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Particulate Matter National Ambient Air Quality Standards: Scope and Methods Plan for Urban Visibility Impact Assessment

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Office of Air Quality Planning and Standards
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Research Triangle Park, NC 27711

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Scope and Methods Plan for
Urban Visibility Impact Assessment**

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LIST OF ACRONYMS/ABBREVIATIONS

AQI	Air Quality Index
AQS	EPA's Air Quality System
ASOS	Automated Surface Observing System
Ca	Calcium
CAA	Clean Air Act
CAIR	Clean Air Interstate Rule
CASAC	Clean Air Scientific Advisory Committee
CBSA	Consolidated Business Statistical Area
CCN	Cloud Condensation Nuclei
CCSP	US Climate Change Science Program
Cd	Cadmium
CMAQ	Community Multiscale Air Quality
CONUS	CMAQ simulations covering continental US
CSA	Consolidated Statistical Area
CTM	Chemical Transport Model
Cu	Copper
DRE	Direct Radiative Effects
EPA	United States Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
GEOS	Global Scale Air Circulation Model
GI	Group Interviews
Hg	Mercury
ICR	Information Collection Request
IFG	Investigative Focus Groups
IMPROVE	Interagency Monitoring of Protected Visual Environment
IPCC	Intergovernmental Panel on Climate Change
ISA	Integrated Science Assessment
Km	Kilometer
N	Nitrogen
NAAQS	National Ambient Air Quality Standards
NCEA	National Center for Environmental Assessment
NOAA	National Oceanic and Atmospheric Administration
NO _x	Nitrogen oxides
NPS	National Park Service
NRC	National Research Council
NWS	National Weather Service
OAQPS	Office of Air Quality Planning and Standards
OAR	Office of Air and Radiation
OMB	Office of Management and Budget
ORD	Office of Research and Development
PM	Particulate Matter

PM _{2.5}	Particles with a 50% upper cut-point of 2.5 μm aerodynamic diameter and a penetration curve as specified in the Code of Federal Regulations.
PM ₁₀	Particles with a 50% upper cut-point of 10± 0.5 μm aerodynamic diameter and a penetration curve as specified in the Code of Federal Regulations.
PM _{10-2.5}	Particles with a 50% upper cut-point of 10 μm aerodynamic diameter and a lower 50% cut-point of 2.5 μm aerodynamic diameter.
Pb	Lead
PRB	Policy Relevant Background
REA	Risk and Exposure Assessment
RF	Radiative Forcing
RH	Relative Humidity
SEARCH	Southeastern Aerosol Research and Characterization Study
S	Sulfur
SO ₂	Sulfur Dioxide
SO _x	Sulfur Oxides
STP	Standard Temperature and Pressure
TOA	Top-of-atmosphere
UVA	Urban Visibility Impact Assessment
VAQ	Visual Air Quality
Zn	Zinc

1 INTRODUCTION

2 The U.S. Environmental Protection Agency (EPA) is presently conducting a review of
3 the particulate matter (PM) national ambient air quality standards (NAAQS). EPA's overall plan
4 and schedule for this PM NAAQS review presented in the *Integrated Review for the National*
5 *Ambient Air Quality Standard for Particulate Matter* (US EPA, 2008a). That plan outlines the
6 Clean Air Act (CAA) requirements related to the establishment and reviews of the NAAQS, the
7 process and schedule for conducting the current PM NAAQS review, and two key components in
8 the NAAQS review process: an Integrated Science Assessment (ISA) and a Risk and Exposure
9 Assessment (REA). It also lays out the key policy-relevant issues to be addressed in this review
10 as a series of policy-relevant questions that will frame our approach to determining whether the
11 current primary and secondary NAAQS for PM should be retained or revised.

12 The ISA prepared by EPA's Office of Research and Development (ORD), National
13 Center for Environmental Assessment (NCEA) provides critical assessment of the latest
14 available policy-relevant scientific information upon which the NAAQS are to be based. The
15 ISA will critically evaluate and integrate scientific information on the health and welfare effects
16 associated with exposure to PM in the ambient air. The REA, prepared by EPA's Office of Air
17 and Radiation (OAR), Office of Air Quality Planning and Standards (OAQPS) will be developed
18 in two parts addressing: (1) human health risk and exposure assessment and (2) quantitative
19 assessments of urban visibility impairment and qualitative assessments of other welfare-related
20 effects. This document describes the scope and methods planned to conduct the quantitative
21 urban visibility assessment (UVA) to support the review of the secondary (welfare-based) PM
22 NAAQS (U.S. EPA, 2009b). The UVA will draw from the information assessed in the ISA,
23 and will include, as appropriate, quantitative estimates of urban visibility conditions and public
24 preferences associated with recent ambient levels of PM, with levels simulated to just meet the
25 current standards, and with levels simulated to just meet possible alternative standards. A
26 separate document describes the scope and methods planned to conduct quantitative assessments
27 to support the review of the primary (health-based) PM NAAQS (U.S. EPA, 2009). Preparation
28 of these two planning documents coincides with the development of the first draft PM ISA (U.S.
29 EPA, 2008b) to facilitate the integration of policy-relevant science into all three documents.

1 This planning document is intended to provide enough specificity to facilitate
2 consultation with CASAC, as well as for public review, in order to obtain advice on the overall
3 scope, approaches, and key issues in advance of conducting the UVA and presentation of results
4 in the first draft of the UVA. NCEA has compiled and assessed the latest available policy-
5 relevant science available to produce a first draft of the ISA and related Annexes (US EPA,
6 2008b), which we have reviewed and used in the development of the approaches described
7 below. This includes information on atmospheric chemistry, source emissions, air quality, urban
8 visibility conditions, public perception/preference studies and other PM-related welfare effects.
9 CASAC consultation on this planning document coincides with its review of the first draft ISA.
10 CASAC and public comments on this document will be taken into consideration in the
11 development of the first draft UVA, the preparation of which will coincide and draw from the
12 second draft ISA. The second draft UVA will draw on the final ISA and will reflect
13 consideration of CASAC and public comments on the first draft UVA. The final UVA will
14 reflect consideration of CASAC and public comments on the second draft UVA.

15 OAQPS will prepare a policy assessment that will discuss the policy implications of the
16 key studies and scientific information contained in the final ISA and the quantitative analyses
17 contained in the final UVA. The policy assessment is intended to “bridge the gap” between the
18 scientific review and the judgments required of the EPA Administrator in determining whether,
19 and if so, how, it is appropriate to revise the secondary NAAQS for PM. The policy assessment
20 will present various policy options for standard setting together with a discussion of how the
21 underlying interpretations of the urban visibility impact assessments and evidence-based
22 information regarding other non-visibility welfare effects inform consideration of the adequacy
23 of the current standards, and the appropriateness of alternative secondary standards that could be
24 considered by the EPA Administrator. The policy assessment will focus on the basic elements
25 of the PM air quality standards: indicators, averaging times, forms¹, and levels. These elements,
26 which serve to define each secondary PM NAAQS, will be considered collectively in evaluating
27 the public welfare protection afforded by the standards.

¹ The “form” of a standard defines the air quality statistic that is to be compared to the level of the standard in determining whether an area attains the standard.

1 This introductory chapter includes background on the current PM standards and the
2 quantitative assessments conducted for the last review; the key issues related to designing the
3 quantitative assessments in this review, building upon the lessons learned in the last review; and
4 an overview introducing the planned assessments that are described in more detail in later
5 chapters. The planned assessments are designed to estimate ranges of urban visual air quality
6 impairment that are associated with recent ambient levels, with ambient levels simulated to just
7 meet the current standards, and with ambient levels simulated to just meet alternative standards
8 that may be considered. The major components of the assessments briefly outlined in the
9 Integrated Review Plan (U.S., 2008a, Section 6), are conceptually presented in Figure 1-1, and
10 are described in more detail below in Chapters 2, and 3, respectively. The schedule for
11 completing these assessments is presented in Chapter 4.

12 **1.1 BACKGROUND ON LAST PM NAAQS**

13 As a first step in developing this planning document, we considered the work completed in the
14 most recent review of the PM standards, completed in 2006 (71 FR 61144, October 17, 2006)²,
15 and in particular, the quantitative assessments conducted in support of that review. At that time,
16 public welfare effects were addressed under/divided into two main categories: visibility impacts
17 and other welfare effects. Regarding visibility impacts, EPA took into account that the Regional
18 Haze Program³, implemented under sections 169A and 169B of the CAA, is providing ongoing
19 protection against visibility impairment in Class I areas. The 2006 PM NAAQS review therefore
20 focused on evaluating the levels of visibility impairment occurring in urban areas and on
21 assessing available information on public preferences regarding at what point PM-related urban
22 visibility impairment becomes unacceptable to the individual. At that time, EPA's focus
23 continued to remain on particle mass and EPA determined that size-fractionated particle mass,
24 rather than particle composition, remained the most appropriate approach for addressing PM-
25 related urban visibility effects. EPA conducted a quantitative assessment to provide additional
26 information and insights that could help inform decisions on the standards. These assessments

² See also http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html

³ See <http://www.epa.gov/air/visibility/program.html> for more information on EPA's Regional Haze Program.

1 and the resulting recommendations regarding an appropriately protective secondary standard for
2 urban visibility impacts are described in section 1.1.1 below.

3 With respect to the other welfare effects category, it was recognized that the chemical
4 composition of the particle was more relevant to associated ecosystem effects than was particle
5 mass or size. The chemical and physical properties of PM can vary greatly with time, region,
6 meteorology, and source categories, thus complicating the assessment of potential welfare
7 impacts. In particular, the last review concluded that the nitrate and sulfate components of PM
8 have the most widespread ecological relevance when deposited. However, because of the
9 difficulty in determining the particulate matter contribution to the total load of N and S in
10 sensitive ecosystems, an appropriate secondary PM standard to address these effects remained
11 elusive. As a result, EPA did not conduct any quantitative assessments for these N and S effects,
12 nor for the other non-visibility PM-related public welfare effects (e.g., materials damage,
13 climate) due to a paucity of relevant current information.

14 The rationale for the 2006 final decision on the appropriate revisions to the secondary PM
15 NAAQS included consideration of: (1) the latest scientific information on visibility effects
16 associated with PM; (2) insights gained from assessments of correlations between ambient PM_{2.5}
17 and visibility impairment prepared by EPA; and (3) specific conclusions regarding the need for
18 revisions to the current standards (i.e., indicator, averaging time, form, and level) that, taken
19 together, would be requisite to protect the public welfare from adverse effects on visual air
20 quality.

21 EPA proposed to revise the secondary standards to provide additional protection against
22 PM-related public welfare effects including urban visibility impairment, effects on vegetation
23 and ecosystems, and materials damage and soiling, by making them identical in all respects to
24 the suite of proposed primary standards for fine and coarse particles. EPA also solicited
25 comment on adding a new sub-daily PM_{2.5} secondary standard to address visibility impairment in
26 urban areas. CASAC provided advice to EPA in several letters to the Administrator stating
27 support for the sub-daily standard. On September 21, 2006, EPA announced its final decisions to
28 revise the secondary NAAQS for PM to provide increased protection of public welfare by
29 making them identical to the revised primary standards (71 FR 61144, October 17, 2006).

1 Specifically, EPA revised the level of the 24-hour $PM_{2.5}$ standard to $35 \mu\text{g}/\text{m}^3$, retained the level
2 of the annual $PM_{2.5}$ annual standard at $15 \mu\text{g}/\text{m}^3$, and revised the form of the annual $PM_{2.5}$
3 standard by narrowing the constraints on the optional use of spatial averaging. With regard to
4 the standards for coarse particles, EPA retained PM_{10} as the indicator for purposes of regulating
5 the coarse fraction of PM_{10} (referred to as thoracic coarse particles or coarse-fraction particles;
6 generally including particles with a nominal mean aerodynamic diameter greater than $2.5 \mu\text{m}$
7 and less than or equal to $10 \mu\text{m}$, or $PM_{10-2.5}$). EPA retained the 24-hour PM_{10} standard at 150
8 $\mu\text{g}/\text{m}^3$ and revoked the annual PM_{10} standard because available evidence generally did not
9 suggest a link between long-term exposure to current ambient levels of coarse particles and
10 health or welfare effects.

11 **1.1.1 Overview of Visibility Impairment Assessment in the Last Review**

12 In the last PM NAAQS review key information was developed in both the Criteria
13 Document and Staff Paper on: (a) the nature of PM-related visibility impairment, including
14 trends in visual air quality; (b) the characterization of current visibility conditions and the
15 quantitative relationships between ambient PM and visibility; (c) the impacts of visibility
16 impairment on public welfare; and (d) approaches to evaluating public perceptions and attitudes
17 about visibility impairment. The assessments conducted by EPA associated with this
18 information are described briefly below.

19 **Nature of PM-related Visibility Impairment**

20 The science of PM-related visibility impairment was already well understood at the time
21 of the last review. The relevant aspects of this science are briefly described here. Visibility,
22 which can be defined as the degree to which the atmosphere is transparent to visible light, is
23 determined by the scattering and absorption of light by particles and gases, from both natural and
24 anthropogenic sources. Fine particles are more efficient per unit mass at scattering light than
25 coarse particles. The classes of fine particles principally responsible for visibility impairment are
26 sulfates, nitrates, organic matter, elemental carbon, and soil dust. The scattering efficiency of
27 certain classes of fine particles, such as sulfates, nitrates, and some organics, increases as relative
28 humidity rises because these particles can absorb water and grow to sizes comparable to the
29 wavelength of visible light. In addition to limiting the distance that one can see, the scattering

1 and absorption of light caused by air pollution can also degrade the color, clarity, and contrast of
2 scenes. Visibility conditions are often described in terms of visual range (in distance units), light
3 extinction (in inverse distance units), or haziness (in deciviews units).

4 Direct relationships exist between ambient pollutant species and their contributions to
5 light extinction and thus to visibility impairment. EPA’s guidance for tracking progress under
6 the regional haze program specifies an algorithm for calculating total or “reconstructed” light
7 extinction by multiplying the concentrations of each major fine particle constituent by its
8 extinction efficiency (EPA, 2005a, section 2.8.1). Because certain fine particle constituent,
9 extinction efficiencies increase significantly with increases in relative humidity, a measure of un-
10 speciated PM_{2.5} mass concentration is not as precise a metric as the light extinction.
11 Nonetheless, by using historic averages, regional estimates, or actual day-specific measurements
12 of the component-specific percentage of total mass, one can develop reasonable estimates of
13 light extinction from PM mass concentrations. In the last review, EPA concluded that fine
14 particle mass concentrations could be used as a general surrogate for visibility impairment (EPA,
15 2005a, p. 2–74).

16 Due to regional differences in typical relative humidities and PM pollutant mixes,
17 visibility levels between the eastern and western U.S. are significant, especially in non-urban
18 areas. For example, in Class I areas, visibility levels on the 20 percent haziest days in the West
19 are about equal to levels on the 20 percent best days in the East. For example, the average visual
20 ranges on the 20 percent haziest days in eastern and western urban areas are approximately 20
21 km and 27 km, respectively (Schmidt et al., 2005). By contrast, visibility levels in urban areas
22 show far less difference between eastern and western regions. (See discussions below).

23 **Characterization of Current Conditions and Correlations Between Urban Visibility and** 24 **PM_{2.5} Mass**

25 As mentioned above, the assessment of visibility impairment in the last review was
26 primarily focused on visibility impairment in urban areas. Data available indicate that urban
27 areas generally have higher loadings of PM_{2.5} and, thus, higher visibility impairment than
28 monitored Class I areas. In an effort to better characterize urban visibility, EPA analyzed the
29 extensive newly available data on PM_{2.5} ambient air concentrations primarily in urban areas. The

1 PM_{2.5} Federal Reference Method (FRM) monitoring network and national data base of PM_{2.5}
2 ambient air concentrations had expanded greatly since the 1997 PM_{2.5} NAAQS had been
3 promulgated and included 24-hour measurements of total PM_{2.5} mass, continuous measurements
4 of hourly (total) PM_{2.5} mass, and 24-hour duration PM_{2.5} chemical speciation (component)
5 measurements. These federal reference method (FRM) measurements of PM_{2.5} mass data
6 allowed for analyses that explored factors that had historically complicated efforts to address
7 visibility impairment nationally, including regional differences related to levels of primarily fine
8 particles and to relative humidity. The analyses showed a consistently high correlation between
9 visibility, in terms of reconstructed light extinction, and PM_{2.5} concentrations (daily, hourly, and
10 block hourly) for urban areas in a number of regions across the U.S. and, more generally, in the
11 eastern and western U.S. The correlations in urban areas were generally similar in the East and
12 West, in sharp contrast to the East/West differences observed in rural areas.

13 While the average daily relative humidity levels are generally higher in the East than in
14 the West, in both regions relative humidity levels are appreciably lower during daylight as
15 compared to nighttime hours. By focusing on the daylight time period with lower relative
16 humidity levels, visibility impacts related to East/West differences in average relative humidity
17 were minimized. Both 24-hour and shorter-term daylight hour averaging periods were considered
18 in evaluations of correlations between PM_{2.5} concentrations in urban areas and visibility in
19 eastern and western areas, as well as nationwide. Clear and similarly strong correlations were
20 found between visibility and 24-hour average PM_{2.5} in eastern, western, and all urban areas (U.S.
21 EPA, 2005a, Figure 6-3). Somewhat stronger correlations were observed between visibility and
22 PM_{2.5} concentrations averaged over certain sub-daily (e.g., a 4-hour) time periods (U.S. EPA,
23 2005a, Figure 6-5), principally because the relative humidity, which effects the extinction
24 efficiency of much of the PM, varies less during any of the sub-daily time periods than over
25 entire days. During the 12-4 pm time period, the average visual ranges on the 20 percent haziest
26 days in eastern and western urban areas were approximately 26 km and 31 km, respectively
27 (Schmidt et al., 2005).

28 The correlations between visibility and PM_{2.5} concentrations during daylight hours,
29 which tend to have the lowest relative humidity levels, were relatively more reflective of PM_{2.5}

1 mass rather than relative humidity effects and aerosol composition, in comparison to correlations
2 based on a 24-hour averaging time. Another rationale for considering the use of daylight sub-
3 daily time-periods was the expected greater importance of visibility during hours when most
4 people are awake and most scenes are better illuminated.

5 **Impacts of Urban Visibility Impairment on Public Welfare**

6 Congress and the EPA have long recognized that impairment of visibility is an important
7 effect of PM on public welfare, and that visibility impairment is experienced throughout the U.S.
8 in urban areas as well as in remote Class I areas, as discussed above. Visibility conditions
9 directly impact people's enjoyment of daily activities in all parts of the country. Individuals
10 value good visibility for the sense of well-being it provides them directly, both in places where
11 they live and work, and in places where they enjoy recreational opportunities. Survey research on
12 public awareness of VAQ using direct questioning typically reveals that 80 percent or more of
13 the respondents are aware of poor visual air quality (Cohen et al., 1986).

14 The importance of VAQ to public welfare across the country has also been demonstrated
15 by the establishment of a number of other programs, goals, standards, and planning efforts in the
16 U.S. and abroad to address visibility concerns in urban and non-urban areas. Several state and
17 local governments have developed programs to improve visual air quality in specific urban areas,
18 including Denver, CO; Phoenix, AZ; and, Lake Tahoe, CA. At least two states have established
19 statewide standards to protect visibility. In addition, interest in visibility protection in other
20 countries, including Canada, Australia, and New Zealand has resulted in various studies, surveys,
21 and programs. Methods developed in conjunction with these regulatory and planning activities
22 are discussed below in the next section. A number of studies have also been designed to quantify
23 the benefits (or willingness to pay) associated with potential improvements in visibility both in
24 national parks and in urban areas (Chestnut and Dennis, 1997; Chestnut and Rowe, 1991).

25 In the last review, EPA conducted a pilot study in Washington D.C. in order to test both
26 the session design and survey questions that could potentially be used in a broader focus group
27 effort. This small pilot study was briefly discussed in the preliminary draft Staff Paper (US EPA,
28 2001) and in the technical report (Abt Associates, 2001) to elicit CASAC and public comment on
29 the use of this type of approach to help inform EPA's review of the secondary PM NAAQS, and,

1 more specifically, to elicit comments on various aspects of the survey methodology used in the
2 pilot project. The project was premised on the view that public perceptions of and judgments
3 about the acceptability of visibility impairment in urban areas are relevant factors in assessing
4 what constitutes an adverse level of visibility impairment in the context of this NAAQS review.
5 EPA received general support for the use of this type of approach, and also received advice from
6 members of CASAC as to how the survey methodology could be improved.

7 **Approaches to Evaluating Public Perceptions and Attitudes**

8 Survey methods and tools have been applied and evaluated in various studies, such as
9 those done in Denver, Phoenix, and the Lower Fraser Valley in British Columbia. One such tool,
10 a sophisticated visual air quality simulation technique, known as the WinHaze program
11 developed by Air Resources Specialists, Inc. (Molenar et al.,1994) produces images that
12 standardize non-pollution related effects on visibility so that perceptions of these images are not
13 biased due to these other factors. The studies in Phoenix and British Columbia, and the pilot
14 study in Washington, DC used survey approaches based on that used in Denver. This approach
15 involved conducting a series of meetings with civic and community groups to elicit individual
16 ratings of a number of images of well-known local vistas having varying levels of visual air
17 quality. Even with variations in each study's approach the public perception survey methods
18 used in these studies produced reasonably consistent results from location to location, with each
19 study indicating that a majority of participants find visual ranges within about 40 to 60 km to be
20 acceptable. These public perception studies use images of urban and distant scenic views under
21 different visibility conditions together with survey techniques designed to elicit judgments from
22 members of the public about the acceptability of differing levels of visual air quality. The fact
23 that each of the U.S. public perception and preference studies occurred in western cities with
24 similar scenic vistas of distant mountains was viewed as a limitation in the evidence available in
25 the last review regarding establishing an appropriate level of protection for urban visibility at the
26 national level. It remained an open question as to whether public preferences for given levels of
27 VAQ would be consistent in different regions of the country and looking at different types of
28 urban scenes.

1 **1.1.2 Overview of Qualitative Assessments of Other Welfare Effects in the**
2 **Last Review**

3
4 Other non-visibility PM-related effects qualitatively assessed in the last review included
5 impacts on vegetation and ecosystems, materials damage and soiling, and climate. Because PM
6 size classes used in human health risk assessment do not necessarily have relevance for
7 vegetation or ecosystem effects, a conclusion of the last review was that an ecologically-relevant
8 indicator for PM should be based on constituents of greatest and most widespread environmental
9 significance. The CD and Staff Paper, therefore, focused on the effects of deposited nitrates and
10 sulfates on receiving ecosystems. Reactive nitrogen, nitrogen saturation, nitrogen inputs to
11 aquatic habitats and acidifying deposition were considered for the purpose of assessing impacts
12 of deposited PM to ecosystems. The Staff Paper identified a group of ecosystems known to be
13 sensitive to excess N and S inputs. A list of characteristics that could be used to predict or locate
14 other potentially sensitive ecosystems was also developed as a component of the last review.
15

16 In materials damage and soiling attributed to PM components, both fine and coarse
17 particles were recognized as contributors, however, there was not sufficient data to support a
18 distinct secondary standard based on deposition to material surfaces.
19

20 In the last review, information available regarding atmospheric and suspended PM effects
21 on climate change processes and in altering the penetration of solar UV-B radiation focused
22 generally on global- and regional- scale processes and provided an insufficient basis for
23 characterizing how differing levels of ambient PM in areas across the U.S. would contribute to
24 these larger scale effects. Limitations to using PM effects on climate as a basis for the secondary
25 standard included the lack of information on how PM alters cloud properties and disrupts
26 hydrological cycles, as well as the lack of data on PM speciation.
27

28 In considering the available evidence on each of these types of PM-related welfare
29 effects, EPA noted that there was much information linking ambient PM to potentially adverse
30 effects on materials and ecosystems and vegetation, and on characterizing the role of
31 atmospheric particles in climatic and radiative processes. However, given the substantial

1 limitations in the evidence, especially the lack of evidence linking various effects to specific
2 levels of ambient PM, the Administrator concluded that the available evidence did not provide a
3 sufficient basis for establishing a separate and distinct secondary standard for PM based on any
4 of these effects alone. The Administrator further concluded that sufficient information was not
5 available at that time to consider either an ecologically based indicator or an indicator based
6 distinctly on soiling and materials damage, in terms of specific chemical components of PM.
7 Further, consistent with the rationale and recommendations in the Staff Paper, the Administrator
8 agreed that it was appropriate to continue control of ambient fine and coarse fraction particles,
9 especially long-term deposition of particles such as particulate nitrates and sulfates that
10 contribute to adverse impacts on vegetation and ecosystems and/or to materials damage and
11 soiling.

12
13 In selecting an appropriate level of protection for these effects, the Administrator
14 believed that any standards should be considered in conjunction with the protection afforded by
15 other programs intended to address various aspects of air pollution effects on ecosystems and
16 vegetation, such as the Acid Deposition Program and other regional approaches to reducing
17 pollutants linked to nitrate or acidic deposition. Based on these considerations, and taking into
18 account the information and recommendations of CASAC and staff, the Administrator, as
19 previously noted, revised the then current secondary PM_{2.5} and PM₁₀ standards by making them
20 identical in all respects to the proposed suite of primary PM_{2.5} and PM_{10-2.5} standards.

21
22

23 **1.2 GOALS OF ASSESSMENTS IN THE CURRENT REVIEW**

24 A critical step in designing the quantitative assessments associated with an evaluation of
25 urban visibility impacts is to clearly identify the policy-relevant questions to be addressed by
26 these assessments. As identified above, the Integrated Review Plan presents a series of key
27 policy questions (U.S. EPA, 2008a, Section 3). To answer these questions, EPA will integrate
28 information from assessments of urban PM air quality, visibility conditions, and public
29 preferences as we evaluate both evidence- and assessment-based considerations.

30

1 More specifically, to focus the UVA, we have identified the following goals: 1) to
2 characterize PM impacts on Visual Air Quality (VAQ) for hourly, sub-daily, and 24-hour
3 averaging times for various urban areas in order to determine current VAQ levels, as a basis for
4 estimating levels of VAQ associated with “just meeting” current and potential alternative
5 standards, and to characterize the PM levels and components responsible for VAQ; (2) to
6 develop information beyond what was available in the last review regarding public preferences
7 for urban VAQ in geographically diverse urban areas to help inform judgments by the
8 Administrator regarding establishment of a secondary PM NAAQS that would provide the
9 requisite degree of public welfare protection from adverse levels of PM-related urban visibility
10 impairment.

11 **1.3 OVERVIEW OF ASSESSMENTS IN CURRENT REVIEW**

12 This plan outlines the scope and approaches as well as highlights key issues associated
13 with our plans to focus our quantitative assessments on the urban visibility impacts associated
14 with the mixture of fine particle and aerosol compounds found in ambient air, including
15 particulate nitrates and sulfates. A discussion of our initial qualitative approach to considering
16 the information with respect to other PM-related welfare effects is provided below in Appendix
17 A. Both the quantitative and qualitative assessments will draw on the detailed description of
18 the recent state of the science provided in first and second draft ISAs (EPA, 2008b). As
19 described in the Integrated Review Plan (EPA, 2008a) the evaluation of the depositional effects
20 associated with particulate nitrates and sulfates on sensitive ecosystems is being addressed in the
21 joint NO_x/SO_x secondary NAAQS review that is underway.⁴

22
23 In order to evaluate the adequacy of the current suite of secondary standards to provide
24 adequate protection against adverse levels of urban visibility impairment, we envision two areas
25 of quantitative assessments in this review. Figure 1-1 shows the activities associated with each
26 assessment and how information flows among the activities. The following two subsections
27 provide an overview of these planned quantitative assessments, with the components associated

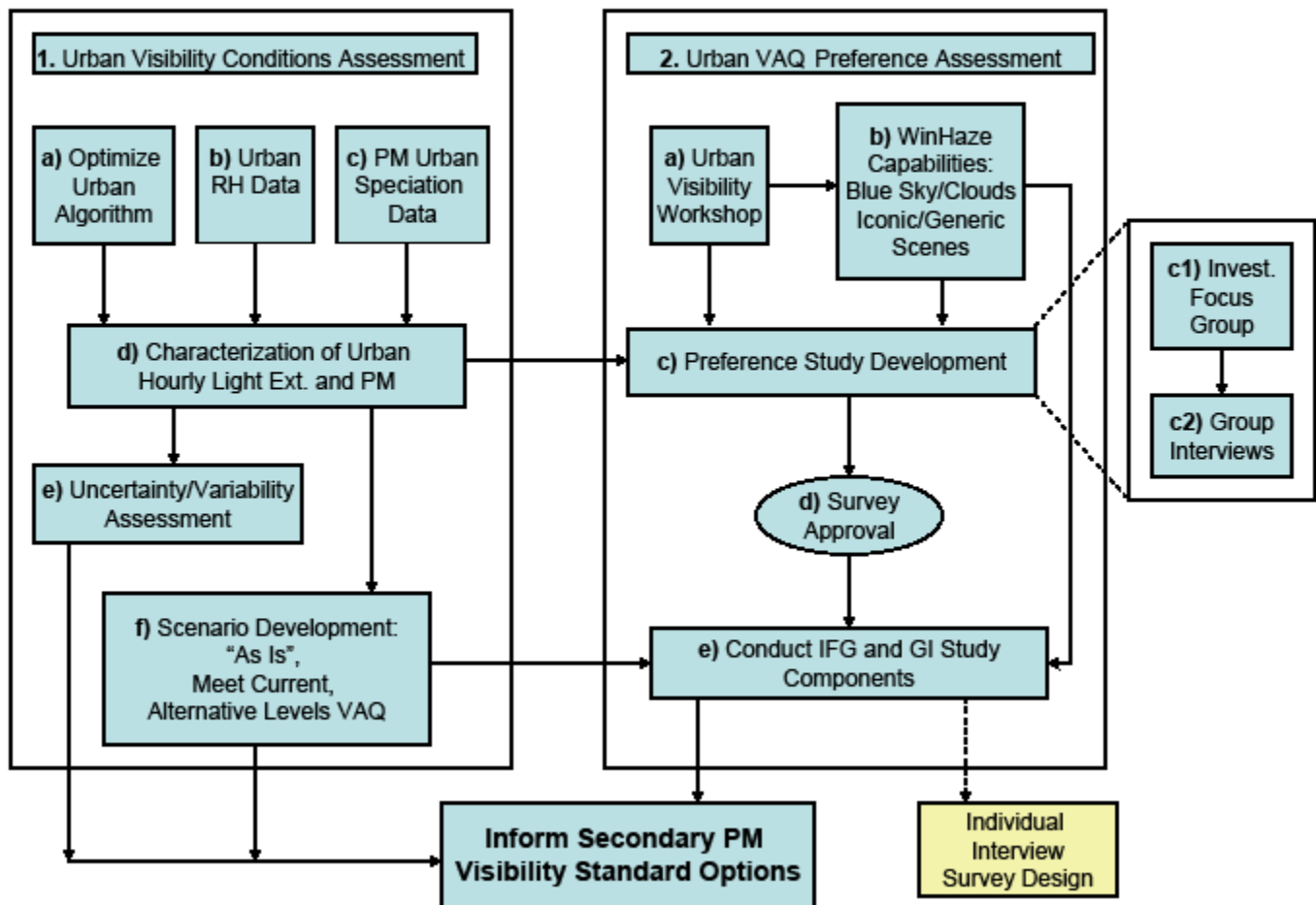
⁴ See <http://www.epa.gov/ttn/naaqs/standards/no2so2sec/index.html> for more information on the NO₂/SO₂ secondary NAAQS review

- 1 with the assessment of urban visibility conditions and those associated with the assessment of
- 2 urban VAQ, discussed in greater detail in chapters 2 and 3, respectively, below.

1 **1.3.1 Urban Visibility Conditions Assessment**

2 The first area of assessment (Boxes 1a-f) is characterization of urban VAQ conditions.

Major Components of PM Urban Visibility Assessment



3
4
5
6 **Figure 1-1 Major Components of the PM Urban Visibility Assessment**
7

8 **Air Quality Analyses**

9 Characterizing urban visibility impacts for the current review of the secondary NAAQS
10 for PM will include conducting air quality analyses to support quantitative assessments in
11 specific locations as well as potentially putting the results into a broader public welfare
12 perspective. These assessments will be designed to characterize current visibility conditions and

1 the potential impacts that are associated with recent ambient levels, with ambient levels
2 simulated to just meet the current standards, and with ambient levels simulated to just meet
3 alternative standards that may be considered. As part of such analyses, explicit and, where
4 possible, quantitative characterizations of the uncertainties associated with the air quality
5 analyses, as well as impact assessments will be developed. Air quality will be characterized in
6 urban areas along with the associated potential of adverse visibility impairment effects for
7 hourly, sub-daily, and 24-hour averaging times. The characterization of urban visibility
8 conditions will generate ambient concentrations and metrics that are most relevant for addressing
9 concerns about characterizing the impacts on VAQ associated with PM exposures.

10 The current review has access to more and better speciated ambient PM data from urban
11 areas than were available for previous reviews, allowing EPA to plan for a more comprehensive
12 and robust assessment of PM_{2.5} characteristics (i.e., concentrations and compositions) in urban
13 areas and their effects on visibility (see Chapter 2 and Table B.1 in Appendix B). In addition, we
14 plan to characterize visibility impairment in terms of an optical metric (light extinction) that is
15 closely related to the adverse public welfare effect of perceived VAQ (see section 1.3.3 and
16 Figure 1.2 below).

17 We plan to estimate and summarize hourly visibility in a number of urban assessment
18 locations under several air quality scenarios: recent conditions (defined as conditions during
19 2005-2007), “just meeting” the current secondary PM NAAQS, and “just meeting” one or more
20 alternative secondary NAAQS. The objectives of this area of the assessment are to determine the
21 current range, time of day, and PM concentration and composition associated with maximum
22 daylight hourly light extinction, taking into account the influence of humidity. This information
23 will help identify the PM species that are most responsible for current haze levels, and the
24 visibility improvements that might be achieved by meeting the current secondary PM NAAQS,
25 the regions of the country that might not meet alternative secondary NAAQS under
26 consideration, and the visibility improvements that might be achieved by meeting alternative
27 secondary PM NAAQS. This type of information may also be useful in informing the second
28 area of assessment described in the following paragraphs.

1 **1.3.2 Urban VAQ Preference Assessment**

2 The second area of assessment (Boxes 2a-e; Figure 1.1) is that of urban visual air quality
3 preferences. In order to help inform what levels of urban VAQ could be judged adverse to the
4 public welfare, we plan to conduct an expanded assessment of the preferences for and value of
5 urban visibility by building on the information available in the last review from public preference
6 studies, including the EPA sponsored pilot study conducted in Washington, D.C., and by
7 conducting additional public preference studies in urban areas, utilizing ongoing refinements to
8 the WinHaze model.

9 As an initial step, EPA sponsored a workshop on October 6-8, 2008 in Denver, Colorado
10 to brainstorm possible approaches and next steps for developing additional information on public
11 preferences for VAQ in urban areas to inform the current PM Secondary NAAQS review. Many
12 useful ideas and suggestions came out of that workshop and have been incorporated in the
13 planned assessment described below in chapter 3.0. For additional details regarding the
14 workshop, see the attached workshop summary in Appendix C.

15 Participants at the workshop identified three different study approaches/methods that
16 could be employed to gather relevant information. These include 1) investigative focus groups
17 (IFG); 2) group interviews (GI); and 3) individual interviews (II) or surveys. In addition,
18 workshop participants identified 13 issues that they felt could be subjects for further
19 investigation. One issue discussed at the workshop was the uncertainty regarding a concern that
20 current urban visibility preference information may not be representative of urban preferences
21 nationwide, since to date, all of the public preference studies have been conducted in western
22 areas using scenes that featured distant mountain backdrops. The limited nature of the
23 preference study information was clearly seen as a critical uncertainty in the last review.

24 Therefore, the second phase of the urban visibility impact assessment includes a plan to
25 conduct both IFG and GI studies to address important issues. First, we are developing plans to
26 conduct an IFG study to address the issue of how to improve communication with study
27 participants through a) selection of appropriate word choices in order to clearly communicate
28 concepts of preferences (e.g., acceptable, unacceptable, adverse), and b) determination of the
29 appropriate amount, type, depth/detail and wording of introductory materials. This IFG study

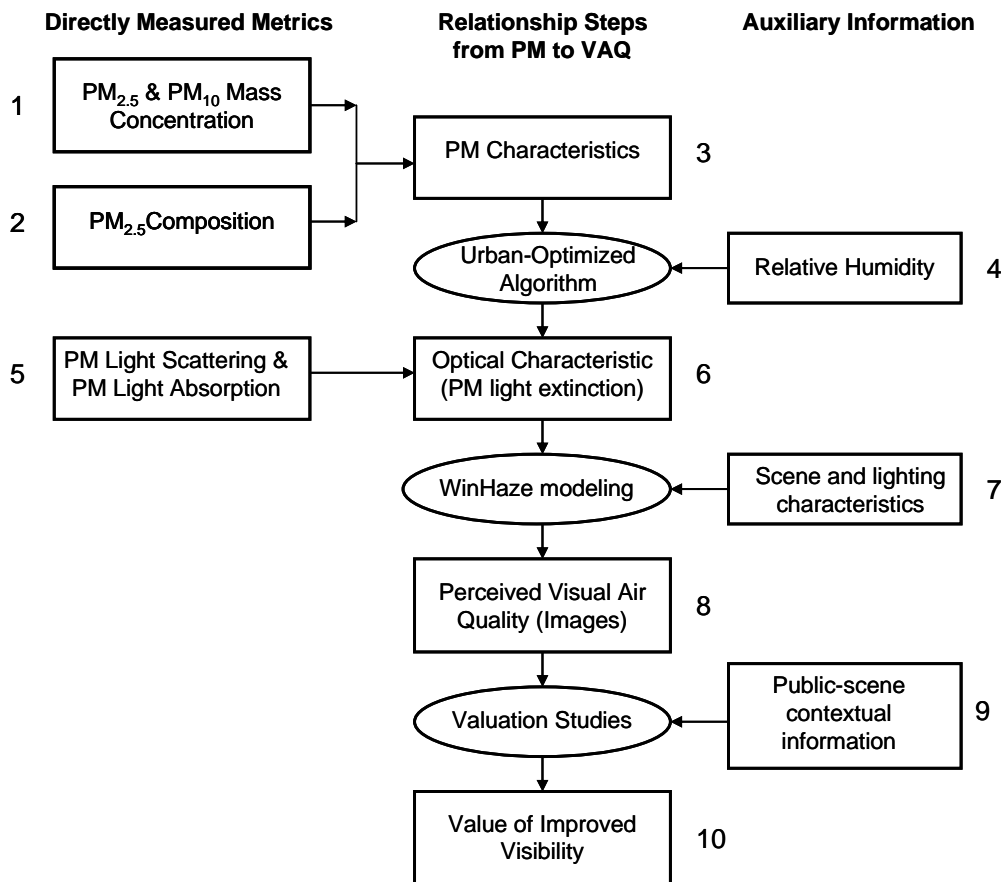
1 would be conducted in one location but include several iterations in order to allow responses
2 from one session to inform/refine the wording and introductory materials used in subsequent
3 sessions. Second, we are planning to conduct a GI study to assess whether concern for PM-
4 related urban visibility impairment varies by region or is a consistent value nationwide. We plan
5 to select at least three non-western urban areas which do not have distant mountain backdrops,
6 and one western city (e.g., Denver, CO or Phoenix, AZ), that was the site of an earlier urban
7 visibility survey, as GI study areas. If at all possible, these urban areas will also be areas
8 selected for assessment in the primary public health risk and exposure assessments. The
9 techniques employed for the IFG and GI studies will be similar to those already successfully
10 employed in earlier public preference surveys. Additional information and detail are provided
11 below in Chapter 3.

12 Prior to beginning these discussions, however, it is important to explain in more detail an
13 alternate standard structure that we are considering to characterize current urban visibility
14 conditions and to measure changes in urban visibility impairment associated with possible
15 revised secondary PM NAAQS. The discussion of the basis for our rationale is provided in
16 1.3.3.

17 **1.3.3 Discussion of Alternative Secondary Standard Structure**

18 In order to select the most appropriate and technically based indicator(s), averaging
19 time(s), form(s) and level(s) for a secondary standard to provide appropriate protection for urban
20 visual air quality, it is important to understand the relatively complex relationship that exists
21 between ambient $PM_{2.5}/PM_{10-2.5}$ mass concentrations and visibility effects on the public welfare
22 (e.g., impairment of VAQ) (see Figure 1.2). This complexity is introduced at several points by
23 different suites of variable factors that modify this relationship over time and space. When
24 examining Figure 1-2, it is important to realize that visibility is an instantaneous process – air
25 quality and relative humidity at each moment determines the visibility at that moment.
26 However, human valuations of visibility may reflect average visibility over longer periods than
27 an instant. For simplicity, and because of the at-best hourly temporal scale of most existing air
28 quality data and relative humidity data, the discussion here considers averaging periods no
29 shorter than one hour.

1 The first set of factors that modify this relationship includes the composition of the
 2 atmospheric particles in these size fractions, and the co-occurring level of relative humidity.
 3 These two factors alter the atmospheric optical characteristics so that a wide range of optical
 4 visibility conditions (also termed haze or light extinction) can occur for a given concentration of
 5 $PM_{2.5}/PM_{10-2.5}$ mass. This is due to the differential impacts of various component species in PM
 6 on light scattering and/or absorption, and the role relative humidity plays in changing the optical
 7 characteristics of some hygroscopic particles. It is important to note that the same level of
 8 ambient haze can be obtained with different combinations of PM component concentrations and
 9 relative humidity.



10 **Figure 1-2 Progression from PM Characteristics to Visibility Effects**

11 A second set of complicating factors occur in moving from a given level of haze (light
 12 extinction) to public perception of VAQ (boxes 7-10). Thus, the same level of light extinction
 13 can be associated with differing levels of protection of the public welfare effect of concern, (i.e.,

1 perceived visual air quality), depending on the sensitivity of the scenes involved. This phase in
2 the progression represent a dramatic increase in data needs and complexity, requiring the
3 incorporation of scene and lighting characteristics that influence whether and to what extent a
4 specific change in light extinction can be perceived, and public judgments concerning the
5 importance/value of that perceived change in VAQ for a particular setting. These latter
6 judgments, while related to the perceived degree, frequency, and timing of haziness, could also
7 be influenced by the unique site specific features of the scene (e.g., public/scene contextual
8 factors, apparent intrinsic scenic value), as well as individual preferences and potentially local or
9 regional expectations that are currently not well understood. Because the use of a perceptual or
10 visibility valuation metric would require incorporating the effects of urban-specific scene
11 sensitivity and public/scene contextual information for every applicable urban area, we conclude
12 its selection as a metric would be impractical in the context of setting a national standard.

13 The influence of this latter set of factors can be minimized, however, if scene and lighting
14 characteristics are selected to be similarly sensitive to small incremental changes in haze levels.
15 In public perception surveys these factors are held constant for each scene, so that there is a one
16 to one correspondence between perceived VAQ and the light extinction level associated with it
17 in the pictures selected. Preference or valuation studies can also be conducted to determine the
18 benefits associated with maintaining an acceptable level of this environmental good or service
19 (e.g., VAQ).

20 There is a possible mismatch between the averaging periods for the current PM
21 secondary standards (24-hour and annual averaging times), and those most appropriate for
22 visibility impairment. The current averaging times were selected to protect for acute and chronic
23 health exposures, respectively, not daytime visibility impairment. For example, a 24-hour
24 average also incorporates nighttime PM levels, and while visibility impairment by PM occurs
25 both during the day and at night, the physical and physiological/perceptual aspects of the
26 daytime and nighttime PM-visibility relationships are very different. Because nighttime
27 visibility effects are less well understood, we continue to believe that it remains appropriate to
28 focus solely on daytime PM-related visibility conditions for purposes of quantifying visibility-
29 related welfare impacts.

1 In the last review, EPA developed the sub-daily afternoon 4-hour average approach in
2 order to reduce, relative to a 24-hour approach, the variability in protection levels afforded by a
3 national standard by limiting the contribution of relative humidity, which is generally lowest in
4 the afternoon compared to other periods of the day. This approach has technical merit and
5 remains under consideration in this review. In addition we are considering use of a more
6 integrated structure that incorporates these two important sources of variability (e.g., PM species
7 composition and relative humidity) directly.

8 A standard with this structure could include a nationally uniform level (with associated
9 form and averaging time) of PM light extinction that would be determined by the Administrator
10 to represent an appropriate level of protection for urban VAQ. The ambient standard would then
11 be specified as the level of ambient PM such that the calculated or measured PM light extinction
12 level meets the level of protection of public welfare set by the Administrator. Compliance could
13 be determined by measuring PM mass concentrations at a given site. Using the algorithm to
14 incorporate known relationships between PM mass and speciated components at that site, in
15 combination with local or regional relative humidity data, one could then calculate the level of
16 PM light extinction associated with that concentration of PM mass. Alternatively, it would also
17 be possible and likely less costly to directly measure the PM contributions to PM light extinction
18 using a nephelometer to measure the PM light scattering and an aethalometer to measure the PM
19 light absorption. The estimated or measured PM light extinction would then be compared to the
20 level of PM light extinction set by the Administrator, including averaging time and form. Thus,
21 whether a certain ambient concentration of PM would attain the standard would depend in part
22 on the species and relative humidity, which vary geographically and temporally.

23 This alternative standard structure approach is distinct from the current 24-hour PM_{2.5}
24 secondary and afternoon sub-daily 4-hour approaches in several ways. First, it could be used to
25 provide a consistent level of VAQ protection, regardless of urban-specific PM species mix and
26 relative humidity levels that vary throughout the day. Second, this approach could allow one to
27 more directly relate ambient PM mass concentrations to an atmospheric optical metric, such as
28 PM light extinction, which is more directly associated with the public welfare effect of concern
29 (e.g., visibility impairment). Third, it could accommodate measured or estimated PM light

1 extinction information for an even shorter integration time (e.g. hourly), which would allow
2 consideration of the instantaneous nature of visibility impacts. PM light extinction levels can be
3 calculated in terms of measured or modeled ambient PM species concentrations at any relative
4 humidity. Thus, EPA believes it is appropriate to explore this alternative approach, with an aim
5 of setting a national standard that provides sufficient, but not more than necessary protection
6 throughout the United States by taking into account the recognized sources of variability from
7 relevant ambient factors.

2 ASSESSMENT OF URBAN VISIBILITY CONDITIONS

2.1 OVERVIEW

Box 1 at the top of the Figure 1.2 represents information on mass concentrations of PM_{2.5} and PM₁₀. Mass concentration data are currently collected to determine compliance with the primary and secondary NAAQS for PM_{2.5} and PM₁₀. Currently, such compliance monitoring for PM_{2.5} is based on 24-hour filters, rather than hourly measurements. Thus, additional data from the somewhat smaller network of non-compliance monitors is needed to establish hourly PM_{2.5} mass concentration values. PM₁₀ compliance monitoring makes use of both 24-hour filters and continuous instruments providing hourly concentration values. We will estimate PM light extinction from measured or estimated PM_{2.5} and PM₁₀ mass, composition, and relative humidity using a refined urban-optimized linear algorithm. For urban areas it is usually the case that the ambient concentrations of PM_{2.5} (in combination with humidity growth effects) contribute more to PM light extinction than do ambient concentrations of the PM_{10-2.5}. Therefore, special attention to the contribution of PM_{2.5} to light extinction is merited. The summary of the visibility estimates will be based on statistics such as the numbers of hours with PM light extinction greater than selected benchmarks, (e.g., 98th percentile daily maximum daylight 1-hour light extinction values).

In the last review, practical PM_{2.5} measurement considerations argued (at least implicitly) for an averaging period of at least several hours, because accurate measurements of 1-hour PM_{2.5} concentrations were problematic and little research had been completed and assessed on a Federal Reference Method for such measurements. Since that time, however, more continuous PM_{2.5} data has become available and we have a better understanding of its quality from site-to-site. In addition, high time resolution (e.g., hourly) PM light extinction values can be directly measured today (box 5, Figure 2.2) using either a transmissometer or a combination of nephelometer (light scattering) and aethalometer (light absorption) instruments.⁵ Currently there

⁵ A transmissometer can directly measure the total light extinction over a long open path, using a widely spaced light source and light detector; it inherently captures the effect of relative humidity, but also measures the light extinction by fog and precipitation, which would require data processing to remove. Additionally, transmissometers require extensive efforts to calibrate. An ambient temperature nephelometer measures light scattering over a short closed path (internal to the instrument) and also inherently captures the effect of relative humidity provided the path is not

1 is no Federal Reference Method for PM light extinction based on one or both of these
2 instrumental approaches, but a reference method could be developed if needed or useful.⁶
3 Therefore, we plan to explore the appropriateness of an hourly averaging time, which on the
4 surface appears more compatible with the instantaneous nature of visibility impact. However,
5 the framework for the quantitative analysis will also allow consideration of 4-hour and longer
6 averaging periods.

7 **2.1.1 Policy Relevant Background PM Light Extinction**

8 There are several methods for characterizing PRB concentrations of PM within the
9 United States. As described in the ISA (US EPA, 2008b), some methods rely upon analyses of
10 measured PM concentrations at remote rural locations while other methods utilize air quality
11 chemical transport models (CTMs) to estimate PRB. In the last review, PRB for PM_{2.5} on a 24-
12 hour average basis was characterized by summarizing the non-sulfate portion of PM_{2.5} measured
13 at Interagency Monitoring of Protected Visual Environment (IMPROVE) sites in remote areas
14 between 1990 and 2002. Sulfate was omitted because it is attributable almost entirely to
15 anthropogenic emissions. It was noted that this method likely results in an underestimate of
16 PRB. In the last Staff Paper, the range of mid-day 4- to 8-hour average PM_{2.5} mass levels
17 described for consideration as a possible secondary PM_{2.5} standard were compared to percentile
18 points in the estimated distribution of 24-hour average PM_{2.5} PRB. Also, the previous Staff Paper
19 referenced estimates of annual average PRB for light extinction made by the National Acid
20 Precipitation Assessment Program in 1991 (NAPAP, 1991).

21 In this review, we plan to consider applying the CTM modeling being done to estimate
22 PRB for PM_{2.5} for health risk assessment purposes to the visibility risk assessment. The CTM-
23 based approach is based on a “zero-out” model simulation in which anthropogenic emissions
24 inside the U.S., Canada, and Mexico are set to zero while all biogenic emissions for these areas

heated or dehydrated. An aethalometer collects PM on a filter and continuously measures the resulting light absorption, for which humidity is not a factor in either the atmosphere or the instrument. The sum of the light scattering from a nephelometer and light absorption from an aethalometer is PM light extinction in inverse distance units

⁶ There is a conceptual distinction between using a transmissometer versus a nephelometer/aethalometer combination as the Reference Method for a secondary PM NAAQS. The former instrument’s measurement of light extinction would include a very small effect of light extinction due to gases, while the latter instrument would report only extinction effects due to PM.

1 and biogenic and anthropogenic emissions from elsewhere in the world are not altered. This
2 approach can provide more spatial and temporal resolution for estimating PRB compared to the
3 use of measurements given the sparse nature of remote measurement sites and the concern that
4 even remote sites are affected by non-local anthropogenic sources.

5 For this assessment, we are planning to rely upon a CTM-based approach which involves
6 coupling the global-scale circulation model GEOS-Chem (Fiore, et al, 2003) with the regional
7 scale air quality model CMAQ (Byum, et. al., 2006 and Byum, et. al, 1999). The GEOS-Chem
8 model is run on a global scale and is used to provide estimates of transported pollutant from
9 emissions of natural and anthropogenic sources outside the U.S., Canada, and Mexico. These
10 transported pollutant concentrations are used to provide the “boundary condition” concentrations
11 for two CMAQ simulations covering the continental US and adjacent portions of Canada and
12 Mexico (CONUS), one simulation with all emissions to evaluate model performance and one to
13 estimate PRB. In the CMAQ simulation to estimate PRB, only natural emissions in the U.S.,
14 Canada, and Mexico are considered. The details of this modeling approach, including the input
15 data sets and model chemistry are described in Chapter 3 of the ISA. The following is a brief
16 summary.

17 The two models were applied to simulate one year of air quality data for 2004. The base
18 case CMAQ run for 2004 includes meteorology and all the anthropogenic and natural sources
19 both within and outside of the U.S., Canada and Mexico. This run was performed to provide a
20 comparison of model predictions with measurements. The ISA characterizes the CMAQ
21 performance for the annual average concentrations and most of the seasonal averages of PM_{2.5} at
22 remote sites as “very good” in the East and Midwest. In the West, predictions at remote sites are
23 “generally too low in all seasons”. The ISA notes that degraded performance in the West is not
24 unexpected because the grid resolution in the CMAQ model simulation (36 km for this
25 application) will smooth out significant variations in terrain that influence measured
26 concentrations, particularly concentrations attributable to anthropogenic emissions which in the
27 West are often concentrated in basin settings where local meteorological conditions coupled with
28 local emissions of primary particles may dominate PM_{2.5} concentrations. However, looking
29 across the U.S., the model does correctly reproduce broad geospatial differences in that predicted

1 PM_{2.5} concentrations are lower at western locations than they are in the East consistent with
2 measured data. Also, natural emissions in the West are less concentrated in basin settings, and
3 western terrain may therefore have less effect on model performance when estimating PRB.

4 In addition to the “base case” run which includes all anthropogenic and biogenic
5 emissions, CMAQ was also run for a second scenario to estimate PRB, with the same boundary
6 conditions but with only natural emissions from within the U.S., Canada, and Mexico. The
7 hourly outputs from this second CMAQ run were used to calculate seasonal and annual average
8 estimates of PRB within seven regions of the U.S. These data are provided in Table 3-26 of the
9 ISA. For the purposes of the visibility risk assessment, it would be desirable to extract and
10 summarize the distribution of hourly PM_{2.5} mass and PM_{2.5} species concentration estimates from
11 the PRB CMAQ run, and to estimate PRB for light extinction from these concentration
12 estimates. An alternative and less time consuming approach would be to develop PRB levels of
13 hourly light extinction using other information sources, such as the PRB estimates for PM_{2.5}
14 mass and information about background levels developed in the previous review.

15 **2.1.2 Recent Conditions**

16 In assessing recent levels of PM-related visibility impairment in urban areas, we plan to
17 develop a set of hourly light extinction estimates for the years 2005 through 2007 for a set of
18 urban assessment locations. The planned approach is to start with 24-hour measurements of
19 PM_{2.5} mass, develop and apply diurnal profiles to estimate hourly mass concentrations, develop
20 and apply hourly speciation factors to estimate hourly concentration of each species affecting
21 visibility, and hourly relative humidity. These hourly data will be converted into hourly PM
22 light extinction levels, using an urban-optimized algorithm. The range of hourly and sub-daily
23 PM light extinction values is expected to vary considerably among urban areas, seasonally, and
24 regionally.

25 We also plan to assess whether and how to include PM_{10-2.5} data in the estimates of PM
26 light extinction. PM_{10-2.5} is only a significant contributor to PM light extinction when its
27 concentrations are comparable or greater than the PM_{2.5} concentration. For urban areas without
28 collocated PM_{2.5} and PM₁₀ monitoring, the PM_{2.5} crustal component determined using speciation
29 monitoring may be scaled up to estimate the PM_{10-2.5} concentration. Urban areas in the arid

1 regions of the southwestern U.S. are likely the only ones where $PM_{10-2.5}$ will be a significant
2 component of PM light extinction. While we have not yet selected the urban assessment
3 locations, where feasible, we plan to select from among the set of urban locations used for the
4 PM health risk assessment, to leverage the planning and analytical work addressing those areas.

5 These estimates of hourly PM light extinction over three years for a set of assessment
6 locations will help inform selection of an appropriate range of haze conditions to be used in
7 public perception focus group studies (see 3.0 below). The combination of these two areas of
8 quantitative analysis is intended to provide information regarding how often unacceptable
9 visibility conditions occur under current levels of PM urban air quality.

10 **2.1.3 “Just Meeting” the Current and Potential Alternative Secondary PM** 11 **NAAQS**

12 Some urban assessment locations will not meet the current or potential alternative
13 secondary PM NAAQS under recent air quality conditions. To assess urban visibility conditions
14 under a scenario of “just meeting” the current or potential alternative secondary PM NAAQS in
15 each study area individually, we will develop a method of adjusting hourly PM concentrations so
16 that in each area the highest concentration monitor just meets the more stringent of the annual
17 and 24-hour secondary NAAQS. That monitor will have a design value for the other averaging
18 period below the NAAQS, and other monitors will have design values for both averaging periods
19 that are less than the NAAQS. At this time we plan to use the corresponding adjustment
20 method(s) being employed in the PM health risk assessment work, wholly or in part. One
21 difference is that we plan to include hourly concentration results in our analyses for the
22 secondary NAAQS, while the health risk assessment work focuses on annual average and 24-
23 hour average concentrations. Thus, it may be necessary to assume that each hour in a day
24 experiences the same adjustment (possibly by species) as does the day as a whole.

25 The alternative secondary PM standards to be analyzed in this review have not been
26 selected, but we expect that one or more of them could be based on achieving a range of hourly
27 PM light extinction levels as may be informed by the available public preference information.
28 Several alternative standards based on different combinations of form and level will be studied,
29 and we expect that a standard which incorporates the urban optimized linear algorithm structure

1 will be among the alternative standard options considered, including one based on the three-year
2 average of the 98th percentile daily maximum 1-hour light extinction level. Other percentiles and
3 forms structured in other ways (e.g., an allowed number of exceedances per year) may be
4 considered also. Initially, we will assume a three-year evaluation period.

5 **2.2 DATA SOURCES, TYPES, AVAILABILITY, AND APPLICATION**

6 Table B-1 (in Appendix B) shows the types, availability, time period, and intended
7 applications of data that will be used to create a characterization of recent urban visibility
8 conditions. We do not anticipate using ASOS visibility monitoring data in this urban visibility
9 assessment.⁷ Because urban visibility has never been regulated using hourly PM data or light
10 extinction measures, there is no extensive state/local or EPA monitoring program which would
11 provide the most relevant data for a large number of monitoring sites of interest. We plan to use
12 only air quality data that are available in the Air Quality System, plus any well organized,
13 significant data sets that are in-hand by April 15, 2009. At the present time, we anticipate that
14 the Southeastern Aerosol Research and Characterization Study (SEARCH) monitoring program
15 will be a source of relevant data that will be used; some SEARCH data are available on the
16 internet, while more data on additional air quality parameters reportedly exist but would have to
17 be obtained via personal contact with the SEARCH researchers.

18 Some but not all PM_{2.5} monitoring stations have submitted hourly relative humidity data
19 to AQS. These data will be used where they are sufficiently complete on a site-year basis. If a
20 site-year of such data is not sufficiently complete, all estimates for the year will be drawn from
21 the National Weather Service (NWS) database. It will be necessary to identify the NWS site
22 most representative of each monitoring site in each assessment location.

23 While we intend to use continuous PM_{2.5} speciation data, nephelometer, aethalometer,
24 and transmissometer data contained in AQS, it should be noted that these data are not used in the
25 NAAQS regulatory program and so EPA does not provide guidance to monitoring agencies on
26 the operation of these types of monitors or on data validation procedures, nor does EPA

⁷The utility of airport visual range measurements that are made with open path instruments that include fog and precipitation is severely limited for characterizing current urban PM visibility conditions. In addition, most

1 systematically review or audit the operation of these types of monitors. Nevertheless, we believe
2 that using these data will provide Administrator with a more informative quantitative analysis
3 than would ignoring these data.

4 Another consideration is the selection of appropriate monitors to analyze for urban areas
5 with a variety of monitoring sites. For the purposes of an urban visibility assessment, data from
6 micro-scale and middle-scale sites (as recorded in AQS) will not be used, as these may not be
7 representative of air quality over the distance range relevant to visual air quality.

8 **2.3 DEVELOPMENT OF AN URBAN OPTIMIZED LINEAR** 9 **ALGORITHM**

10 The IMPROVE algorithm, an example of a linear algorithm, was developed and recently
11 refined to use IMPROVE network PM speciation data and climatological relative humidity data
12 to estimate PM light extinction in remote areas. This algorithm's principal use is to generate the
13 Regional Haze Rule metric so it was optimized for remote area sites typical of the visibility-
14 protected federal Class I areas. Thus, the algorithm's treatment of the contribution of organic
15 PM to light extinction is consistent with the aged aerosol that is expected for remote areas, but
16 may not be appropriate for the abundance of freshly produced organic aerosol associated with
17 urban areas. Coarse particle mass (i.e. $PM_{10-2.5}$) data are also used in the IMPROVE algorithm to
18 estimate the contribution of the coarse fraction to PM light extinction. Many urban monitoring
19 sites do not measure coarse mass, which if substantial, would need to be accounted for in some
20 way to reduce a possible bias in urban PM light extinction estimates.

21 An analysis of the IMPROVE algorithm's performance in predicting urban light
22 extinction will be conducted and changes made as necessary to create a new urban optimized
23 linear algorithm for use in this assessment with FRM/FEM $PM_{2.5}$ mass data and the Chemical
24 Speciation Trend network data that are available in many urban areas. It will also be evaluated
25 for use with high time resolution speciation and optical measurement to the extent possible for
26 the limited available datasets. Light extinction estimates from the resulting urban-optimized
27 linear algorithm will be used to generate estimates of daylight hourly PM light extinction.

available airport visual range data are collected and archived in coarse ranges of conditions (e.g. $VR \geq 10$ miles),
restricting its utility in quantitative analysis.

2.4 DEVELOPMENT OF RELATIONSHIPS BETWEEN PM LIGHT EXTINCTION AND PM_{2.5} MASS CONCENTRATIONS IN URBAN AREAS

The Staff Paper in the previous review of the PM NAAQS contained an analysis in which scatter plots and regressions were used to explore the relationship between historical 24-hour light extinction (calculated from 24-hour PM mass and species measurements and both actual and 10-year average 24-hour average relative humidity values, using the IMPROVE algorithm available at the time, and 24-hour PM_{2.5} mass. This analysis underscored the sensitivity of PM light extinction to PM species mix and humidity, and how a secondary PM standard using a 24-hour PM_{2.5} mass indicator would allow a wide range of 24-hour PM light extinction in complying areas. We do not plan to update this analysis for this review as it is not reasonable to expect an updated analysis of historical data to provide any new insights regarding 24-hour average light extinction given that mass concentrations of PM_{2.5} air pollution has not greatly changed since the last review. However, in the scenario of just meeting the current PM_{2.5} secondary standard, the composition of PM_{2.5} air quality may be substantially different than historical air quality. For example, sulfate and nitrate levels may be considerably lower. Such differences may change the conclusions reached in the last review, because with lower sulfate and nitrate present in the air, light extinction would be less sensitive to relative humidity. It will be possible to use the simulated hourly air quality and light extinction values from this scenario to feed an analysis similar to that in the previous Staff Paper, and we are considering whether such an analysis is warranted. However, we will not use 10-year average relative humidity data, which were used in a sensitivity study in the last Staff Paper. Use of such averages clearly would obscure actual variability in the relationship and make a standard based on a PM_{2.5} mass indicator appear to be capable of achieving a more uniform and constant level of protection for urban visibility than it actually would provide.

The previous Staff Paper also reported the results of an analysis of the correlation between 4-hour, mid-day average PM_{2.5} concentrations and 4-hour average PM light extinction, which showed that there was more correlation within the eastern and western U.S. regions than for the 24-hour case, and more similarity in the slope of the regression relationship between eastern and western regions. This analysis led staff to consider an indicator based on mid-day

1 PM_{2.5} mass suitable for a revised secondary standard. However, that analysis used the
2 assumption that the 24 hourly species profiles during the day were the same as the 24-hour
3 species profile for purposes of estimating PM light extinction averaged over several hours, an
4 assumption that tends to make the correlation between PM light extinction and PM_{2.5} mass
5 appear better than it might be. For the current analysis, we plan to re-examine this assumption.
6 If a different approach to hourly speciation is chosen, we will consider repeating this element of
7 the previous Staff Paper. We plan also to consider conducting the same analysis for the “just
8 meeting” current standards scenario, for the same reasons explained in the previous paragraph,
9 even if the same approach is taken to hourly speciation.

10 If either of the above two types of analysis is undertaken, relationships between both
11 same-period and maximum daylight hourly light extinction levels and 24-hour and/or mid-day
12 PM_{2.5} concentrations would be assessed by season and individual urban area. This will include
13 generation of scatter plots of PM light extinction versus PM_{2.5} concentration. Particulate matter
14 light extinction budgets (i.e., the fraction of light extinction by each of the major species) will be
15 estimated using the urban optimized linear algorithm for estimating light extinction from PM
16 species.

17 **2.5 UNCERTAINTY AND VARIABILITY**

18 Uncertainty associated with the use of the urban optimized linear algorithm relating PM
19 and relative humidity to light extinction will be characterized as part of the revision process.
20 Uncertainty associated with the use of available data and the techniques and assumption that
21 may be employed to generate the required information used in this assessment will also be
22 described. Specific methods to characterize or document the magnitude of any bias and
23 uncertainty associated with these assessments have not yet been developed, but we will do so as
24 an integral part of the assessment.

3 QUANTITATIVE VISUAL AIR QUALITY IMPACT ASSESSMENT

3.1 OVERVIEW AND PURPOSE

As was described in Chapter 1 above, a lack of information regarding public preferences for urban visual air quality was considered one of the key limitations cited by the Administrator (71 FR 2681, January 17, 2006) in the proposal notice regarding the establishment of a separate, sub-daily secondary PM NAAQS to protect urban visibility. Specifically, “the Administrator took into account the results of the public perception and attitude surveys in the U.S. and Canada, State and local visibility standards within the U.S., and visual inspection of photographic representations of several urban areas across the U.S. summarized in section IV.A.1 of the proposal. In the Administrator’s judgment, these sources provide useful but still quite limited information on the range of levels appropriate for consideration in setting a national visibility standard primarily for urban areas, given the generally subjective nature of the public welfare effect involved...” and “...attitudes with regard to the acceptability of various degrees of visibility impairment in urban areas across the country.” (71 FR 61206/8). Similarly, some CASAC Panel members “...recognized that developing a more specific (and more protective) level in future reviews would require updated and refined public visibility valuation studies, which CASAC strongly encouraged the Agency to support prior to the next review.” (71 FR 61207, October 17, 2006).

The primary objective of this assessment, therefore, is to develop information beyond what was available in the last review to help inform judgments by the Administrator regarding establishment of a secondary PM NAAQS that would provide the requisite degree of public welfare protection from adverse levels of PM-related urban visibility impairment. This chapter describes a series of activities (see Figure 2.1 above), some of which have already occurred, are underway, or are planned for this review, while others fall outside the resource and time constraints of this current review. Nonetheless, each activity completed in this review is expected to contribute to and help lay the groundwork for the development of subsequent steps, in particular, public perception/valuation survey designs or methods that could be employed in future studies or NAAQS reviews.

3.2 METHODS, APPROACHES, AND TOOLS

On October 6-8, 2008 the EPA sponsored an urban visibility workshop in Denver, Colorado to identify and discuss methods and materials that could be used in “next step” projects to develop additional information about people’s preferences for reducing existing impairment of urban visibility, and about the value of improving urban visibility. Invited individuals came from a broad array of relevant technical and policy backgrounds, including visual air quality (VAQ) science, sociology, psychology, survey research methods, economics, and EPA’s process of setting NAAQS. The 23 people who attended the workshop (including one via teleconference line) came from EPA, the National Oceanic and Atmospheric Administration (NOAA), NPS⁸ academia, regional and state air pollution planning agencies, and consulting firms. For a complete summary of the workshop, see the Workshop Summary Report in Appendix C.

Participants at the workshop identified three different study approaches/methods that could be employed to gather relevant information. These include 1) investigative focus groups; 2) group interviews; and 3) individual interviews. Each type of study requires different degrees of sophistication and statistical rigor. Investigative focus groups (IFG) are often used as the first stage of survey development and are intended to explore what people are thinking and understanding about the topics they are being asked about -- these are very interactive sessions, with a greater focus on understanding what people are thinking than on the answers they provide. Focus groups can use participants from either convenience groups (e.g., students, civic clubs, church groups) or individuals selected from the general population (known as a random recruitment process). Group interviews (GI), on the other hand, are used to test a survey instrument. Background material may be shown to the group without a group discussion. Individual responses to survey questions are then collected with relatively little feedback or discussion. The moderator may answer questions to clarify what is meant by a question, or the directions on how to complete the survey. After the survey instrument questions are answered, an interactive session can be held to help improve the survey instrument. The final study type is the

⁸NPS is currently conducting a study designed to estimate the benefits of visibility improvement in national parks and wilderness areas that are expected as a result of the Regional Haze Rule. While the results of this work are not expected to be directly applicable to the issue of urban visibility preference/valuation, the experience of their team in conducting this similar study was deemed an important source of information to include in the urban workshop.

1 individual interview (II), or survey. This final survey component is used to determine
2 respondents' preferences and/or valuation responses. Individual interviews can be held in group
3 sessions for efficiency (such as to show slides to a large group of people simultaneously), but the
4 responses are collected from each individual. In person interviews, or surveys completed at
5 home, can also be used as an individual interview. The design of a survey project must consider
6 both the reliability and validity of the responses. Workshop participants identified 13 issues that
7 they felt could usefully be subjects for further investigation (see pages 15/16 of the Workshop
8 Summary Report,
9 http://vista.cira.colostate.edu/improve/Publications/GrayLit/gray_literature.htm)

10

11 **3.2.1 Planned Assessments**

12 Based on this revised issue list, we are developing plans to conduct an IFG study to
13 address the first two topics regarding the improvement of communication with study participants
14 through a) selection of appropriate word choices in order to clearly communicate concepts of
15 preferences (e.g., acceptable, unacceptable, adverse), and b) determination of the appropriate
16 amount, type, depth/detail and wording of introductory materials. This IFG study would be
17 conducted in one location but include several iterations in order to allow responses from one
18 session to inform/refine the wording and introductory materials used in subsequent sessions.

19 Another key issue discussed at the workshop was the uncertainty regarding a concern that
20 current urban visibility preference information may not be representative of urban preferences
21 nationwide, since to date, all of the public preference studies have been conducted in western
22 areas using scenes that featured distant mountain backdrops. This was clearly seen as a critical
23 uncertainty in the information available in the last review. Therefore, the second phase of this
24 assessment includes a plan to conduct a GI study to address whether concern for PM-related
25 urban visibility impairment varies by region or is a consistent value nationwide. We plan to
26 conduct GIs in at least three non-western urban areas which do not have distant mountain
27 backdrops, and one GI in a western city (e.g., Denver, CO or Phoenix, AZ), that was the site of
28 an earlier urban visibility survey, for comparison.

1 **Scene Selection**

2 Selection of appropriate scenes for use in urban visibility studies is an important step in
3 study design, as not all scenes are equally sensitive to changes in haze levels. In general, long-
4 distance views are more sensitive to changes in perceived haze level as a function of changed
5 light extinction compared to those with short-distance views. In order to be comparable to the
6 western studies which used scenes where distant mountains were the backdrop of the scenic
7 photographs, it will be important to try to select other urban scenes that have a long sight path.
8 Since most urban areas in other regions of the country do not have distant mountains as a
9 backdrop for urban scenes, alternative views such as from the edge of some urban areas of the
10 skyline may be of sufficient distance to constitute sensitive scenes. In situations where there are
11 no distant scenic elements, the color of the sky near the horizon or the presence of white clouds
12 may be among the most sensitive indicators of visibility impacts. Workshop participants
13 considered the use of clouds in a blue sky as a distant scenic element a topic for an IFG. We
14 have decided to review a series of WinHaze photos currently being developed with
15 skycolor/cloud conditions to determine in-house whether these scenes appear similarly sensitive
16 to previously developed western scenes. If we determine that they are sufficiently sensitive, they
17 will be used in the study design. All scenes for use in assessment studies will be carefully
18 selected to have sensitive scenic elements.

19 Another topic identified as usefully investigated with a focus group study is whether a
20 single set of generic scenes could be successfully used in cities across the U.S. We have
21 decided to show at least two types of scenes in each urban area that is used for a study. One
22 view will be an “iconic” scene (i.e. one that is recognizable to area residents and having
23 acknowledged intrinsic value), while the other scene will be a “generic” scene selected because it
24 is a familiar type of urban scene with no obvious clues that would indicate the urban area or
25 region it was from (e.g. an urban park). The exact same generic scene would be used in all
26 study locations. The purpose in having the iconic scene is to identify acceptable visibility levels
27 for a valuable view in each urban area, while the purpose of the generic scene is to present
28 viewers in each of the study locations with the identical combination of scene and haze
29 characteristics to test for the consistency of public response across differing regions in
30 determining acceptable urban visibility levels. The degree of consistency of the preference level

1 in response to the generic urban scene versus the responses to iconic city views may shed some
2 light as to the importance of haze protection by type of scene shown and regional differences in
3 expectations and preferences.

4 **Assessment Scenarios**

5 Study participants would be shown iconic and generic scenic photos having a range of
6 light extinction level conditions superimposed on them using WinHaze technology designed for
7 this purpose. The upper end of the light extinction range could be selected to correspond to the
8 typical daytime maximum hourly light extinction value under the current PM_{2.5} secondary
9 NAAQS level (i.e. 35µg/m³) for typical urban PM compositions and high relative humidity
10 conditions (e.g. RH=90%), and the lower end of the range could correspond to daytime
11 maximum hourly light extinction conditions for days with mean regional natural background
12 light extinction levels due to naturally occurring levels and composition of PM under low
13 relative humidity (RH<50%) conditions.

14 Recognizing that urban haze conditions vary over time to form a distribution of
15 conditions, studies would be designed to elicit information on the haze level thought to be
16 unacceptable if it occurs more often than some number of days per year. For example, the
17 current daily PM_{2.5} NAAQS control level (i.e. 35µg/m³) applies to the 98 percentile, so it can be
18 exceeded up to 7 days out of 365 days in a year without violating the standard. Studies could be
19 designed to specify a range of both the frequency and level of daily maximum light extinction
20 that could be acceptable in urban areas. Alternately, for consistency, the frequency could be set
21 to the same as the current daily PM_{2.5} NAAQS and the survey used to assess the maximum daily
22 haze level that should not be exceeded 98% of the time. It is expected that a standard number of
23 scenes depicting roughly equally spaced haze conditions through the full range would be
24 generated for use in the studies.

25 **Visual Display Methods**

26 There are a number of methods available for presenting images to study participants.
27 These were discussed at length at the workshop. The traditional approach would be to use a
28 standard number of photos/images depicting roughly equally spaced haze levels through the full
29 range of conditions. An alternate approach that was suggested in the workshop was to provide

1 participants with high quality computer monitors equipped with a “dial in” capability where
2 participants could adjust haze levels in a continuous manner through the full range of conditions
3 to select desired and undesirable ranges. It is not clear at this time whether such an approach
4 would be advantageous or feasible. We plan to explore this in house prior to finalizing study
5 design.

6 **Valuation Studies**

7 A final group of topics identified by workshop participants were related to using
8 investigative focus groups to assess various approaches (e.g., willingness to pay, conjoint
9 analysis) available to determine how the public values improvements in urban visual air quality.
10 While we recognize the usefulness and desirability of such information, adding studies to address
11 these topics/issues will greatly increase study design complexity and require additional time and
12 resources that may not be available in this review.

13 **3.3 CHARACTERIZATION OF UNCERTAINTY/PLANNED** 14 **SENSITIVITY ANALYSIS**

15 The factors that contribute to uncertainty of the results from geographic focus groups
16 include those related to the design of the focus groups and those that are inherent to differences
17 among the participants. Variations in participants’ ability to perceive visual haze differences are
18 expected to be relatively small since participants will be screened for normal corrected vision
19 and exclude colorblind individuals. However, participants’ judgments of the unacceptable level
20 of haze will likely vary more than their perceptual capabilities. Inclusion of sufficient numbers
21 of participants that are representative of the general population should provide mean responses
22 that represent the public. Focus groups would include features to test for participant consistency
23 of results as a way to detect such problems.

24 Study responses will be assessed separately for each scene and urban areas and by
25 participant subgroups (e.g., age, education, etc.) to determine the sensitivity of urban haze levels
26 judged to be unacceptable by such groupings. The use of different iconic scenes to show various
27 haze levels to the participants of the four urban areas selected for survey studies may result in
28 different mean responses across the different urban study sites. Despite efforts to use scenes
29 selected to be similarly sensitive to perceived haze changes associated with various changed light

1 extinction levels, the scenes are unlikely to be identically sensitive. Also these iconic scenes
2 may have different intrinsic value to the residents of each of the urban areas. These concerns
3 would not be an issue for responses to the same generic scenes used for all studies. Results from
4 the generic scenes should help in the interpretation of the reasons for difference in response to
5 the iconic scenes among the four urban study sites. If significantly different responses are
6 obtained among the different urban areas to the generic scenes, they would likely be attributed to
7 regional differences in the public's valuation of haze levels.

8 **3.4 BROADER CHARACTERIZATIONS**

9 Haze levels judged to be unacceptable on the basis of study responses will be used to more
10 broadly characterize a range of unacceptable haze levels for urban areas across the country. This
11 assessment would estimate the frequency, seasonality and regional patterns of urban haze levels
12 that could reasonably be judged to be unacceptable, as well as help identify the PM species and
13 humidity levels that are principally responsible for various candidate unacceptable haze levels.
14 The sensitivity of these results to reasonable variations of levels judged to be unacceptable would
15 also be tested.
16

4 SCHEDULE AND MILESTONES

1
2 Table 4-1 lists the key milestones for the Urban Visibility Impact Assessment (UVA) that
3 is planned as part of the current PM NAAQS review. Consultation with the CASAC PM Panel is
4 scheduled for April 1-2, 2009 to obtain review of the first draft Integrated Science Assessment
5 (ISA) and to obtain input on the plans to conduct quantitative assessments. EPA staff will then
6 proceed to develop quantitative assessments of urban visibility conditions and preferences
7 associated with recent PM ambient concentrations and levels representing just meeting the
8 current PM standards. This information will be presented in the first draft PM UVA. CASAC
9 and public comments on this plan will be taken into consideration in the development of the first
10 draft UVA, the preparation of which will coincide and draw from the second draft ISA. The first
11 draft report is scheduled to be released for CASAC and public review in August 2009. EPA will
12 receive comments on this draft document from the CASAC and the general public at a meeting
13 planned for September 2009. The second draft UVA will draw on the final ISA and will reflect
14 consideration of CASAC and public comments on the first draft UVA. The second draft UVA
15 will include assessments for just meeting potential alternative standards. We plan to release the
16 second draft UVA in March 2010 for review by CASAC and the general public at a meeting that
17 is planned for April 2010. Staff will consider these review comments and prepare a final UVA,
18 currently planned to be completed in July 2010. The final UVA will reflect consideration of
19 CASAC and public comments on the second draft UVA. The final ISA and final REA will
20 inform the policy assessment and rulemaking steps that will lead to a final decision of the PM
21 NAAQS. Our current schedule includes plans for issuing a proposed rule in January 2011 and a
22 final rule in October 2011.

1

2 **Table 4-1 Key Milestones for the Urban Visibility Impact Assessment (UVA) for the PM**
3 **NAAQS Review**

4

Milestone	Date
Release first draft PM ISA	December 2008
Release draft PM UVA Scope and Methods Plans	February 2009
CASAC/public review and meeting on first draft PM ISA	April 1-2, 2009
CASAC consultation on draft PM UVA Scope and Methods Plans	April 2, 2009
Release second draft PM ISA	July 2009
Release first draft of the PM UVA	August 2009
CASAC/public review and meeting on second draft PM ISA and first draft UVA	September 2009
Final PM ISA	December 2009
Release second draft of the PM UVA	March 2010
CASAC/public review and meeting on second draft of the PM UVA	April 2010
Final PM UVA	July 2010

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APPENDICES

1 **APPENDIX A : QUALITATIVE ASSESSMENT OF**
2 **OTHER WELFARE EFFECTS**

3 In addition to the well known PM-related effects on visual air quality, other
4 welfare effects are associated with ambient PM. These effects include those associated
5 with deposited particles (e.g., impacts on ecosystems and man-made materials), and those
6 that result from particles that remain suspended in the air (e.g., direct and indirect climate
7 effects). Each of these other welfare effects will be discussed in turn below. As with
8 many PM-related effects, the chemical constituents that make up PM largely determine
9 the nature, degree, and direction of the effects. As a result, the PM_{2.5} and PM₁₀ size
10 classes used for human health risk assessment do not necessarily correlate well to other
11 PM welfare effects due to the fact that PM chemistry is often the driving factor, not
12 particle size, through in some cases these two characteristics occur together. With the
13 exception of materials damage, these discussions exclude those effects associated with
14 the deposition of particulate sulfates and nitrates, as those effects are being
15 discussed/assessed under the ongoing NO_x/SO_x secondary NAAQS review.

16 **ECOLOGICAL EFFECTS OF PARTICULATE ORGANICS AND**
17 **HEAVY METAL DEPOSITION**

18 Assessment of environmental risk associated with deposited PM is dependent
19 upon 1) elucidation of pathways of exposure, 2) characterization of ecologically
20 important PM components, and 3) identification of ecological receptors that are
21 susceptible to various components in particulate pollution.

22 Pathways of PM exposure for ecological receptors can include direct deposition to
23 the receptor surface via wet, dry or occult deposition, or transfer from one environmental
24 compartment or organism to another. Depending on the size of the particles and other
25 environmental conditions, deposited PM may have come from local sources or have been
26 transported long distances.

27 The components that make up a given mass concentration of PM can vary
28 significantly both temporally and spatially. This heterogeneous nature of PM has

1 confounded efforts to evaluate PM-related effects on ecosystem function at the
2 ecosystem, regional, watershed, or national scale. However, second only to the
3 widespread impacts of deposited particulate nitrates and sulfates, particulate heavy metal
4 deposition has also consistently been implicated as toxic to (adversely impacting) a
5 number of ecological receptors on more local scales.

6 Ecological receptors that have been shown to be sensitive to heavy metal
7 deposition include vegetation, soil microfauna, aquatic biota and terrestrial organisms.
8 With respect to vegetation, Chapter 9 of the ISA details effects of heavy metal
9 contamination on forests. This is not surprising, since forest ecosystems are a significant
10 ecological receptor for PM contaminants. PM dry deposition to leaf surfaces and the
11 inner canopy is well documented. Impacts include growth suppression, toxicity to root
12 colonizing microorganisms, impairment of root development and induction of the
13 phytochelatin intracellular metal-binding peptides. The EPA (2004) demonstrated
14 elevated phytochelatin levels in red spruce stands with high numbers of dead trees and
15 that metal stress increased at higher elevations. Quantitative assessment of PM damage to
16 forests potentially could be conducted by overlaying PM sampling data and elevated
17 phytochelatin levels. However, limited data on phytochelatin levels in other species
18 currently hinders use of this peptide as a biomarker for PM. It may be possible to apply
19 environmental modeling techniques to new data on PM concentrations and tree responses
20 associated with elevational changes to better understand how PM toxicity impacts
21 ecosystem functioning; however, there is currently not sufficient data available for such
22 an analysis.

23 PM may be deposited directly on the leaf surface and be taken up by the plant or
24 inhibit photosynthesis. Vegetation can also be indirectly impacted by soil-chemistry
25 changes due to PM deposition or alterations in the amount of solar radiation reaching the
26 leaf surface. Increased pollutant levels have led to a decrease in plant diversity at the
27 ecosystem level. Plants vary in sensitivity to PM and susceptible species can be
28 monitored for adverse effects associated with exposure. Lichen and mosses have been
29 deployed as biomonitors for heavy metal deposition with limited success; however, there
30 is insufficient data to evaluate their use as bioindicators. A limitation to incorporating

1 plant data into a qualitative analysis of particulate damage is that toxic effects of some
2 components of PM on plants are not well characterized and it is difficult to isolate these
3 endpoints from other environmental stressors.

4 With respect to PM effects on soil and soil-associated microfauna, more
5 information has become available since the last review. Heavy metals such as Zinc (Zn),
6 Copper (Cu) and Cadmium (Cd) and some pesticides have been shown to be toxic to soil
7 fungi and bacteria. This topic is covered in greater detail in Chapter 9 of the ISA.
8 Toxicity of deposited particulate matter to soil biota may also have broader implications
9 at the ecosystem level. Many plant species are dependent upon bacteria and fungal
10 associations to obtain nutrients from the rhizosphere. Nutrient and organic matter cycling
11 and carbon utilization may be adversely impacted by shifts in soil microflora populations.
12 Due to the site-specific composition of PM and the ability of soil-associated biota to
13 undergo population shifts in response to ecological stressors and the lack of data, it is not
14 possible to quantify this effect at this time. Long-term atmospheric deposition studies
15 from ice, snow, peat, and lake sediment samples present temporal data on changes in PM
16 that may be applicable to future analyses.

17 Fauna may also be an ecological receptor for PM components (e.g., heavy metals,
18 PM-associated organics). Chapter 9 of the ISA details limited new data on effects of PM
19 on terrestrial invertebrates, amphibians, birds and mammals. Pathways of PM exposure
20 to fauna include ingestion, absorption, and tropic transfer. PM may also be transferred
21 between aquatic to terrestrial compartments. There is limited evidence for
22 biomagnification of heavy metals up the food chain except for mercury (Hg) which
23 moves readily through environmental compartments. Quantitative assessment of
24 particulate metal toxicity to biota is limited due to the heterogeneous composition of PM,
25 lack of data on the bioavailability of PM components, and uncertainties in cumulative
26 exposure effects. Many of the particulate pollutants demonstrated to have effects on
27 biota are already regulated under the air toxics program.

28 Adverse effects of particulate matter on ecosystem components including
29 vegetation, soil microfauna, aquatic biota and terrestrial organisms have been

1 demonstrated from point-sources such as coal-fired power plants, quarries, cement, and
2 metal smelting operations. Typically, concentrations of metals and organics associated
3 with particulate matter are highest in proximity to the source and decrease with
4 increasing distance from the operation. Chapter 9 of the PM ISA summarizes the effects
5 of PM originating from point sources on receiving ecosystems. Concentrations of heavy
6 metals and organics associated with point-sources are generally much higher than levels
7 measured away from the site limiting the applicability of point-source data to a national
8 assessment of ambient PM effects.

9 Non-point sources of PM such as urban areas are significant contributors to
10 particulate loading in the environment. Emissions are generally highest in urban settings
11 where vehicular traffic, industrial processes and home heating contribute PM to the
12 atmosphere. Urban runoff from rooftops, paved areas and buildings may result in
13 transfer of particulate components to different ecological compartments (soil, water,
14 vegetation, or atmosphere). Chapter 9 of the ISA presents evidence for higher PM
15 concentrations in urban areas. Data on the individual components of PM is currently
16 only available for a few urban areas.

17 Roadway and near-roadway deposition of PM represent chronic non-point sources
18 of heavy metal pollution. Elevated levels of Cd, calcium (Ca), Cu, lead (Pb) and Zn in
19 soils near roadways are attributed to tire wear, road paint and vehicle exhaust. Seasonal
20 differences in PM composition near roadways may be attributed to winter tire use and
21 deicing chemicals. Pollutant concentrations decrease with increased distance from
22 roadways, however, transfer of near roadway PM to other environmental compartments is
23 possible via runoff, plant uptake or tropic transfer. More data on seasonal composition of
24 near roadway PM and tropic transfer of toxic compounds to organisms such as deer,
25 vultures, groundhogs and raccoons that forage on roadsides are needed to quantitatively
26 assess impacts of PM to ecological receptors.

27 In summary, characterization of PM effects on ecosystem functioning are
28 confounded by the complex composition of particulate pollutants and the geographic
29 heterogeneity of deposition. The potential for ecosystem shifts due to deposition and

1 subsequent movement of PM through pathways of exposure in the environment exists but
2 there is currently insufficient data to quantify the contribution of PM. It is also not
3 possible at this time to quantify ecosystem goods and services that are provided with
4 reductions in PM levels in the atmosphere. Europe and other countries are using the
5 critical load approach to assess pollutant effects at the level of the ecosystem. This type
6 of assessment requires site-specific data and information on individual species responses
7 to PM. The United States currently applies an exposure-based approach to set secondary
8 standards, however, there are efforts underway to use critical load calculations as way to
9 assess ecological risk.

10 **MATERIALS**

11 The effects associated with deposition of atmospheric pollution, including
12 ambient PM, to material surfaces are related to both physical damage and impaired
13 aesthetic qualities. Because the effects of PM are exacerbated by the presence of acidic
14 gases and can be additive or synergistic due to the complex mixture of pollutants in the
15 air and surface characteristics of the material, this discussion will also include those
16 particles and gases that are associated with the presence of ambient NO_x and SO_x, as
17 well as NH₃ and NH_x for completeness. More detailed discussion of these effects on
18 materials can be found in Chapter 9 of the PM ISA and in Chapter 9 of the Annexes to
19 the NO_x/SO_x secondary ISA.

20 **Materials Damage Effects**

21 Materials damage effects associated with deposited particulate matter (especially
22 sulfates and nitrates) include the corrosion of metals, degradation of painted surfaces,
23 deterioration of building materials such as limestone, concrete and marble and weakening
24 of paper, plastics, elastomers and electronic components. Particles contribute to this
25 damage by adding to the effects of natural weathering processes, and because of their
26 electrolytic, hygroscopic and acidic properties, and their ability to sorb corrosive gases
27 (principally SO₂). Deposited pollutants that damage materials may undergo chemical
28 transformations and are commonly oxidized to acids. Oxides of nitrogen damage textiles,
29 electronics and dyes. Deposition of SO₂ to stone results in a chemical reaction with
30 calcium carbonate to form gypsum. Both wet and dry deposition contributes to

1 particulate accumulation and subsequent damage to surfaces. However, the presence of
2 moisture accelerates some materials damage such as corrosion of metals. In general, SO₂
3 is more corrosive than NO_x although mixtures of NO_x , SO₂ and other particulate matter
4 corrode some metals at a faster rate than either pollutant alone. There are significant costs
5 associated with remediation of materials, however, in the most recent ISA there is not
6 sufficient new evidence to conduct a quantitative assessment of damage attributed to PM.

7 **Soiling Effects**

8 PM deposition onto surfaces such as paint, metal, glass and stone can lead to
9 soiling. Soiling results when PM accumulates on an object and alters the optical
10 characteristics (appearance). The reflectivity of a surface may be changed or presence of
11 particulates may alter light transmission. These effects can impact the aesthetic value of
12 a structure or result in reversible or irreversible damage to statues, artwork and
13 architecturally or culturally significant buildings. Formation of black crusts due to
14 carbonaceous compounds and buildup of microbial biofilms results in discoloration of
15 surfaces. Limited new data suggest an increased role for microbial colonizers in
16 contributing to the soiling of buildings. Presence of air pollutants may synergistically
17 enhance microbial biodeterioration processes. Due to soiling of building surfaces by PM,
18 the frequency and duration of cleaning may be increased. There is not sufficient new
19 evidence to conduct a quantitative assessment of materials damage due to soiling.

20 **CLIMATE**

21 Since the last review, new information is available on the role and interactions of
22 atmospheric PM in climate processes. The Intergovernmental Panel on Climate Change
23 (IPCC) published a series of reports in 2007, including information on the effects of PM
24 on climate. The US Climate Change Science Program (CCSP) published a series of
25 reports in 2008 and 2009 some of which address, in part, the effects of PM on climate,
26 including “Atmospheric Aerosol Properties and Climate Impacts” completed in January
27 2009. There is a considerable ongoing research effort focused on understanding aerosol
28 contributions to fluctuations in global mean temperature and precipitation patterns.

1 Components of PM are known to have both direct and indirect effects on climate.
2 Aerosols affect the Earth's energy budget by scattering and absorbing radiation (direct
3 effect) and by modifying the cloud amount, lifetime, and microphysical and radiative
4 properties (indirect effects). For example, the presence of SO_4^{2-} and organic carbon
5 particles decrease warming from sunlight by scattering shortwave radiation back into
6 space. Moreover, the direct absorption of radiant energy by PM leads to heating of the
7 troposphere and cooling of the surface, which can change the relative humidity and
8 atmospheric stability thereby influencing the clouds and precipitation (semi-direct effect).
9 The addition of manmade aerosols to the atmosphere may change the radiative fluxes at
10 the top-of-atmosphere (TOA), at the surface, and within the atmospheric column. Such a
11 perturbation of radiative fluxes by anthropogenic aerosols is designated as aerosol
12 climate forcing, which is distinguished from the aerosol radiative effect of the total
13 aerosol (natural plus anthropogenic). The aerosol climate forcing and radiative effect are
14 characterized by large spatial and temporal heterogeneities due to the wide variety of
15 aerosol sources, the spatial non-uniformity and intermittency of these sources, the short
16 atmospheric lifetime of aerosols (relative to that of the gases), and processing (chemical
17 and microphysical) that occurs in the atmosphere.

18 Improvements in atmospheric measurement and modeling of PM components
19 since the last review have enabled a more detailed understanding of the solar direct
20 radiative effects (DRE) of aerosols. Networks of monitoring instruments including
21 satellite systems, surface-based remote sensing sun-photometers and aerosol-lidar
22 systems are facilitating more advanced analysis of climate parameters. New atmospheric
23 models and improved algorithms reflect the dynamic nature of particulate interactions
24 and have further refined the role of PM components in global climate change. Global
25 estimates of aerosol direct radiative forcing (RF) were recently summarized using a
26 combined model-based estimate (Foster et al. 2007). The overall, model-derived aerosol
27 direct RF was estimated as -0.4 watts per square meter (W/m^2), indicating a net cooling
28 effect in contrast to greenhouse gases which have a warming effect.. Information
29 provided by new instrumentation and modeling has further characterized the complex
30 role of PM in climate processes, however, the uncertainties are still too large to inform
31 policy-making on the adequacy of a secondary PM standard. As described in CCSP SAP

1 2.3, the influence of aerosols on climate is not yet adequately taken into account in our
2 computer predictions of climate and an improved representation of aerosols in climate
3 models is essential to more accurately predict the climate changes.

4 Since the last review, more information is available on indirect effects of PM on
5 cloud formation and feedback but the interaction of PM with clouds remains the largest
6 source of uncertainty in climate estimates. Particulates in the atmosphere indirectly
7 affect both cloud albedo and cloud lifetime. Aerosols act as cloud condensation nuclei
8 (CCN). Increased particulates in the atmosphere available as CCN with no change in
9 moisture content of the clouds have resulted in a decrease in the radii and number of
10 cloud droplets in certain clouds. When the size and number of droplets decreases, the
11 albedo of the cloud subsequently increases. Smaller particles slow the onset of
12 precipitation and prolong cloud lifetime. This effect, coupled with changes in cloud
13 albedo, increase the reflection of solar radiation back into space. The interactions of
14 aerosols and linkages between clouds and the overall climate system are complex and
15 limit the feasibility of conducting a quantitative analysis.

16 The previous OAQPS Staff Paper concluded that available data on PM effects on
17 climate were global and regional in scale and not applicable to quantifying effects at a
18 local level. Since the last review, more data is available on local and regional effects of
19 PM (for example, CCSP SAP 3.2) although the focus continues to be on global-scale
20 processes. It has been previously established that PM can alter precipitation patterns. A
21 series of new studies detailed in the ISA have added to existing evidence that rainfall
22 suppression can occur in local areas where atmospheric aerosol levels are elevated.
23 Increased particulate matter in the atmosphere decrease wind speeds, which, in turn
24 decrease evaporation rates and subsequent precipitation events. Due to insufficient data
25 for many regions of the U.S., local and regional microclimate variations and
26 heterogeneity of cloud formations it is not currently feasible to conduct a quantitative
27 analysis for the purpose of informing revisions to the PM standard in this review.

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**APPENDIX B : TABLE B.1 DATA TYPES,
AVAILABILITY, TIME PERIOD, AND INTENDED
APPLICATIONS**

1 **Table B.2 Availability of Ambient PM and Light Extinction Related Data for the Assessment.**

Measurement Type	Availability	Time Periods	Intended Application
24-hour PM _{2.5} mass by FRM/FEM, local conditions, in units of ug/m ³ AQS parameter 88101	<p>Potential assessment locations typically will have several sites, with sampling schedules that may be 1:1, 1:3, or 1:6.</p> <p>Data from micro-scale and middle-scale sites (as recorded in AQS) will not be used, as these may not be representative of air quality over the distance range relevant to visual air quality.</p>	2005-2007	These data will be the common base from which estimates of hourly speciated PM _{2.5} concentrations will be developed by application of temporal and speciation profiles
24-hour PM _{2.5} speciation data from the urban Chemical Speciation Network	Potential assessment locations typically will have one or two sites, with sampling schedules that may be 1:3 or 1:6. Some but not all PM _{2.5} mass samplers will have collocated speciation samplers.	2005-2007	These data will be used to speciate the 24-hour PM _{2.5} mass concentrations. Available speciation data will be spatially interpolated to the location of the FRM/FEM monitors when not collocated.
24-hour PM ₁₀ by FRM/FEM, standard temperature and pressure (STP) conditions AQS parameter 81102	<p>Potential assessment locations typically will have one or two sites, with sampling schedules that may be 1:3 or 1:6. Some but not all PM_{2.5} mass samplers will have collocated speciation samplers.</p> <p>Data from micro-scale and middle-scale sites (as recorded in AQS) will not be used, as these may not be representative of air quality over the distance range relevant to visual air quality.</p>	2005-2007	The IMPROVE algorithm for estimating light extinction includes a term for PM _{10-2.5} . There are very few PM _{10-2.5} monitoring sites that use the recently established FRM for PM _{10-2.5} . EPA staff has not yet developed a plan for whether and how to use these PM ₁₀ data in the algorithm. Difficulties include likely cases of non-collocation and mis-matches of sampling schedules, and the errors than can occur when subtracting PM _{2.5} concentrations obtain by low-volume samplers from PM ₁₀ concentrations obtain from high-volume samplers. Also, PM ₁₀ data are submitted based on STP conditions, and in principle should be adjusted to local conditions before PM _{10-2.5} is calculated by subtraction.
<p>Continuous (hourly) PM_{2.5} mass, by non-FRM/FEM methods considered to acceptable quality for AQI reporting</p> <p>AQS parameter 88502 Any method code allowed by AQS</p>	Only assessment locations with at least one site with this type of data will be considered.	2005-2007	These data will be used to develop estimates of hourly PM _{2.5} FRM/FEM mass, via diurnal profiles. Profiles will be expressed as the ratio between concentration in one hour and the 24-hour concentration, with the mean of the 24 1-hour ratios constrained to be 1.0. Some PM _{2.5} FRM/FEM monitors will have collocated continuous monitors. Others will have to have profiles

Measurement Type	Availability	Time Periods	Intended Application
for use with this parameter code			from other site(s) in the same study area applied.
Continuous (hourly) PM2.5 mass, by recently approved FEM methods AQS parameter 88101	Limited sites are operational	2008	No data is available for 2005-2007, since that was before approval of these FEMs. EPA may consider the 2008 data if it is collocated with light extinction measurements, to help assess the quality of light extinction estimates made from PM2.5 mass and species concentrations, if earlier year collocated data needs to be supplemented.
Continuous (hourly) PM10 mass by FEM methods AQS parameter code 81102 Method codes: 076, 079, 081, 122, 150, 151, 156	A large number of CBSAs and CSA have at least one of these monitors.	2005-2007	EPA staff has not yet developed a plan for whether and how to use these PM10 data. EPA will consider making the presence of one of these monitors a condition of being selected as an assessment location, if hourly PM10-2.5 is judged to make a significant contribution to the light extinction budget.
Hourly PM2.5 Speciation AQS parameters: 88403 (sulfate) 88307 (EC) 88305 (OC) Data only from the following instruments will be used: Thermo sulfate method code 875 Sunset carbon, method code 867 (EPA does not consider any available continuous nitrate data to be suitable for use in the risk assessment.)	Sulfate data are available in AQS for Cedar Rapids, IA; Davenport, IA; Columbia, SC; Anderson, SC; Greenville, SC; Indianapolis, IN; Knoxville, TN; and New York City NY. Carbon data are available in AQS for Chicago, IL; Detroit, MI; New York City, NY; and Seattle, WA. The above data will be used only if collocated with a 24-hour PM2.5 speciation sampler. Staff will request similar data from the SEARCH program.	Any available. For instruments with data from 2005-2007, no older data will be used.	These data will be used to develop diurnal profiles for sulfate, elemental carbon, and organic carbon, which will be applied to 24-hour speciation concentrations. Staff will explore regional differences in the shapes of these profiles, but given the sparsity of the data it can be anticipated that potentially significant uncertainties will be introduced by the need to extrapolate profiles to other locations. Staff will also explore whether profiles need to be segregated by season.
Relative Humidity AQS parameter 62201 (hourly) and 68110 (24-hour average)	Many monitoring sites in AQS report hourly relative humidity from on-site instruments. NWS provides hourly relative humidity at other sites.	2005-2007	Hourly relative humidity data (or estimates) will be used in the IMPROVE algorithm to estimate hourly light extinction.
Nephelometer light scattering.	About 88 nephelometers have operated at	2005-2007	Where possible, these hourly data will be compared to

Measurement Type	Availability	Time Periods	Intended Application
AQS parameter code 11203	some time in 32 CBSAs. Staff will need to investigate further which of these are heated versus unheated.		the estimates of hourly light scattering developed for the same cities and hours using PM2.5 concentrations, as a check on the realism of the method used to create the latter estimates for locations without nephelometers.
Aethalometer light absorption	About 33 aethalometers have operated at some time in 33 CBSAs. These have reported in AQS in units of mass concentration of black carbon. Staff will need to explore whether and how to estimate atmospheric light absorption from these values.	2005-2007	Where possible, these hourly data will be compared to the estimates of hourly light absorption developed for the same cities and hours using PM2.5 concentrations, as a check on the realism of the method used to create the latter estimates for locations without aethalometers.
Transmissometer light extinction, in units of MM ⁻¹	Staff are still investigating the availability of this type of data in AQS. It is expected that very few such instruments have been operated by state/local monitoring agencies. Staff are also investigating other sources of data, including the SEARCH program and the PM Supersites studies.		Where possible, these hourly data will be compared to the estimates of hourly light extinction developed for the same cities and hours using PM2.5 concentrations, as a check on the realism of the method used to create the latter estimates for locations without transmissometer.

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1 **APPENDIX C : DENVER URBAN VISIBILITY**
2 **WORKSHOP SUMMARY REPORT**
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6 On October 6-8, 2008 the EPA sponsored an urban visibility workshop in Denver,
7 Colorado to identify and discuss methods and materials that could be used in “next step” projects
8 to develop additional information about people’s preferences for reducing existing impairment of
9 urban visibility, and about the value of improving urban visibility. Invited individuals came
10 from a broad array of relevant technical and policy backgrounds, including visual air quality
11 (VAQ) science, sociology, psychology, survey research methods, economics, and EPA’s process
12 of setting NAAQS. The 23 people who attended the workshop (including one via teleconference
13 line) came from EPA, the National Oceanic and Atmospheric Administration (NOAA), NPS,
14 academia, regional and state air pollution planning agencies, and consulting firms. To view the
15 complete report go:

16 [http://vista.cira.colostate.edu/improve/Publications/GrayLit/gray_literature.h](http://vista.cira.colostate.edu/improve/Publications/GrayLit/gray_literature.htm)
17 [tm](http://vista.cira.colostate.edu/improve/Publications/GrayLit/gray_literature.htm)
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