CHARACTERIZATION OF REGIONAL VISIBILITY CONDITIONS

The study of past and current regional visibility offers a wealth of information concerning the spatial and temporal scales involved, the magnitude and urgency of the problem and the major contributors to regional visibility impairment. Some work of this kind has been done, though much remains to be accomplished. The data available for interpretive analysis is marginal. National Weather Service (NWS) visibility observations offer the only long term, national-scale data. However, they are limited by their semiquantitative nature and generally restricted range and resolution. Data from several recent short to moderate term (1 to 8 year) regional monitoring programs are available. By design programs such as VIEW, SCENES, RAQS RESOLVE and PANORAMAS have provided optical and aerosol data to determine the levels and causes of visibility impairment within their respective study areas. Though the quality of these data are generally superior to airport observations, their restricted spatial and temporal coverage limits their utility for long-term continental scale analysis. In spite of these difficulties, existing data should be systematically investigated to extract the available information and as a means to identify and design programs to fill data deficiencies.

Study of spatial and temporal distributions of regional visibility is a logical starting point since it offers the chance of simplifying subsequent efforts. Some work has been conducted to identify areas of similar visibility by time of year, primarily using NWS observations. Further analysis should be conducted to identify areas of similarly varying visibility by time of year and areas with similar historic trends. The main objective of this analysis is to identify a set of visibility regions within which regional visibility is sufficiently similar so that additional regional analysis and monitoring need only be done for one representative location per region.

Successful identification of visibility regions should be followed by analysis to characterize each. This should include descriptive regional and inter-region comparisons of current visibility levels, historic trends, and diurnal and annual variations. Associations between visibility levels and meteorological conditions should be investigated. The interaction between regional and urban visibility is an important research topic. Studies are needed to determine what fraction of urban impairment is regional; what pollutants are of greatest importance within the urban setting; whether urban areas can be categorized by source make up, size, or region and what are the urban impacts on regional visibility.

To the degree possible, causes of visibility impairment for each region should be identified. Visibility trends can be compared to historical changes in pollution emission sources as a means to infer gross cause/effect relationships. If sufficient aerosol data are available, extinction budget analysis should be performed. The two commonly used methods to perform extinction budget analysis, Mie theory and regression analysis, often provide significantly different results. Regression analysis has tended to show a much larger contribution by sulfur aerosol and a much smaller contribution by organic aerosol than the theoretical approach. Possible causes of these discrepancies include faulty aerosol data masking the statistical relationships between certain aerosol components (e.g. organic) and extinction; and faulty assumptions

concerning aerosol index of refraction, size or shape distributions for Mie calculations. Specifically designed field and laboratory measurement programs should be conducted to resolve these questions. Error propagation analysis for both extinction budget analysis methods may prove a valuable approach to understanding the discrepancies between them.

The data analysis described above should test the limits of existing data and identify deficiencies. In this way it provides the starting point for the design of future monitoring programs to further characterize regional visibility. These could take the form of short term special studies, routine long term monitoring and/or an augmentation of existing programs.

While some of the specific spatial, temporal and characterization studies have been accomplished in both the Eastern and Western U.S., there has not been a comprehensive assessment of regional haze in the East, beyond interpretation of satellite and NWS data. The establishment of a visibility-particle Eastern network to obtain a data base to support a standard to address regional haze problems in the East is needed. This along with continued support of western characterization research efforts in these same subject areas is clearly needed.

SUMMARY OF RESEARCH RECOMMENDATIONS

1. Visibility-particle eastern network
2. Visibility region identification, and characterization with existing and where necessary, supplemental data
3. Extinction analysis by region
4. Extinction budget analysis techniques research
5. Urban visibility characterization

4.0 EMPIRICAL APPROACHES TO SOURCE ASSESSMENT

4.1 Studies of Specific Categories of Interest

4.1.1 Large point sources - smelters, power plants and industrial complexes

a. Contribution to attributable plumes (plume blight). Project VISTTA has made a major contribution to understanding and modeling visible plumes from smelters and power plants. The major source of error in plume optics models lies in predicting the size, shape and structure of the plume and the meteorological conditions which give rise to cohesive, visible plumes. Other problem areas are: determining the sometimes variable emission rate of nitrogen oxides and the amount and size distribution of primary particulates in the light scattering range. Additional analyses of the existing VISTTA data base would help define problem areas in EPA's plume model as well as those of other developers and provide a guide to model improvement, especially in complex terrain. Measurements of plume structure by photography, correlation of plume structure with meteorological parameters - especially turbulence at plume altitudes, and analysis of model predictions of plume blight occurrence over the longer term such as periods of a year are needed. Lidar studies would provide valuable details of plume structure to augment photographic measurements.

b. Contribution to regional haze and layered haze. This area is reasonably well understood due to the results of studies such as VISTTA, MISTT, Tennessee Plume Study, Cold Weather Plume Study and PEPE. Additional analysis of the existing field data with emphasis on visibility would be useful. Although power plants and smelters have been reasonably well characterized for contributions to visibility reduction, very little work has been done on industrial complexes and similar large point sources. Some characterization of emissions including size distribution of primary particulates and the transformation of the emissions to particles through chemical reaction is needed for industrial operations such as steel mills, refineries, etc.

4.1.2 Large area sources - urban plumes, forest fires, natural emissions and industrial complexes

a. Urban plumes. Project MISTT has documented the importance of urban plumes for forming sulfate, ozone, and light scattering aerosols as measured by bscat. The chemistry of sulfate is fairly well understood. However, more work is needed to characterize the transformation, removal, response to changes in relative humidity, and optical properties of other components-especially carbon soot, organic aerosol, ammonium nitrate and coarse particles. Project MISTT did not cover a wide enough variety of meteorological conditions, seasons, and geographic areas to define the frequency of occurrence of urban plumes or the geographic range of influence of urban plumes. Therefore, additional field studies of urban plumes are needed to define the chemical processes occurring, the visibility reducing species

other than sulfate, the meteorological conditions which cause an urban plume to form, the distance over which urban plumes will have an impact, and how urban plumes disperse into the general regional background.

b. Forest fires. Wild and prescribed forest fires make a significant contribution to regional haze both in the eastern and western United States. Little is known about the mass and size distribution of primary aerosol or the subsequent formation of secondary aerosol in forest fire emissions. Additional field studies are needed to characterize the behavior of forest fire plumes, to characterize the chemical and physical properties of the emissions, and to relate the visibility effect to the type and mass of the material burned.

c. Natural Emissions. Natural and biological processes lead to emissions of reduced sulfur species, nitrogen oxides, ammonia, and a variety of organic vapors. Ammonia emissions are very important since the concentration of ammonia may determine whether nitrates appear as nitric acid vapor or ammonium nitrate particulate and natural emissions are probably a major source of ammonia. However, ammonia as well as other nitrogen and sulfur compounds are being looked at in the Acid Deposition Program.

Organic emissions from trees and plants include species such as terpenes which are very effective in forming organic aerosol. In the western United States the organic fraction of the aerosol collected on filters is approximately the same order of magnitude as sulfate. In the eastern United States the organic fraction is smaller but still on the order of 1/3 of the sulfate. It is also possible that some organic aerosol is present in the atmosphere but is not found on filters because it evaporates between the time of collection and the time at which the filter is weighed. Additional laboratory and field studies are needed to determine the aerosol forming potential of natural organic emissions, the rate of natural emissions, and the composition of the organic aerosol.

4.1.3 Small area sources

a. Diesel exhaust. Diesel exhaust is a major source of atmospheric soot. Further studies are needed to characterize the size of the diesel soot particles and the quantity of soot emitted for various types of diesel vehicles; driving modes; ambient temperature, pressure, etc.; and of the aerosol forming potential of gaseous emissions from diesels.

b. Road dust. Fugitive emissions from traffic, largely expected to be particles from dirt roads or from dirt tracked onto hard surface roads, make an important contribution to the local aerosol concentration. Further studies are needed to determine what fraction of the road dust is within the fine particle range and will thus contribute to regional haze.

c. Agricultural burning. In some areas of the country prescribed burning of fields is used as a routine technique to remove the previous year's growth and prepare the soil for planting. As is the case with forest fires, more information is needed on the quantity and properties of the smoke.

d. Wood smoke from home heating. A substantial effort is underway to determine the chemical and biological properties of wood smoke from home heating as a function of fuel type and completeness of combustion. However, these studies do not include the measurements necessary to determine the effects on visibility. A small amount of additional effort, funded through the visibility program, would enable a visibility field and laboratory component to be added to ongoing studies of wood smoke.

4.2 Source Identification and Impact Evaluation

4.2.1 Receptor models

a. General. This technique depends on utilizing detailed composition measurements of ambient aerosols to determine their sources and the contribution of each source. When the composition of individual sources is known, the chemical species balance technique can be applied to a single sample. When the sources or their composition are not known various types of statistical analyses, such as factor analysis and multiple regression analysis, may be applied to infer types of sources. This technique requires multiple samples. The output is a group of chemical species which show the same pattern of variation in concentration from sample to sample. These groups of chemical species may frequently be identified with types of sources.

For either of these techniques it is necessary to know the composition of potential sources, not only the major components which give rise to visibility-reducing aerosol but also those minor components which may be used to identify specific sources. The statistical analysis approach may identify previously unexpected soruces whose identity will have to be confirmed by comparison of experimentally determined composition with that predicted. Thus, for all of the sources discussed earlier, composition measurements need to be available to develop fingerprints or signatures for the primary particles and the secondary products, especially for organic aerosols. For carbon soot it seems possible that microscopy may be able to differentiate between various source types.

b. Sulfate. Source-receptor models yield the concentration of sulfate but do not provide a convenient way to distinguish sulfate from various types of sources or from individual sources of the same type. This problem arises since sulfate is a secondary product formed by conversion of SO_2 to sulfate. The conversion rate depends on a variety of atmospheric conditions as well as reaction time. The Acid Deposition Program is supporting some work which might lead to the ability to differentiate between sulfate from coal and sulfate

from oil combustion sources. Some work is also underway to determine if different power plants use coal with trace elements which differ sufficiently to serve as tracers of opportunity. However, even if it is possible to use source apportionment to apportion primary aerosol from various coal-fired power plants the problem of conversion would limit the ability to apportion sulfate to the various power plants.

c. Organic aerosol. Analysis of the organic composition of source and ambient aerosols should help in apportioning this component of visibility-reducing aerosol. However, the same problems exist as in the case of sulfate. If the primary aerosol particulate differs in composition from the secondary aerosols it would be possible to appportion it. It might also be possible to use the composition of the secondary organic aerosol to identify types of sources even though one could not differentiate within source types. However, more extensive studies of the organic composition of ambient and source aerosol is needed and should provide a useful tool for identifying sources. One objective would be to identify stable organic compounds or groups that could be used as tracers.

d. Soot. Carbon soot has a variety of sources - diesel combustion, oil combustion, gasoline combustion, forest fires, wood smoke, industrial sources, etc. There is some evidence that the shape and structure of soot particles, as determined by optical or electron microscopy, may be used to differentiate the various sources of soot. This approach would appear to be a profitable one for research. The C12/C14 ratio can be used to differentiate fossil carbon from modern carbon. Also specific gases, e.g., methyl chloride, have been shown to be potential tracers for wood smoke.

e. Volatile aerosols. Recent experimental studies using heated nephelometers indicate that a significant fraction of the light scattering aerosol is volatile below 100°C. Extinction budget analysis by Mie theory and by regression analysis give differing weights to the various components. Organic particles and NH_4NO_3 particles are known to be in equilibrium with vapor phase material. These observations suggest that a portion of the light scattering particles in the atmosphere, when collected on filters, may evaporate either during the collection process or during storage before the filters are weighed. This problem may be particularly important in pristine western areas where non-volatile sulfate particles are a smaller fraction of the total light scattering material.

Experimental studies in the field and in laboratory simulations are required to determine how important this process may be and what chemical species and sources are involved.

4.2.2 Artificial tracers

The major problem in the use of artificial tracers is that there is no convenient tracer which converts from gas to aerosol in the same manner as SO_2. Within the Acid Deposition Program studies are investigating the use of sulfur-35 (radioactive) or sulfur-34 (non-radioactive) for use as tra-

cers which behave in the same manner as SO2. If these were available they would provide a very useful way of tracing individual sources of SO_2 and determining the amount of sulfate particulate which came from each one. There are also possibilities of using transitional metal oxides added to to coal combustion or stacks of coal-fired power plants as tracers. These provide information on the transport and dispersion of power plant plumes and the apportionment of the primary particulate but do not tell us anything about SO2 or other gaseous transformation rates.

4.2.3 Back trajectory methods

Source apportionment techniques provide information on the types of sources. To determine the geographical location of the source it is necessary to utilize back trajectories showing where the air came from. Additional work is needed to provide state-of-the-art, user friendly models with this capability. The models should allow flow in different directions within at least four separate layers within the boundary layer and additional independent flow in a ground removal layer and above the boundary layer zone. The routinely available wind data provides information at 6:00 and 18:00 GMT. To obtain accurate trajectories it is necessary to use empirical factors or dynamical models to interpolate the wind field between the twice daily radiosonde data and account for the nighttime jet and the midday drag from convective mixing. Back trajectory models could be developed that can be run on a personal computer. The technique needs to be applied to existing field data. New studies are needed to validate multi-day trajectories completed by these models.

4.2.4 Combinations

Combined applications of artificial tracers and tracers of opportunity, back trajectories, and source receptor techniques based on chemical composition or microscopy need to be developed and applied. New field studies are needed to obtain the specific data in terms of emissions, source and ambient composition and wind information needed to apply these techniques.

In particular, methods described in Section 4.2.2 and 4.2.3 are sometimes used to help investigators determine whether source profiles derived statistically from factor analysis are reasonable. However, derivation of profiles from factor analysis is still very much a subjective art. In order for more quantitative techniques (such as chemical mass balance) to be used by program offices to apportion fine particulate observations at rural/remote sites a protocol or distinct set of rules needs to be derived regarding the application of the methods in 4.2 to regional scale analyses. Such work is needed to reduce the subjectivity and increase the reproducibility of receptor methods which are applied in regulatory programs to address regional scale problems.

5.0 DETERMINISTIC MODELING

5.1 General

a. Visibility is sensed instantaneously although the effect may "persist" for a finite time (e.g., many hours or days for haze). It is not the result of accumulated deposition or average concentration. Therefore, visibility models should simulate least short time averages. The concentration pattern of a visible plume changes rapidly. Instantaneous optical properties are needed for plume optics models. On a larger scale, such as for regional models, aerosol concentration changes more slowly. However, one to three hour averages are needed. Standards for fine particles, set to protect visibility, may be given in terms of 24-hour or longer averages. However, models will be needed to predict shorter term visibility in order to determine improvements in visibility produced by a variety of possible control strategies for fine particle concentrations and averaging times.

b. Regulatory analysis models are needed which can be run frequently, cheaply, and quickly so that the effect of changing levels of emissions and distribution of emission sources can be determined. In the case of regional or mesoscale models it should be possible to conveniently establish source-receptor relationships. It will often be important to determine what sources contribute to visibility reduction in a given region or to determine the influence of a specific source.

c. The performance of a model is best established by comparing the model simulation with real world measurements.

5.2 Plume optics models

Several plume optics models exist and their results have been intercompared. The model which has had the most use and is most readily available to the scientific community is called PLUVUE. The major need is an improved technique for determining the often very short-term plume shape construction and the visual as well as pollutant concentration pattern, especially in other than simple terrain situations.

5.3 Regional models

5.3.1 Requirements for regional visibility models

(1) Averaging time should permit resolution on the order of one up to three to six hours.

(2) The model should have a removal layer where dry deposition occurs, multiple layers in the boundary layer to allow for wind sheer and at least one and preferably multi-layers in the transport zone above the boundary layer.

(3) The model should be able to account for formation of sulfate which is the key aerosol species.

(4) Advanced versions of the model should be able to handle carbon soot, organic aerosols, nitrate, other fine mass and coarse mass in that general order of importance.

(5) The model must allow the SO2 transformation rate to vary as a function of light intensity, cloud interaction, relative humidity and aerosol content. Full-scale chemical transformation mechanisms for gas phase transformations provide no improvement over parameterization unless the full chemistry for cloud droplet reactions and reactions in aerosol mechanisms are included with the same degree of sophistication.

(6) There must be a convenient technique for determining source-receptor relationships.

(7) There must be a mechanism for taking aerosol concentration and converting it to optical parameters. This will require some way of accounting for the size distribution of the aerosol although a complete aerosol dynamics capability may not be necessary for the initial version of a regional model.

(8) The regional model should have a realistic treatment of sub-grid scale phenomenon involving urban and power plant plumes.

(9) It should be possible to run the model easily and inexpensively on readily available computers since multiple runs and multi-year runs will be required to investigate regulatory strategy options.

(10) It would be desirable to have a user friendly version, perhaps simplified for use on a personal computer.

5.3.2 Model availability

There are a number of regional models which have been intercompared in a study resulting from the US and Canadian interest in acid rain. From this intercomparison there appears to be a number of models which do reasonably well in predicting wet deposition of sulfate and presumably would also do a reasonable job on sulfate concentrations which are a prerequisite to predicting visibility impairment. There are also several models which have been developed specifically for visibility work. Most of these models fall into two types, Lagrangian and Eulerian, which have there own specific advantages and disadvantages. The Lagrangian model provides for convenient source-receptor relationships but cannot easily handle non-linear processes. The Eulerian model is convenient for introducing non-linear processes but does not provide a convenient technique for determining source-receptor relationships. It also requires some form of parameterization, not yet well established, to account for sub-grid processes. A third type of regional model developed especially for visibility uses a Monte Carlo technique which combines some of the best features of both the Lagrangian and Eulerian models.

Current model development work is primarily in two areas. First is the acid rain model being developed at NCAR. This regional acid deposition model, RADM, is expected to be a highly sophisticated model including all of the processes which are known to be important in determining wet and dry deposition of sulfate and nitrate on a regional scale. However, it is not expected to be available for general use since the computer requirements and complexities are such that it is expected to be run for only a few episodes and only at NCAR. NCAR will also develop an "engineering" model which will be a mathematical model of the RADM. It is expected that this model will have only three layers, including only one layer within the primary transport layer, and will not provide a simple way to understand the various processes that are occurring. It will also be designed for the acid rain phenomenon for which monthly averages or seasonal averages are adequate. Therefore, it is not anticipated that it will serve the needs of visibility modeling, especially in regard to averaging time, accuracy of trajectories, convenient source-receptor relationships, and inexpensive running cost.

Another model development effort is the regional fine particle model, an in-house ASRL project. This program will utilize the regional oxidant model as a starting point and will add chemical transformation modules for the conversion of SO2 to sulfate and eventually for the formation of nitrate and organic aerosol. Full-scale chemical kinetic models will be used for the transformation processes comparable in sophistication to those used in the regional oxidant model. This model will also include a full-scale simulation of aerosol dynamics in that the formation of condensible species and the condensation and coagulation processes will be simulated. This will be a very useful research model but will not satisfy the needs of the visibility modeling program. It is currently envisioned that it will only have three layers, a dry deposition layer, one layer within the boundary layer and one layer above the boundary layer. This will be adequate for longterm averages but not for modeling episodes as is required of the visibility model. It also will be a very sophisticated model which will require highly trained and skilled personnel to run as well as large computers and long running times.

5.3.3 Development of a regional visibility model

It had been initially hoped that either the acid deposition program or the regional fine particle modeling program would provide the basic model which could then be adapted for visibility. It appears that the cost and complexity of using these models and of adding a visibility module are considerable. Therefore, consideration should be given to utilizing the existing Monte Carlo visibility model and making some improvements to it as an alternative to trying to utilize either the acid rain or regional fine particle modules. Desirable enhancements to the Monte Carlo model include: 1) Add carbon aerosols. An emission inventory for carbon soot will be required no matter what model is used and can be easily added to the Monte Carlo Model. 2) Add a hydrocarbon/NOx ratio parameterization as a method for predicting ozone. This is a relatively

simple technique which will not greatly increase computational cost and will provide an index of the oxidizing power of the atmosphere which can be used especially for improving the cloud conversion process and aerosol conversion process. 3) Add a dynamic model to use for wind field interpolation. 4) Add a parameterization for organic aerosols.

5.4 Special situations

There are a number of special situations which may require either specific models or development or modification of existing models. These include: (1) area source impact, (2) point source impacts, (3) fugitive source impacts, (4) techniques for examining impact of multiple sources, (5) visibility impacts in complex terrain situations, (6) visibility impacts during extended stagnations within a local or mesoscale area. It seems likely that there is such a variety of special situations that the models should be put together to satisfy the specific situation or problem rather than trying to anticipate situations and devise models for all of them. For most of these situations there will be models which will predict the aerosol concentration under some type of averaging situation. The visibility program should provide a technique for converting aerosol concentrations to visibility parameters.

One situation, intermediate between urban models and regional models, occurs frequently enough to justify separate consideration. This is the case in which the urban (or other type) plume, because of stagnation or complex terrain situations may move back and forth across an area for several days building up pollution to serious levels. Such situations occur in a number of western areas. Thus, while the area covered may be mesoscale, the chemistry and aerosol dynamics in the model must be capable of handling multi-day reaction sequences.

Simple optical models are probably adequate for calculating visibility from aerosol concentration in the well-mixed haze frequently encountered in the east. In western areas, however, elevated haze layers and other non-uniform situations require a more complex accounting of optical properties of the atmosphere. Optical models need to be developed for these situations.

5.5 Conservative screening techniques

It would be desirable for many of these situations, especially the plume optics and the regional models, and some of the area and point source impacts, to develop conservative screening techniques which could be used to determine if more sophisticated modeling is needed.

5.6 Model Evaluation

This should involve verification of sub-modules or components of a larger model as well as comparison of the ultimate model predictions against measurements from various real world networks.

5.6.1 Visibility

For visibility studies we are fortunate in having a remarkable data base, that of the National Weather Services human observer visibility measurements. These are available every hour from several hundred stations within eastern North America. While the human observer visibility data do not have the resolution that might be obtained from an instrumental measurement, it does provide adequate resolution for model evaluation. While there is some criticism of the human observer data as being subjective and perhaps not always accurate, there are a number of reasons for believing that this is a very useful and reliable data base. Analysis of this data base has indicated that there are large geographical regions, each covering perhaps several states, in which 5-10 National Weather Service Stations give the same pattern of visibility changes. When one receives comparable data from a number of stations the confidence in the individual data bases is increased. The NWS data also agree with measurements from satellites which show the area and intensity of low visibility episodes. Furthermore, comparisons of sulfate concentrations for those periods and areas in which network data is available show a high correlation with the National Weather Service human visibility data. Further work in using the results of the NWS human observer network and of satellite measurements of the hazy visibility blob are needed to provide data bases for validation of regional models.

5.6.2 Transport

The transport and dispersion module of a model can frequently be verified independently of the chemistry or optics component. For regional scale models there is a need for data on the transport and dispersion of tracers, especially over multi-day periods so that the dispersion processes of the diurnal cycle are included. There have been two studies in which a few releases of a perfluoro compound have been made and tracked on the order of 500 to 1000 miles. Additional studies of this type are probably needed although they are fairly expensive. Currently there are no plans for further studies of this type but they will be necessary to validate the current hypotheses regarding long-range transport (transport beyond several hundred miles). Tracer studies are needed particularly in the pristine West where long range transport of urban, forest fire, and smelter plumes are thought to be especially important and where complex terrain effects on transport cannot be predicted with confidence.

Another way to get at these processes involves the use of a fluorescent aerosol tracer with measurement by lidar. This has an advantage over the flourocarbon tracer in that one may map out the entire three-dimensional structure of the plume and follow it as it moves and disperses. The fluorocabon tracer can only be measured as an integrated sample at a point.

In view of the limited extent and high cost of tracer studies, it is desirable to seek additional means of obtaining data to check transport modules. Analysis of NWS visibility distance data and

observation of hazy areas in satellite images indicate that during certain episodes, especially in the summer and fall, hazy air masses or blobs form and move around the country. These blobs have dimensions of hundreds of miles, persist for several days and have surprisingly sharp edges. A regional model, even with a crude sulfate formation mechanism, should be able to give the outline of the blob and its motion if the transport module is accurate. This combination of NWS visibility data and satellite images provides a cost-effective technique for obtaining a data base to evaluate the transport module of regional models.

5.6.3 Chemistry

Chemistry modules can be tested from smog chamber studies or from extensive measurements from platforms moving in power plants or urban plumes. Full-scale predictions which include chemistry, transport and dispersion can be evaluated against measurements from ambient monitoring networks. Unfortunately the network data are not always adequate and when such data are available they frequently do not have adequate spatial or temporal coverage.

5.6.4 Error Sensitivity Analysis

Analysis of models for error sensitivity is also needed. Within the Acid Rain Program protocols are being developed for model evaluation and verification. When these are developed they should be applied to visibility models.

5.6.5 Model Comparison

It should be possible to increase the reliability of both predictive and inferential (source-receptor) models by applying both types of models to the same data base and comparing results.

5.7 Emissions

The Acid Deposition Program has a major effort underway to develop emission inventories. Task Group B will provide anthropogenic emissions of SO_2 and NO_2. Probably NH_3 and ozone-forming hydrocarbons will be included. Task Group A will provide information on natural emissions of sulfur and nitrogen compounds. However, the Acid Deposition Program has minimal interest in emissions of carbon soot or specific organic compounds which are important aerosol precursors. Similarly, natural organic emissions which may be significant aerosol precursors, especially in the pristine west, are of little concern because they are not thought to be important in forming ozone. Therefore, the visibility program must make provisions for obtaining inventories of these emissions as well as those from forest fires and agricultural burning. Emissions of wood smoke from home heating and road dust are being examined in other programs. However, some augmentation will be required to insure that the information needed for visibility models is obtained. For pristine western areas coarse aerosols sometimes account for a significant amount of extinction. More information is needed on both natural and man-made emissions of coarse particles.

5.8 Wind Field

Most existing air quality models use a wind field derived from National Weather Service measurements of the upper air wind speed and direction. These measurements provide a snapshot of the wind speed and direction in the morning and evening (0 and 12 GMT, 6 am and 6 pm EST). Upper air measurements are made at over 60 stations. The data must be interpolated in time and space to provide wind fields for models. These interpolations are known to be inaccurate because the wind speed slows down during the middle of the day due to turbulent mixing in the boundary layer and speeds up at night due to lack of vertical momentum transfer. Also the geographic coverage is inadequate for our modeling purposes. This is an especially severe problem in the pristine West where fewer stations are located and where complex terrain features produce local and mesoscale effects on the wind field.

An attractive line of research is to use dynamical models to interpolate between NWS observations. A dynamical model is being used in the NCAR regional acid rain model. Calculations have shown that trajectories obtained from dynamical wind field models are different from those obtained from empirical wind field models. However, tracer studies will be required to demonstrate which wind field model gives the best agreement with reality. Application of the NCAR dynamical model to eastern visibility models and development of a dynamical model for western visibility models would probably yield a significant improvement in the reliabilty of visibility models.

Additional upper air measurements are also needed. In the pristine West more stations are needed. At all sites additional measurements at midnight and noon would be helpful.

Summary of Reserch Recommendations

A. Empirical Approaches to Source Assessment

1. Specific Source Categories - Developmental Improvement of Techniques and Guidance

   a. Large Point Sources
   b. Large Area Sources
   c. Small Area Sources

B. Empirical Approaches to Source Identification

1. Receptor Oriented Approaches - Development and Improvement of Techniques and Guidance

   a. Aerosol Components
   b. Back-trajectory Models
   c. Data Bases for Model Validation
   d. Combinations and Comparisons of Techniques and Models
   e. Extinction Budget Analysis

2. Deterministic Modeling - Development and Improvement of Techniques and Guidance

   a. Generalized Visibility Modules for Regional and Other Aerosol Models
   b. "Monte Carlo" regional model
   c. Western Regional Model
   d. Data Bases for Model Validation

6.0 VISUAL VALUES

6.1 Psychological Values

6.1.1 Natural Settings

A primary consideration in determining the adversity of an air quality impact on a scenic vista is a determination of whether or not the quality of the visitor experience and/or enjoyment of a class I area is compromised. Assessing visitor experience and enjoyment raises several interesting questions. For example, how can the quality of the recreational experience be measured? Is good visual air quality an important component of the recreational experience? If so, how important is it? How might a given change in visual air quality affect visitor satisfaction with the visual resource? How might the impact on satisfaction with the visual resource affect the overall quality of the recreational experience?

Employing recreation demand theory to assess the quality of a recreational experience is one way to approach the problem. The basic premise of demand theory is that individuals engage in behaviors which will maximize their psychological well-being. If they feel their psychological well-being is less than optimal and that a recreational experience will restore their sense of well-being, they will seek out a recreational experience and engage in behaviors which will provide the needed restoration.

The recreational behaviors a person might engage in to reach a higher state of psychological well-being and the relationship between these behaviors and the environment can be best visualized with a four level demand hierarchy. The first level is the demand to participate in a desired activity. The second is to do so in an environment which offers both the type and quality of attributes desired. The third is to experience short-term psychological satisfactions which come from interacting with desired environmental attributes during activity participation. The fourth level is to realize long-term benefits which might come from a satisfying experience.

Results of the research conducted so far have begun to provide a better understanding concerning the importance of good visual air quality to the recreational experience sought at National Park Service Class I areas. The results have also begun to provide an understanding of

relationships between good visual air quality and visitor satisfaction with the visual resource and the quality of the visitor experience and the level of visitor enjoyment. However, more complete answers to questions such as those posed earlier are needed to prevent the quality of the recreational experience from being negatively impacted by possible reductions in good visual air quality in class I areas. Specifically, additional work is needed with the following emphasis:

1. Further test the hypothesis concerning the naturalness cluster of attributes and determine a more complete picture of which attributes are part of this naturalness.

2. Establish the importance of visibility-related attributes in various types of class I areas.

3. Develop relationships between good visual air quality and visitor satisfaction with the visual resource and the recreational experience.

4. Assess the long-term benefits of good visual air quality.

5. Develop, where possible, quantifiable relationships between visibility "perception" indices and visitor demand for attributes and visitor satisfaction with the quality of these attributes.

6.1.2 Urban Settings

Studies of willingness to pay for improved visibility in urban ares, urban perception surveys, and results of visitor studies in non-urban settings suggest that improved visibility would increase psychological well being in urban areas. Despite increasing work on the effects of illumination on behavior and mood, research on the effect of visibility on psychological attributes in urban settings is almost non-existent. Approaches to identifying and evaluating potential effects are needed.

6.2 Economic Assessment of Visibility Values

The visibility benefit research summarized in Chapter 4 points to two principal limitations in the economic methodology for estimating dollar values of better visibility. The more general problem transcends the visibility application. As research in the visibility area has repeatedly indicated, and as critics (e.g., the UARG sponsored reviews) have pointed out, contingent survey approaches are poor substitutes for market data, and may not provide unbiased answers. Thus, further work to demonstrate the relationship between market based and contingent valuation (CV) based methods is essential, even though such calibration, by definition, cannot be performed on a nonmarket good like visibility. Second, there are a variety of unresolved questions from the visibility benefits research itself that should be addressed. The results of current benefits analysis are quite sensitive to the resolution of some of these questions.

6.2.1 The General Issue

CV and related analyses continue to be controversial, given the potential for a wide variety of biases associated with surveys in general and the contingent technique in particular [See Schulze et al. (1981) or Randall et al. (1981)]. Bishop (1979) heightened concern with his finding that in an experimental comparison between real cash payments and willingness to pay (WTP) elicited from a survey, the average WTP was over 50 percent higher than average realized cash payments. Though more recent unpublished work by Bishop finds no statistical discrepancy in survey derived estimates, the issue is not yet satisfactorily resolved. Thus, further work comparing market and contingent techniques on goods traded in well established markets (thus, excluding visibility, for which market data are unavailable) is recommended. It would be particularly useful if a framework similar to the Bishop design were expanded to include comparisons among question formats and the CR method.

6.2.2 Specific Issues on Visibility Valuation

- Valuation in Multiple Good Setting: Recent studies have indicated that respondents' valuation for a specific environmental good falls when competing environmental (or potentially nonenvironmental) claims are included in the survey process [see Randall et al. (1981) and Rae (1984)]. A split sample survey valuing visibility in isolation and in competition with other goods is recommended to resolve this uncertainty.

- Specifying Visibility in Distributional Terms: Most of the existing visibility benefits work, excepting Loehman (1981) and Rae (1984), is based on respondents valuing an average change in visibility in miles. Visibility, however, is a distribution of daily conditions. It is quite conceivable an individual would assign a low value to a modest average change in visual range, but would value highly visibility improvements on particularly poor days, especially in the summer or when recreation is involved. It is not clear when these poor days are averaged over a year, that the resulting aggregate valuation is the same as when based on average visual range improvement. Further research on the depiction of visibility conditions to respondents is necessary to resolve this issue.

- Relationship between visibility and recreational (or other) activities: While research in this area has been undertaken by Tolley et al. (1984) and by the National Park Service, further efforts to explore this complementarity are likely to be productive.

- Nonuser and Existence Value: Empirical research on nonuse values for visibility has been problematic, as the results of Randall et al. (1981) clearly demonstrate. While this is a "high risk" research area, it is of sufficient importance to try to narrow the existing uncertainty.

APPENDIX F. SUMMARY OF PUBLIC COMMENTS

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APPENDIX F
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SUMMARY OF COMMENTS

This summary covers written comments EPA received in response to its November 9, 1984 (49 Fed. Reg. 44770), notice soliciting public comment on the issues and alternatives being addressed by the Visibility Task Force with regard to its charge of developing a long-range strategy for addressing visibility impairment caused by pollution-related regional haze. This summary does not cover comments presented at the public hearings announced by this same November 9 Federal Register notice.

This summary groups the comments into the three general categories of issues the commenters addressed: (1) the proper goals, evaluation criteria, and definitions of visibility-related terms the Visibility Task Force should use; (2) alternative regulatory strategies for addressing regional haze; and (3) visibility research.

I. GOALS, CRITERIA, AND DEFINITIONS

Goals. The National Parks and Conservation Association, the St. Cloud Environmental Council, and the West Michigan Environmental Action Council urged EPA, generally, to move forward firmly to control regional haze. The West Michigan Environmental Action Council noted also that such impairment can significantly disrupt the enjoyment of the environment and adversely affect economies through the loss of scenic vistas.

Several members of the oil industry--Chevron, the American Petroleum Institute (API), and the Western Oil and Gas Association (WOGA)--stated that visibility protection for mandatory Class I areas should not be extended to other areas without a further Congressional mandate. Chevron and API noted that environmental groups participating at the

Denver public meeting (December 5, 1984) agreed with this position.

UARG stated that a goal should be to ascertain with much greater certainty than currently exists the trade-off the public is willing to make between the cost of electricity and the value of visibility. The public must make this trade-off because both electricity and visibility are "goods" used by everyone. That is, UARG explained, one cannot view the regulation of visibility improvements as a way to internalize the costs of electricity production because those costs are already internalized--electricity users (the public) must bear all of the costs of electricity production including the financial cost and whatever visibility impairment that it causes.

Evaluation Criteria. API and WOGA agreed with each of the Visibility Task Force's proposed criteria for evaluating alternative strategies for visibility regulation, but urged EPA to define precisely the nature of each criterion. For example, these commenters stated, the "cost-effectiveness criterion" should be expressed in terms of the cost of the strategy per degree of visibility improvement. API stated that this concept is not new, noting that the San Francisco Bay Air Quality Management District's criteria for setting control priorities to meet ambient standards is $/ppm decrease in pollutant concentration.

The Oregon Forest Industries Council stated that it was important to tailor any long-range regional haze strategy so that it would maintain and improve the economic viability of the forest industry, which is just emerging from a difficult economic recession. This commenter also stated that it was important to develop cost-benefit data for each strategy.

The Colorado Mountain Club, on the other hand, stressed the economic importance of natural resources. It noted that Colorado's natural recreational resources--including high peaks, scenic areas, good visibility, and clean air--support a stable, state-wide tourism and outdoor recreation industry of major economic importance. A cohesive recreational management policy is needed for these resources, the commenter stated, most of which are on public lands managed by diverse agencies.

Definitions. Salt River Project expressed considerable concern about the definition of "visibility" and "visibility impairment." Specifically, Salt River Project encouraged EPA to refine its concept of regional haze based on the commenter's analysis of National Park Service photographs, which revealed three types of haze: (1) uniform haze (characterized by a discontinuity in the vertical distribution, and which corresponds most closely to EPA's concept of regional haze); (2) ground-based layered haze (which occurs predominantly in winter); and (3) elevated, layered haze (which is somewhat synonymous with visible plumes, but which has an origin that is not necessarily tied to emission sources). Salt River Project stated that EPA may also require a "no haze" haze-type, which would occur when none of the three preceding haze-types is perceptible.

In refining these definitions, Salt River Project stated that EPA should establish a dialogue with the scientific community to arrive at a consensus for the definition of visibility and visibility impairment. This consensus agreement would then be submitted to an advisory subcommittee of the EPA's Science Advisory Board.

Also, in connection with these definitions, Salt River Project urged EPA to adopt a concept of "prevailing background" since it is practically impossible to establish a true natural background. The prevailing background, being variable in space and time, is therefore site-specific and should be considered as a time-averaged value at a given site, Salt River Project asserted.

Chevron and API stated that EPA should specify procedures for the federal land managers to follow in their adverse impact determinations. API stated also that EPA should give quantitative parameters--which could be area-specific--to the federal land managers to judge what is an "adverse" impact requiring mitigation. API stated that it agreed with the Environmental Defense Fund's comment (at the Denver public meeting) that it is critical to focus on the definition of good and bad visibility. WOGA also stressed the need for an objective standard against which to measure adverse impacts on visibility.

II. ALTERNATIVE REGULATORY STRATEGIES

Integrated Approach. Chevron, WOGA, and API agreed with EPA that any regulatory program to protect visibility from regional haze should be integrated with other control programs that might affect visibility. WOGA noted in particular that EPA should credit NSPSs with visibility improvement as part of the integrated program concept.

Chevron and API explained that an integrated approach (1) provides a mechanism for EPA to consider the cumulative air quality benefits of the broad range of alternative regulatory strategies, and (2) results in the most cost-effective controls being implemented, as well as helping form the basis for more equitabale regulatory strategies.

Public Willingness to Pay. UARG stated that EPA should use the public's willingness to pay for visibility improvements to measure the adversity of any visibility impairments. If the public is not willing to fund the improvement, the status quo cannot be regarded as a state of adversity. Also, UARG stated, if there is no adverse effect on the public, no secondary ambient standard can be justified.

In this regard, UARG stated that it has assessed the errors and uncertainties in the draft report prepared for EPA by SAI entitled "Visibility and Other Air Quality Benefits of Sulfur Dioxide Emission Controls in the Eastern United States" (the SAI report). This assessment reveals that even a 12 million ton per year SO_2 reduction scenario would produce benefits of less than one percent of the multi-billion dollar price tag for controls. Since these costs would be wholly out of proportion to the benefits, no SO_2 controls can be justified, UARG concluded.

Integral Vistas. API and WOGA stated that EPA should delete the concept of integral vistas since it is not authorized by the Clean Air Act.

Forest industry representatives agreed: the Oregon Forest Industries Council stated that protection of integral vistas created the potential for giving decisional authority about local land use matters to the federal government, and the Industrial Forestry Association stated that protection of integral vistas could curtail essential slash burning even though the resulting smoke may have little impact on a Class I area itself.

Modification of Clean Air Act Section 169A. API and WOGA stated that EPA should not seek legislative modification of Section 169A to explicitly cover protection of visibility from regional haze. API stated that it would take time to obtain congressional action; WOGA noted that EPA should take a hard look at Section 169A to see if protection of visibility from regional haze is covered.

Clean Air Act Section 126. API and WOGA stated that EPA should not seek any legislative change to Section 126 since that authority is presently receiving a thorough examination in connection with interstate ozone and acid rain impacts. API noted further that there is inadequate knowledge about visibility impairment for it to be a driving force for legislative change to Section 126, and stated that Section 126 was not intended as a vehicle to regulate regional haze.

Episode Control. API and WOGA supported a legislative amendment to Clean Air Act Section 123 that would allow seasonal variability of emission limitations.

Emission Trading. API and WOGA supported creating trading rights between new and existing sources over a wide area as a cost-effective approach to solving many regional air pollution problems.

The Industrial Forestry Association also supported the concept of emission trading, which it stated could be applied to essential slash burning operations such that if future prescribed burning emissions are below the natural pristine levels of smoke from wild fires, the future emissions could be traded for natural baseline levels.

On the other hand, the American Mining Congress (AMC) stated that a flexible NSPS that would allow emissions trading between copper smelters and electric utilities is not economically or politically feasible. AMC noted that (1) SAI's economic analysis regarding this concept failed to take into account the large financial commitments already made by several companies in the industry to achieve state implementation plan (SIP) compliance, and (2) choosing a lower and more realistic baseline would necessarily decrease the calculated savings attributable to this trading policy. A full analysis, AMC stated, would show essentially no difference in capital and operating costs at any given level of sulfur dioxide emissions for smelters and powerplants.

Also, AMC stated, there has been no field measurement to confirm the assertion that visibility would be improved under an emissions trading policy by more vigorous controls on smelters because of an assumed beneficial effect of NO_x on the oxidation rate of sulfur dioxide emissions from powerplants. AMC also noted that smelters could not cause the urban plume blight problem, which is caused by urban nitrogen oxide emissions. In addition, there would be political resistance to interstate trading. (AMC noted, however, that its concerns do not apply to the currently-allowed policy of emission trades.)

Prevention of Significant Deterioration (PSD) Program. WOGA and API opposed the idea of requiring minor sources to undergo visibility review as part of the PSD preconstruction review; EPA instead should publish de minimus criteria for exempting small projects using, for example, a version of the Level I screening criteria in EPA's "Workbook for Estimating Visibility Impairment."

WOGA noted also that redefining the PSD particulate matter increments to realize regional haze benefits may result in a multitude of different increments for the numerous haze conditions of Class I areas, thus further complicating the PSD program. WOGA stated that it agreed, however, that states and federal land managers should be allowed to set state-wide, regional, or local visibility objectives implemented through the PSD program if EPA provides technical guidance such as objective visibility standards and a validated reference method.

Non-Traditional Sources. API and WOGA agreed that if visibility controls are warranted, the most cost-effective controls should be implemented first whether they involve traditional or non-traditional sources.

Primary Standard for Visibility. API stated that it was premature to recommend a primary standard for visibility to Congress because (1) many areas of the country are still trying to attain the primary health standard, and (2) the Visibility Task Force should thoroughly evaluate all the visibility benefits associated with controls for attaining the primary national ambient air quality standards before suggesting visibility-specific controls. API also noted that such a course of action is probably unnecessary since visibility will likely improve in the future due to continued implementation of current program control such as NSPS.

Secondary National Ambient Air Quality Standard (SNAAQS). WOGA stated that promulgation of a SNAAQS is not a workable strategy to reduce regional haze because (1) EPA would have to define many different SNAAQS to cover the array of unique haze characteristics throughout Class I areas, which would be too complicated and time-consuming; and (2) instead, EPA should propose a specific, objective,

and validated reference method to measure compliance with such a standard.

Retiring Old Plants. API stated that it was concerned that a program feature of retiring old plants could cover refineries and chemical plants, as well as utilities, when there are better and more cost-effective control approaches for the former facilities.

Regional Strategies. The Oregon Department of Environmental Quality stated that visibility strategies must be regional in nature to reflect the "visual value differences" among regions.

The Oregon Forest Industry Council agreed, stating in particular that EPA should allow the present liaison among Idaho, Oregon, and Washington to develop the most cost-effective strategy for the Northwest to reflect the uniqueness of the area.

Prescribed Burning. The Industrial Forestry Association stated that the Visibility Task Force must recognize the ecological, biological, and management relations between fire and natural resources in any visibility regional haze programs it proposes; otherwise, the resulting regional haze visibility rules could (1) increase the incidence and severity of wild fire, (2) exacerbate the acute air quality degradation caused by natural fires that may be more harmful to human health, (3) contribute to a loss of annual habitat maintained by natural and prescribed fires, (4) increase insect and disease outbreaks, (5) create relatively greater environmental degradation of other resources such as soil productivity and water quality, and (6) unknowingly influence professional resource management decisions.

The Oregon Forest Industry Council noted that prescribed forest residue burning control techniques have improved greatly since the late 1970s.

The Industrial Forestry Association noted, as discussed above, that emission trading could be used to allow the continued practice of essential slash burning.

III. VISIBILITY RESEARCH

Current Research. AMC, Chevron, and API stated generally that current research is inadequate to provide sufficient data and analytical tools to show that a program to protect visibility from regional haze is needed. Until such data and tools are developed, these commenters stated, EPA should delay adopting visibility-specific control measures.

API and WOGA expressed specific concern with the reference in EPA's November 1984 outline of alternative regulatory strategies regarding the characterization of regional haze trends as based on human observations at airports from 1948 to the present. Such data, these commenters noted, may not reflect accurate regional haze trends because (1) the visual observers, their training, their methods, and the visual range targets have changed over the years; and (2) the observations of haze characteristics were secondary to ensuring that airplane landings and takeoffs could be done safely.

Similarly, API and WOGA expressed concern that the same quality assurance problems may also exist in projections of future regional visibility trends. Thus, API and WOGA stated, the Visibility Task Force should carefully qualify this data.

In this regard, the Oregon Forest Industries Council stated that suitable historical visibility trend data for the Pacific Northwest should be obtained from forest agencies, which possess data based on daily reports by forest lookouts that include visibility estimates.

Salt River Project expressed concern that the planned analyses of certain ongoing programs (VIEW, SCENES, and RESOLVE) might be flawed because the meteorological data that has been collected during those programs may not allow detailed source-receptor analyses. The reasons are, first, that surface meteorological data are strongly influenced by local drainage flows, and their use in inferring transport directions is minimal. Second, the National Weather Service rawinsonde network, which might provide better indications of transport, could also provide misleading results because the spacing between National Weather Service rawinsonde stations of several hundreds of miles is too large to depict haze transport.

The Utility Air Regulatory Group (UARG) expressed--in detail--its concern regarding the draft report prepared for EPA by SAI entitled "Visibility and Other Air Quality Benefits of Sulfur Dioxide Emissions in the Eastern United States." UARG noted two general problems with this report.

First, UARG stated, the report mischaracterizes the improvements in visibility that SO_2 controls can produce. This results because the report overstates the ability of 8 and 12 million tons per year (mtpy) emission reduction scenarios to benefit the public because, among other things, SAI (1) actually modeled emission reductions totaling 9.4 and 13.1 mtpy, respectively; (2) assumed that SO_2 emission reductions and changes in sulfate concentrations are linearly related; (3) used an inflated

value for the intrinsic contrast targets; and (4) did not perform a comprehensive and reliable assessment of the confidence that can be placed in its results.

The second principal flaw in the SAI report, according to UARG, was that its estimates of the value of visibility improvements are unreliable. In this regard, UARG criticized SAI for examining reductions in electric utility emissions and in regional haze as the vehicle to improve visibility, when in fact both electricity and visibility are "goods" used by everyone. Regulation of visibility improvements cannot be viewed as a means to internalize the cost of electricity production, UARG stated, because those costs are already internalized--electricity users (the public) must bear all of the costs of electricity production including the financial costs and whatever visibility impairment that it causes.

Future Research. Because of the deficiencies in the SAI report summarized in the preceding paragraphs, UARG stated that the report cannot support a regulatory program. If EPA decides to pursue the visibility issue, it should initiate a research program to determine whether the public is dissatisfied with current visibility, whether SO_2 controls can produce a visibility improvement that has a significant value to the public, and how much visibility improvement the public is willing to fund, UARG stated.

WOGA and API stated, generally, that EPA must commit to developing and funding a comprehensive visibility research program. API noted, in particular, the value of EPA funding for the Visibility Research Forum.

API and WOGA also agreed generally with the research projects the Visibility Task Force identified in its April, 1984, report regarding the gathering and analysis of data with respect to source-receptor relations and the establishment of a comprehensive monitoring and research program. In particular, these commenters stated, research is needed on parameters for aerosol-visibility relationships, the sources and causes of visibility impairment in the West, all high-quality visibility data, and development of standard operating procedures and a reference method for visibility monitoring techniques.

API also stated that EPA should give research on volatile aerosols a higher priority since they are a significant component of visibility impairment in the West and little is presently known about them. In addition, API stated, the Visibility Task Force should consider the research and data being generated by the California Desert Air Work Group in assessing directly the visibility impact of the Clean Air Act non-attainment plan programs of the South Coast Air Basin and the San Joaquin Valley Air Basin on visibility in the Southeastern California Desert.

The Oregon Department of Environmental Quality stated that it was important for EPA to conduct research to (1) establish a uniform scheme for regional haze measurement, and (2) designate regional air basins (and require states within those basins to adopt a regional-specific control strategy).

Finally, Salt River Project proposed the following priorities (from first priority to last) for the research programs the Visibility Task Force proposed for FY 84: (1) visibility parameters for aerosol-visibility relationships, (2) visibility monitoring techniques, (3) mini-recession SO_2/visibility analysis, (4) western visibility impairment, and (5) aerosol absorption measurements.

For FY 85, Salt River Project recommended the following priorities (again from first to last): (1) workshops/conference, (2) visibility parameters for aerosol/visibility relationships, (3) visibility impairment by volatile aerosols, (4) visibility monitoring techniques, (5) western visibility impairment, (6) aerosol absorption measurements, (7) source-receptor relationships, (8) mini-recession SO_2 visibility analysis, (9) visibility trends, and (10) regional visibility research network.

Finally, GAIA Associates stated that it hoped that EPA will provide funding to the Visibility Research Forum to support attendance by environmental groups at the next year's program.

IV. PROCEDURAL MATTERS

Chevron, API, and AMC stated that EPA should expand the role of visibility experts from industry and the public in developing alternate regulatory strategies for contolling regional haze. API and Chevron noted also that EPA should continue to provide for public meetings and public review and comment on developments (e.g., the Western Visibility Benefits Study) as EPA continues to work on programs to control regional haze.

The Oregon Forest Industries Council stated that the Visibility Task Force should maintain close liaison with the forest industry at national, regional, and state levels. This is especially critical, the commenter stated, when evaluating alternative strategies that will impact the economic viability of the forest industry.

The Oregon Department of Environmental Quality stated that the Visibility Task Force should also maintain close liaison with the joint effort by the states of Oregon, Washington, and Idaho to study regional haze; this joint study could yield important information on techniques for measuring visibility, and the magnitude and sources of regional haze in the Pacific Northwest.

Finally, GAIA Associates described in detail the Visibilty Research Forum in order to supplement the discussion of that group at the Denver public meeting. GAIA stated that the Visibility Research Forum is organized for the exchange of information and ideas about current and planned visibility research carried out in both the public and private sectors of the United States. The Forum's objective is to address the linkages among ongoing visibility research, natural resource management, and visibility and related air quality regulatory programs. The Forum is interested in research efforts to develop sound scientific information and planning tools appropriate for regulatory and administrative processes, corporate planning, and natural resource management. In addition, the Forum provides a neutral setting for dialogue among visibility researchers, managers, and planners in the federal and state agencies and affected industry groups.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

January 3, 1985

MEMORANDUM

SUBJECT: Summary of Public Meetings of the Interagency Visibility Task Force

FROM: John Bachmann
Task Force Chairman

TO: See Below

The Interagency Visibility Task Force held two public meetings in December to discuss the work of the task force and receive public suggestions and comment. The meetings were announced in the November Federal Register (attached) and both written and oral public participation was solicited. Some 41 individuals and/or organizations requested the additional background materials mentioned in the notice. This memorandum summarizes the oral presentations and discussions that occurred at each of the meetings, some of which have implications for developing long-term strategy alternatives. Further perspectives and insights from the public are expected in the written submissions that are due by mid-January.

DENVER MEETING - DECEMBER 5, 1984

The Denver meeting was held in a conference room of the Customs House and ran from 11:30 a.m. to 4:30 p.m. MST. Attendees (see attached) included representatives of several task force agencies, a number of utilities, mining and some other industries, two State Agencies, private contractors, and environmental organizations. The discussants included a substantial number of those present.

FORMAL PRESENTATIONS

John Leary - State of Colorado

The meeting opened with my brief overview of the background and mission of the task force and order of discussion. Following this introduction, John Leary of the Colorado Department of Health gave a presentation on 1) a study of alternative control strategies on urban visibility in Denver through the year 2000 and 2) the six Rocky Mountain State visibility strategy study.

The urban visibility analysis started with the current relative frequency of four wintertime visual range (visibility) categories as represented by photographs and projected the change in frequency of these categories through the year 2000 under alternative emissions scenarios. According to the analysis, the major sources of wintertime urban haze in Denver are mobile sources (gasoline and diesels), refineries and industry, power plants, woodstoves, and space heating. With no further controls on any of these sources, the frequency of poorer than average visibility categories in Denver will shift from 50% to 80% of winter days where natural conditions are a minor factor. Under this scenario, the total source contribution in 2000 would be of 139% of current levels. If Federal regulations were to be applied to heavy and light duty diesels, this figure would drop to 114% of current, and with other strategies already planned by the State, the total would be 106% of current. Other approaches are being examined that might result in improvements by 2000.

During the discussion of this analysis, John Leary and the other Colorado State representatives appeared to agree that the major ways in which the Federal government might assist the State with respect to urban haze were 1) more stringent regulations of diesel particulate emissions and 2) additional research and/or resources to examine the causes, benefits, and control of urban haze.

Leary then outlined the western states visibility study. Task force members have already received the first summary document prepared for this study. The purpose is to develop a uniform approach to visibility standards and to identify the key technical and policy issues. The project consists of three phases, two of which are completed:

I. Issues and Options;

II. Select Preferred Option; and

III. Address specific issues with standard format chosen.

Colorado may use the results of this work in developing their visibility SIP for class I area protection. Leary indicated that the State was looking for visibility standards that were readily understandable and permitted monitoring at a reasonable cost. The States are considering doing studies that would, through photographs or other means, elicit public opinion on desirable or acceptable visibility levels.

In the ensuing discussion Ivar Tombach (AeroEnvironment) suggested that the states' goals of simplicity and understandability in visibility standards might be difficult to reconcile with a consistent measurement technique. Tom Dodson (US Navy) emphasized that studies eliciting opinion on desirable or acceptable visibility should also present information to the public on the costs of achieving such visibility levels.

Anne Vickery

Anne Vickery made a presentation on behalf of the Colorado Mountain Club, a long standing organization now numbering some 8000 members. The presentation consisted of a series of slides showing a number of impressive vistas seen from various mountains. The views included long paths that extended from class I area to class II area, class II to class II and class II to class I. The Mountain Club strongly feels that such vistas between class I areas deserve the same protection as class I areas themselves; they therefore support the idea of "integral vistas," but might go beyond current interpretations. The Club maintains ledgers at each of the 54 high peaks (> 14000 ft), in Colorado that record on the order of 500-700 signatures per year each. Ms. Vickery pointed out that tourism accounts for some $4 billion to the Colorado economy and that good visibility is an important factor that attracts visitors. She provided a report prepared by the Mountain Club on the importance of natural resources to the Colorado economy (attached). She also submitted several reports done for the Forest Service of visitors to wilderness areas that indicate Clean Air and good visibility are among the highest ranked attributions of such areas.

In response to a question regarding the Mountain Club observations on current visibility and perceived future threats to the areas of concern, Ms. Vickery indicated that degredation of visibility has been noted in some of the southern areas (Durango and Winimucha) and on the "Front Range." In particular, Pike's Peak used to be visible from Long's Peak on a regular basis; this is rare view at the present time. She feels that future oil shale development could present serious problems, but that if care were taken in control and location, such development could proceed. In addition, she indicated that the southwestern and Mexican smelter control could be important to Colorado.

OPEN DISCUSSION

Following a lunch break, the format shifted to an open discussion by those present. To provide some structure, the time was divided among three broad topics mentioned in the Federal Register Notice:

1. Desirable goals for regional visibility programs

2. Alternative strategies, and

3. Research needs

The discussion was focused on the western U.S. A substantial number of attendees participated. The following summarizes some of the major points made in each area.

Goals for Western Visibility

Bob Yunke (Environmental Defense Fund) opened the discussion in this area. He pointed out that an apparent "schizophrenia" existed in EPA's visibility protection programs. Many of the PSD permitting decisions being

made by Federal Land Managers that involve an analysis of visibility effects now appear to include regional haze, even though the regulations themselves were intended to focus on plume "reasonably attributable" impairment. An example was a decision concerning the Teddy Roosevelt class I area. Thus the Federal Land Managers must make decisions that involve use of regional models or other approaches for assessing haze without official EPA guidance. In essence, a "back door" approach to addressing haze is developing. Yunke pointed out that this problem will emerge again in the upcoming resolution of the two major remaining components in the EDF settlement on Phase I visibility regulations: 1) developing guidance for the BART assessment of sources - Yunke feels any regulation should deal more than just coherent plumes and 2) the regional haze versus plume blight issue will most seriously come into conflict in the context of developing long-range plans. He feels that no real distinction has been made between plumes and haze in the regulatory preamble and that the long-range plan must include haze. If no federal guidelines exist on how to judge state implementation plans, it will be difficult for states to develop adequate procedures and regulations. He feels that the long-range plans must address both area and point source impacts, not only "SO_2" reasonably attributable" impairment but also for haze.

Given the above points, Yunke feels that two areas are paramount in developing goals for federal visibility protection programs.

(1) EPA should act quickly so that no conflict exists between long-range plans developed for plume blight and regional haze, and

(2) The Agency should finally specify the criteria for measuring impairment and resolve any remaining technical issues relating to indicators of visibility and visibility measurement.

Ann Vickery felt that protection of class I areas alone from regional haze or plumes was not enough. Many of the most popular areas are only recently designated as parks or wilderness areas and are not included under class I protection. In her opinion, these areas should be protected. Many of them have more visitors than class I areas and the goal, at least in Colorado, ought to be protecting existing visibility everywhere in the state. Several participants then discussed whether or not addressing regional haze in class I areas in the West would also provide protection for the spaces in between. The general consensus was that, with some possible exceptions, protecting visibility in class I areas probably would go a long way toward protecting visibility in the intervening spaces, because of the density of Class I areas in the West and because regional haze tends to occur on large geographical scales.

Jim Blankenship (Forest Service) raised a Forest Services management dilemna in this context. A number of wilderness areas have been enlarged since the 1977 Act Amendments. These enlargements are class II areas, while the rest of the area is designated as class I. Blankenship feels these class II portions should receive the same protection as the rest of the area. The Forest Service apparently intends to treat both in the same

way. Dennis Hadow (USFS) added that some new wilderness areas are located at distances over a 100 miles from class I areas and thus may not get adequate protection from some sources of impairment without special treatment. It was also pointed out that some states have agreed to allow impact reviews in all cases, for example, Colorado and Wyoming. One commenter noted that the need to protect areas between class I locations would seem to warrant a cooperative effort between States and land managers rather than new Federal regulations.

On the subject of goals, Rob Farber (Southern California Edison), said his reading of the national goal established by Congress is to try to get rid of all man-made pollution. In his words, this is a lofty goal - but unattainable. He suggested a phased approach that would define the areas in which we would want to maintain current visibility and areas in which we would want to improve or allow some degregation. He indicated that we should establish priorities with some areas e.g. the Grand Canyon, receiving higher priority and some receiving lower priority (e.g., some near Los Angeles). The program could start with these kinds of goals, and develop a track record before moving further. Jim Blankenship indicated we should not ignore the mandate and write off class I areas near Los Angeles because detecting visibility would be difficult there. Steve Connolly (Jellinek, Schwartz, Connolly, and Freshman) said that in places like Los Angeles, we are probably doing all we can do to meet health effects goals and that will be as much as can be done to make progress towards improving visibility. Nevertheless, as pointed out by Al Qöyawayma (Salt River Project) and others, some pollutants emitted in Los Angeles, e.g., SO_2 may affect visibilit throughout broad regions and all health criteria have been met. Therefore there may be some instances in which consideration could be given to urban controls beyond those required to meet health related standards.

Bob Yunke then addressed the question of whether or not the task force report should make recommendations for changing the current legislation regarding visibility protection. In his opinion, the point of reference for such legislation is protection of visibility in parks and wilderness areas where the Federal government has a legitimate interest. The goal of preservat of visibility in important vistas in parks and other such areas gives political validity to the program. To raise the prospect of the Federal government involving itself in protection of visibility beyond these areas to, for example urban areas or other spaces in between, would detract from the validity of the program in the western U.S. Yunke would like to see Congress consider applying class I visibility protection to new wilderness areas but would not like to see the national goal otherwise expanded or cut back.

In Yunke's opinion, the critical issue for the task force to address is What is visibility impairment? The law leaves the determination of what is adverse to the Federal Land Manager, but the problem is that EPA has not issued criteria for making the decision. He feels EPA should define quantifia measures and guidelines for determining adverse impairment. One approach would be to set standards for each class I area. As Steve Connolly pointed out, however, the legislative history shows that Congress wanted the decisions on impairment to be subjective, not a hard test a source could pass or flunk in an arbitrary way.

Aaron Mann (Sierra Pacific Power) suggested that one focus for the task force would be to provide the tools for decision making. These include 1) a definition of the units for measuring visibility and impairment in a "reference method" for visibility and 2) an assessment of the sources that contribute to visibility impairment.

Rob Farber asked whether one can control the growth patterns in the western U.S. under the current authorities, because in his opinion the growth of urban sprawl is a major current and future problem with respect to regional haze in the West. In particular, the growth of population and associated emissions in northern Arizonia near the "golden circle" areas should be examined and programs should strike a reasonable balance between point sources and urban area growth. Others suggested that secondary impacts (area and other emissions sources that accompany major point sources) should be addressed in the BACT reviews under the PSD program. Tom Dodson indicated it would be difficult to prepare an air quality management plan for each class or area. Anne Vickery appeared to agree and suggested that she would hate to see each area have to develop individual plans. In her view, it would be better to do it on an "as needed" basis with the threshold question being are you where you want to be in respect to visibility in comparison to where you are now.

Alternative Control Strategies

At this point in the discussion, the focus shifted to the area of control strategy alternatives for the West and asked for comments both on technical control strategies as well as regulatory alternatives. Rob Farber asked whether the task force contractor report on emissions projections in the West included emissions from off-road vehicles, which can cause a semi-permanent fugitive dust problem, and emissions from natural vegetation. Farber indicated that coarse particles may account for about 20% of the extinction budget in the southwest. George Roope (Utah International Inc.) suggested that a regional or detailed management plan could be helpful to industries deciding on appropriate new source locations. On the other hand, Steve Connolly indicated that if each class I area had a predetermined target, it might be difficult to accommodate conflicting goals, useful tradeoffs, and appeals on specific cases. Scott Archer (Bureau of Land Management) indicated it could be quite easy to address such issues in a resource management plan. On the other hand, Jim Blankenship said that the land managers could do all sorts of planning yet have little control in specific instances where there may be an adverse impact.

Ivar Tombach stated that industry needs to have a more stable regulatory future and that requires well thought out plans that don't have to be changed constantly. This would argue against the case-by-case approach or at least in favor of well thought-out criteria and guidelines if a case-by-cas approach is to be implemented. Paul Roberts (Chevron) felt that EPA should provide better guidance and criteria on "adversity" and supported the notion that predictability is very important.

Research Needs

At this point, the discussion moved to the area of research needs and recommendations to be considered by the task force. Rob Farber opened the discussion on the subject of the relative role of EPA, the National Park Service, Department of Defense, and industry with respect to visibility research coordination. Farber suggested that even though EPA is not the major source of visibility research, that it nevertheless should serve a role in coordinating visibility research by the various groups in the country. Most helpful would be some sort of coordinating group that provided an overall guide with respect to who is doing what now in the way of visibility research and suggested time lines for various answers that would be relevant to regulatory programs. This would serve to provide better coordination among groups conducting visibility research and give a better idea of where various groups stand at this point.

Ivar Tombach felt that the first research need is to define visibility in a way that is regulatable. This involves (1) how well we can see real world things, and (2) the clarity of the atmosphere. He again stated the need to fix an index against which standards can be set. Nels Larson (Salt River Project) felt that all visibility monitoring equipment should be made rugged enough to be used in remote areas.

Ron Farber stressed the issue of particle monitoring in light of the new information that a substantial component of visibility impairment may be due t volatile aerosols not collected by traditional monitors. He recommended that care be used in analyzing any of the existing data bases as proposed in the interim research needs document. He also raised the issue of the role of meteorology in normalizing visibility. In his evaluation of the data, a 7-year rolling average is needed to factor out meteorological variability. Al Qoyawayma added that we need much better upper air and local meteorology data in the West. The current radiosonde data are not nearly enough. Discussion ensued with respect to whether better upper air data could be gathered in a cost effective manner. Tom Dodson suggested that with enough planning and cooperation among agencies improved meteorological could be obtained using, data for example mini-sondes that measure 5 kilometer winds. Scott Archer added that the BLM already is operating a 75 mile grid of wind data in the west. Dodson also stressed that research into the question of volatile aerosols was a very high priority.

Rob Farber stated that a good consensus existed among visibility researchers on what should be done on a physical basis but felt that we were weak on what we should do with the physical results. He felt that the work on perception and values conducted by the Park Service and others should be continued, but that many different ways to approach these issues existed and could be used to link to the physical results later. Although EPA has not conducted research on perception, it does maintain a program on visibility values, at least in the economic sense, in OPPE. Bill Malm felt that part of EPA's overall coordination role would be to make a statement of support for research on visibility perception and values that would encourage the Park Service as well as other potential funding agencies to continue work in this area.

WASHINGTON MEETING - DECEMBER 10, 1984

The Washington meeting, held at EPA from 9:30 a.m. to 1:00 p.m., was also relatively well attended by various groups and task force members but many groups, particularly the industry representatives, seemed less inclined to participate in the public discussion. Ironically, some participants were unable to attend or were late due to a ground fog in the East that curtailed or prevented aircraft operations.

I opened the meeting in the same way as in Denver, providing an overview of the task force activities. Then, Doug Latimer of SAI made a presentation on the modelling work and benefits analysis conducted under contract to OPPE in support of the task force. Because the conduct and results of that work are presented elsewhere, I will not summarize his presentation here.

Following the opening presentation, we proceeded to an open discussion under subject headings similar to those used in the Denver meeting. In this case, however, the discussion centered on the goals, strategies, and research needs relating to visibility protection and related issues in the eastern U.S.

Goals

The discussion opened with David Hawkins (National Resources Denfense Council). He stated that visibility goals can be defined in the abstract but that the next step, that is developing policy options, is a much more difficult one. In this area, we should look at a wide range of practical implications. He supports the idea of the policy analysis done to date and feels it is important that EPA continue to have two focuses;

(1) a problem focus, for example, the problem of visibility impairment, acid rain, and so on,

(2) a pollutant focus. This perspective is derived from the fact

that specific pollutants may be involved in multiple problems, for example SO_2, which shows up frequently. A ranking of policy options for a single pollutant should consider options that involve other pollutants and a need exists to look at all the benefits of controlling a single pollutant.

Hawkins feels that the Agency is in pretty good shape on both focuses with respect to sulfur oxides. Susan Buffone (National Parks and Conservatior Association) raised a western related issue. She asked whether the task force report would address international concerns, in particular, whether the issue of the Mexican smelters would be addressed. She also noted that two issues related to visibility were raised in the particulate matter proposal, (1) the question of deferring a secondary fine particle standard, and (2) whether costs should be considered in setting secondary standards.

Betsy Agel (Clean Air Coalition) felt that the problems of visibility go beyond class I areas to class II areas and places such as state parks. She indicated that cost benefit analysis were not done to set these areas aside and therefore questioned whether we could now set dollar values on protecting visibility in such places.

Dave Hawkins said that looking at the history of public agitation over air pollution, people's concerns peak most greatly when they can see or smell it. Therefore, in his opinion, in the goal for visibility protection even in the east, should be the elimination of any man-made degregation of visibility. He then provided a number of examples of the importance of clear skies. He felt that even though visibility appears to be a soft issue compared to health effects and materials damage, there are many clues in the literature and everyday experience suggesting that aesthetic or soft issues are quite important and could affect things that make a difference in the GNP such as worker productivity.

Hawkins feels that the goal of eliminating man-made impairment should be fairly aggressive and that an adverse effect on visibility is that which degrades the clarity of skies and vistas. He feels that approach is implicit in the Act now with respect to the goal and that the goal should not be watered down with practical considerations of cost. Evaluating cost-effective approaches and considering practical realities can and should be factored in to efforts to pursue the goal.

Alternative Control Strategies

John Trijonis (Santa Fe Research) raised what he termed a philosophical point with respect to developing control strategies. That is, air pollution regulations are better the closer they are to the source of the problem. He feels that visibility protection programs should regulate the source - not the effect - using as an example that regulations of automobile emissions have been more effective than the air quality standards in reducing pollution levels. Trijonis feels that it is harder to take the emissions approach under current regulatory authorities. Bill Malm cautioned that if we only look at the suspected sources, we may miss the real cause of the effect and may have to switch programs at that point. Malm feels that if the standard were set on the effect it would be easier to mid-course correct if new information suggested that a major portion of the problem was not being addressed. He feels that we should look at the effect. Trijonis agreed that we should continue to look at the effect, but should base regulations on emissions. Dave Hawkins stated that really both approaches were needed and they complement each other's strengths and weaknesses.

On the question of whether to use existing or request new authorities for dealing with regional haze in the East, Hawkins stated that the Clean Air Coalition would prefer legislative approaches because the current regulatory approaches are quite slow, and may well not work without Congress' support in any case. Because a legislative recommendation might not be accepted, he feels that the task force should include a regulatory approach alternative or alternatives as well. Hawkins said that the reason legislatior is necessary is that the Clean Air Act in its current form is not working with respect to visibility in the East and, therefore it should be fixed.

Research Needs

John Trijonis opened indicating that in his review of the interim researc needs, he would place a low priority on the mini-recession study. He felt that the change in emissions during the recession were probably too small

to see any valid change in visibility. William Wilson responded that the intent was to use models to filter the data and to use the information to evaluate the models. Vicky Evans (Gaia) stated for the record that her organization had been conducting a visibility research forum and had intended to expand this effort to environmental groups. She suggested that the group could use more EPA support. Dave Hawkins suggested that the noise program, despite little in the way of research dollars, was able to provide something of a clearinghouse for noise research and coordinating noise research in the country in the past. He suggested that this might be a useful model for EPA to use in coordinating visibility research.

There were some questions regarding the amounts of funding EPA received for FY84.

Molly Ross of the National Park Service stated that the Parks Services' view was that the mandate for protection of visibility and air quality relatec values extends to all of their areas, not just class I areas. A number of smaller parks are designated as class II.

Dave Hawkins then made some recommendations that EPA consider research in psychological reactions to clean vs. dirty air, citing examples of the effects of light on mood changes and studies of visitation rates to national parks versus haziness.

ADDRESSEES:
Visibility Task Force Members
John O'Connor
Harvey Nozick
Barbara Wauchope
Barbara Bankoff

Attendees
Public Meeting of the Interagency Visibility Task Force
December 5, 1984
Denver, Colorado

Task Force Member	
Scott F. Archer	US BLM/Colorado State Office
John Bachmann	U.S. EPA/OAQPS
Jim Blankenship	U.S. Forest Service
Jim Dicke	U.S. EPA/OAQPS
David Joseph	NPS
Bill Malm	US NPS/Washington Office
Janet Metsa	U.S. EPA/OAQPS
Tom Pace	U.S. EPA/OAQPS
Marc Pitchford	U.S. EPA
Bruce Polkowsky	U.S. EPA/OAQPS
Butch Rachel	EPA Region 8
Sara Schneeberg	U.S. EPA/OGC
Vivian Thomson	U.S. EPA, Washington

Other Attendees	
Paul Adams	A. Coors Co.
Steven Arnold	Colorado Dept. of Health
Prem Bhardwaja	Salt River Project
C.A. Bina	Basin Electric Power Corp.
Bill Blankenship	New Mexico Environmental Enforcement Division
John M. Clause	Colo. Air Pollution Control Div.
Steve Connolly	Jellinek, Schwartz, Connolly & Freshman, Washington, D.C.
James B. Coyne	Peabody Coal Co.

John T. Dale	EPA Region VIII
Tom Dodson	U.S. Navy
Victoria A. Evans	Gaia Associates
Rob Farber	So. Calif. Edison
Marcia Gelman	Hunton & Williams
Rick Hardy	Morrison Knudsen Co., Boise, Id.
Dennis Haddow	U.S. Forest Service
John Leary	Colorado Dept. of Health
Aaron Mann	Sierra Pacific Power
C.V. Mathai	Arizona Public Service Co., Phoe
John McNeill	Colorado-UTE Elec. Assn.
Brian Mitchell	NPS-Air Quality Denver
Ron Ostop	Colorado Springs Dept. of Utilit
Robert Pearson	Public Service Co. of Colorado
Michael A. Poling	American Mining Congress
Al Qöyawayma	Salt River Project
Richard Rawlings	New Mexico Environmental Enforcement Division
Paul Roberts	Chevron Research
George W. Roope	Utah International Inc.
Joe Southerland	Salt River Project
Mike Teague	Hunton & Williams
Louis Thanukos	Appl. Env. Cons.
Ivar Tombach	AeroVironment, Inc.
Anne Vickery	Colorado Mountain Club
Bob Yuhnke	Env. Defense Fund, Boulder, CO

Visibility Task Force Meeting
Washington, D.C.
December 10, 1984

Name	Organization/Address	Phone
Task Force Members		
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Jim Byrne	USDA-FS	703-235-8096
Jim Dicke	EPA, RTP, NC 27711	919-541-5681
David Joseph	NPS, Denver, CO	
Bill Malm	NPS, Ft. Collins, CO	
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Bruce Polkowsky	EPA, RTP, NC 27711	919-541-5540
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William Wilson	EPA, RTP, NC 27711	919-541-2551
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Other Attendees		
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Susan Buffone	NPCA	202-265-2717
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Barbara Goldsmith	ERT, Inc.	617-369-8910
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