Ozone National Ambient Air Quality Standards: Scope and Methods Plan for Welfare Risk and Exposure 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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1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is presently conducting a review of the national ambient air quality standards (NAAQS) for ozone. Sections 108 and 109 of the Clean Air Act (Act) govern the establishment and periodic review of the NAAQS. These standards are established for pollutants that may reasonably be anticipated to endanger public health and welfare, and whose presence in the ambient air results from numerous or diverse mobile or stationary sources. The NAAQS are to be based on air quality criteria, which are to accurately reflect the latest scientific knowledge useful in indicating the kind and extent of identifiable effects on public health or welfare that may be expected from the presence of the pollutant in ambient air. The EPA Administrator is to promulgate and periodically review, at five-year intervals, "primary" (health-based) and "secondary" (welfare-based) NAAQS for such pollutants. Based on periodic reviews of the air quality criteria and standards, the Administrator is to make revisions in the criteria and standards, and promulgate any new standards, as may be appropriate. The Act also requires that an independent scientific review committee advise the Administrator as part of this NAAQS review process, a function now performed by the Clean Air Scientific Advisory Committee (CASAC)

EPA's overall plan and schedule for this ozone NAAQS review are presented in the Integrated Review Plan for the Ozone National Ambient Air Quality Standards Review (EPA, 2011b), which is available at: http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_cr_pd.html. That plan outlines the Clean Air Act (CAA) requirements related to the establishment and reviews of the NAAQS, the process and schedule for conducting the current ozone NAAQS review, and three key components in the NAAQS review process: an Integrated Science Assessment (ISA), a Risk and Exposure Assessment (REA), and a Policy Assessment (PA). It also lays out the key policy-relevant issues to be addressed in this review as a series of policy-relevant questions that will frame our approach to determining whether the current primary and secondary NAAQS for ozone should be retained or revised.

The ISA prepared by EPA's Office of Research and Development (ORD), National Center for Environmental Assessment (NCEA), provides a critical assessment of the latest available policy-relevant scientific information upon which the NAAQS are to be based. The ISA will critically evaluate and integrate scientific information on the health and welfare effects associated with exposure to ozone in the ambient air. The REA, prepared by EPA's Office of Air and Radiation (OAR), Office of Air Quality Planning and Standards (OAQPS), will draw from the information assessed in the ISA. The REA will include, as appropriate, quantitative estimates of human and ecological exposures and/or risks associated with recent ambient levels of ozone, with levels simulated to just meet the current standards, and with levels simulated to just meet possible alternative standards.

The REA will be developed in two parts addressing: (1) human health risk and exposure and (2) welfare-related risk and exposure. This document describes the scope and methods planned to conduct the welfare risk and exposure assessments to support the review of the secondary (welfare-based) ozone NAAQS. A separate document describes the scope and methods planned to conduct quantitative assessments to support the review of the primary (health-based) ozone NAAQS. Preparation of these two planning documents coincides with the development of the first draft ozone ISA (U.S. EPA, 2011a) to facilitate the integration of policy-relevant science into all three documents.

This planning document is intended to provide enough specificity to facilitate consultation with CASAC, as well as for public review, in order to obtain advice on the overall scope, approaches, and key issues in advance of the conduct of the risk and exposure analyses and presentation of results in the first draft REA. NCEA has compiled and assessed the latest available policy-relevant science available to produce a first draft of the ISA and related Annexes (US EPA, 2011a). The first draft ISA has been reviewed by staff and used in the development of the approaches described below. This includes information on atmospheric chemistry, source emissions, air quality, exposure, and related welfare effects. CASAC consultation on this planning document coincides with its review of the first draft ISA. CASAC and public comments on this document will be taken into consideration in the development of the first draft REA, the preparation of which will coincide and draw from the second draft ISA. The second draft REA will draw on the final ISA and will reflect consideration of CASAC and public comments on the first draft REA. The final REA will reflect consideration of CASAC and public comments on the second draft REA. The final ISA and final REA will inform the policy assessment and rulemaking steps that will lead to a final decision on the ozone NAAQS.

This introductory chapter includes background on the current ozone standards and the quantitative risk assessment conducted for the last review; the key issues related to designing the quantitative assessments in this review, building upon the lessons learned in the last review; and an overview introducing the planned assessments that are described in more detail in later chapters. The planned assessments are designed to estimate welfare risks that are associated with recent ambient levels and, if appropriate considering resource and data availability, with ambient levels simulated to just meet the current standards, and with ambient levels simulated to just meet alternative standards that may be considered. The major components of the assessments (e.g., air quality analyses, quantitative exposure assessment, and quantitative welfare risk assessments) briefly outlined in the Integrated Review Plan (U.S. EPA, 2011b)are described in more detail below in Chapters 2 – 6. The schedule for completing these assessments is presented in Chapter 7.

1.1 Background on 2008 Ozone NAAQS Review

As a first step in developing this planning document, we considered the work completed in previous reviews of the primary and secondary NAAQS for ozone and in particular the quantitative assessments supporting those reviews. EPA completed the most recent review of the ozone NAAQS with publication of a decision on March 27, 2008 (73 FR 16436). Based on the final criteria document (CD) (US EPA, 2006) published in March of 2006, and on the final Staff Paper (U.S EPA, 2007) published in July of 2007, the previous EPA Administrator decided to revise the level of the 8-hr average primary ozone standard from 0.08 ppm to 0.075 ppm and to revise the secondary to be identical to the primary. As discussed in more detail in the Integrated Review Plan, the current EPA Administrator decided to reconsider the March 27, 2008 decisions on the revisions to the primary and secondary ozone NAAQS.

1.1.1 Overview of 2008 Review

The assessments conducted as part of the last review focused on national-level O_3-related impacts to sensitive vegetation and their associated ecosystems. The vegetation exposure assessment was performed using an interpolation approach that included information from ambient monitoring networks and results from air quality modeling. The vegetation risk assessment included both tree and crop analyses. The tree risk analysis included three distinct lines of evidence: (1) observations of visible foliar injury in the field linked to monitored O_3 air quality for the years 2001 – 2004; (2) estimates of seedling growth loss under then current and alternative O_3 exposure conditions; and (3) simulated mature tree growth reductions using the TREGRO model to simulate the effect of meeting alternative air quality standards on the predicted annual growth of mature trees from three different species. The crop risk analysis included estimates of crop yields under current and alternative O_3 exposure conditions. The associated changes in economic value upon meeting the levels of various alternative standards were analyzed using an agricultural model. Key elements and observations from these exposure and risk assessments are outlined in the following sections.

1.1.2 Exposure Characterization

In many rural and remote areas where sensitive species of vegetation can occur, monitoring coverage remained limited. Thus, the 2007 Staff Paper concluded that it was necessary to use an interpolation method in order to better characterize O_3 air quality over broad geographic areas and at the national scale. Based on the significant difference in monitor network density between the eastern and western U.S., the Staff Paper further concluded that it was appropriate to use separate interpolation techniques in these two regions: The Air Quality System (AQS; http://www.epa.gov/ttn/airs/airsaqs) and Clean Air Status and Trends Network (CASTNET; http://www.epa.gov/castnet/) monitoring data were solely used for the eastern interpolation, and in the western U.S., where rural monitoring is more sparse, O_3 outputs from the EPA/NOAA Community Multi-scale Air Quality (CMAQ) model system (http://www.epa.gov/asmdnerl/CMAQ, Byun and Ching, 1999; Byun and Schere, 2006) were used to develop scaling factors to augment the monitor interpolation. In order to characterize uncertainty associated with the exposure estimates generated using the interpolation method, monitored O_3 concentrations were systematically compared to interpolated O_3 concentrations in areas where monitors were located. In general, the interpolation method performed well in many areas in the U.S. This approach was used to develop a national vegetation O_3 exposure surface.

To evaluate changing vegetation exposures under selected air quality scenarios, a number of analyses were conducted. One analysis adjusted 2001 base year O_3 air quality distributions using a rollback method (Rizzo, 2005, 2006) to reflect meeting the current and alternative secondary standard options. For "just meet" and alternative 8-hr average standard scenarios, the associated maps of estimated 12-hr, W126 exposures were generated. Based on these comparisons, the following observations were drawn: (1) current O_3 air quality levels could result in significant cumulative, seasonal O_3 exposures to vegetation in some areas; (2) overall 3-month 12-hr W126 O_3 levels were somewhat but not substantially improved under the "just meet" current (0.08 ppm) scenario; (3) exposures generated for just meeting a 0.070 ppm, 4th-highest maximum 8-hr average alternative standard (the lower end of the then proposed range for the primary O_3 standard) showed substantially improved 3-month cumulative, seasonal O_3 air quality when compared to just meeting the current 0.08 ppm, 8-hr average standard.

A second analysis described in the Staff Paper was performed to evaluate the extent to which county-level O_3 air quality measured in terms of various levels of the current 8-hr average form overlapped with that measured in terms of various levels of the 12-hr W126 cumulative, seasonal form. While these results also suggested that meeting a proposed 0.070 ppm, 8-hr secondary standard would provide substantially improved vegetation protection in some areas, the Staff Paper recognized that this analysis had several important limitations. In particular, the lack of monitoring in rural areas where sensitive vegetation and ecosystems are located, especially at higher elevation sites, could have resulted in an inaccurate characterization of the degree of potential overlap at sites that have air quality patterns that can result in relatively low 8-hr averages while still experiencing relatively high cumulative exposures (72 FR 37892). Thus, the Staff Paper concluded that it is reasonable to anticipate that additional unmonitored rural high elevation areas with sensitive vegetation may not be adequately protected even with a lower level of the 8-hr form. The Staff Paper further indicated that it remained uncertain as to the extent to which air quality improvements designed to reduce 8-hr O_3 average concentrations would reduce O_3 exposures measured by a seasonal, cumulative W126 index. The Staff Paper indicated this to be an important consideration because: (1) the biological database stresses the importance of cumulative, seasonal exposures in determining plant response; (2) plants have not been specifically tested for the importance of daily maximum 8-hr O_3 concentrations in relation to plant response; and (3) the effects of attainment of a 8-hr standard in upwind urban areas on rural air quality distributions cannot be characterized with confidence due to the lack of monitoring data in rural and remote areas.

The Staff Paper also presented estimates of economic valuation for crops associated with the then current and alternative standards. The Agriculture Simulation Model (AGSIM) (Taylor, 1994; Taylor, 1993) was used to calculate annual average changes in total undiscounted economic surplus for commodity crops and fruits and vegetables when then current and alternative standard levels were met. Meeting the various alternative standards did show some significant benefits beyond the 0.08 ppm, 8-hr standard. However, the Staff Paper recognized that the modeled economic impacts from AGSIM had many associated uncertainties, which limited the usefulness of these estimates.

1.1.3 Assessment of Risks to Vegetation

The risk assessments in the last review reflected the availability of several additional lines of evidence that provided a basis for a more complete and coherent picture of the scope of O_3-related vegetation risks, especially those faced by seedling, sapling and mature tree species growing in field settings, and indirectly, forested ecosystems. Specifically, new research available at the time reflected an increased emphasis on field-based exposure methods (e.g., free air exposure and ambient gradient), improved field survey biomonitoring techniques, and mechanistic tree process models. Highlights from the analyses that addressed visible foliar injury, seedling and mature tree biomass loss, and effects on crops are summarized below.

With regard to visible foliar injury, the Staff Paper presented an assessment that combined recent U.S. Forest Service Forest Inventory and Analysis (FIA) biomonitoring site data with the county level air quality data for those counties containing the FIA biomonitoring sites. This assessment showed that incidence of visible foliar injury ranged from 21 to 39 percent of the counties during the four-year period (2001-2004) across all counties with air quality levels at or below that of the then current 0.08 ppm 8-hr average standard. Of the counties that met an 8-hr average level of 0.07 ppm in those years, 11 to 30 percent of the counties still had incidence of visible foliar injury.

With respect to tree seedling biomass loss, concentration-response (C-R) functions developed from Open Top Chamber (OTC) studies for biomass loss for available seedling tree species and information on tree growing regions derived from the U.S. Department of Agriculture's Atlas of United States Trees were combined with projections of air quality based on 2001 interpolated exposures, to produce estimated biomass loss for each individual seedling tree species. These analyses predicted that biomass loss could still occur in many tree species when O_3 air quality was adjusted to meet the then current 8-hr average standard. Though this type of analysis was not new to this review, the context for understanding these results had changed due to recent field work at the AspenFACE site in Wisconsin on quaking aspen (Karnosky et al., 2005) and a gradient study performed in the New York City area (Gregg et al., 2003), which confirmed the detrimental effects of O_3 exposure on tree growth in field studies without chambers and beyond the seedling stage (King et al., 2005).

With respect to risk of mature tree growth reductions, a tree growth model (TREGRO) was used to evaluate the effect of changing O_3 air quality scenarios from just meeting alternative O_3 standards on the growth of mature trees.[1] The model was run for a single western species (ponderosa pine) and two eastern species (red maple and tulip poplar). Staff Paper analyses found that just meeting the then current standard would likely continue to allow O_3-related reductions in annual net biomass gain in these species. Though there was uncertainty associated with the above analyses, it was important to note that recent evidence from experimental studies that go beyond the seedling growth stage continued to show decreased growth under elevated O_3 (King et al., 2005); some mature trees such as red oak have shown an even greater sensitivity of photosynthesis to O_3 than seedlings of the same species (Hanson et al., 1994); and the potential for cumulative "carry over" effects as well as compounding should be considered (Andersen, et al, 1997).

[1] TREGRO is a process-based, individual tree growth simulation model (Weinstein et al, 1991) that is linked with concurrent climate data to account for O_3 and climate/meteorology interactions on tree growth. TREGRO has been used to evaluate the effects of a variety of O_3 scenarios on several species of trees in different regions of the U.S. (Tingey et al., 2001; Weinstein et al., 1991; Retzlaff et al., 2000; Laurence et al., 1993; Laurence et al., 2001; Weinstein et al., 2005).

With respect to risks of yield loss in agricultural crops and fruit and vegetable species, little new information was available beyond that of the previous review. However, limited information from a free air field based soybean study (SoyFACE) and information on then current cultivar sensitivities led to the conclusion that C-R functions developed in OTCs under the National Crop Loss Assessment Network (NCLAN) program could still be usefully applied. The crop risk assessment, like the tree seedling assessment, combined NCLAN C-R information on commodity crops, fruits and vegetables, crop growing regions, and interpolated exposures during each crop growing season. The risk assessment estimated that just meeting the 0.08 ppm, 8-hr standard would still allow O_3–related yield loss to occur in some sensitive commodity crops and fruit and vegetable species growing at that time in the U.S.

1.2 Approach for Assessing the Adequacy of the Current Standard

The first step in reviewing the adequacy of the secondary O_3 standard is to consider whether the available body of scientific evidence, assessed in the ISA and used as a basis for the analyses presented in the public welfare-related REA, supports or calls into question the scientific conclusions reached in the last review regarding welfare effects related to exposure to O_3 and other photochemical oxidants (e.g., peroxyacetyl nitrate, hydrogen peroxide) in ambient air. This evaluation of the available scientific evidence will focus on key policy-relevant issues by addressing a series of questions including the following:

- To what extent has new scientific information become available that alters or substantiates our understanding of the effects on vegetation and other welfare effects following exposures to levels of O_3 found in the ambient air?
- To what extent has new scientific information become available to inform our understanding of the nature of the exposures that are associated with such effects in terms of biologically relevant cumulative, seasonal exposure indices?
- To what extent has new scientific information become available that alters or substantiates our understanding of the effects of O_3 on sensitive plant species, ecological receptors, or ecosystem processes?
- To what extent has new scientific information become available that alters or substantiates our understanding of exposure factors other than O_3 that might influence the

associations between O_3 levels and welfare effects being considered (e.g., site specific features such as elevation, soil moisture level, presence of co-occurring competitors, pests, pathogens, other pollutant stressors, weather-related factors)?

- To what extent has new scientific information become available that alters or substantiates conclusions regarding the occurrence of adverse welfare effects at levels of O_3 as low as or lower than those observed previously? What is the nature of the exposure-response relationships of O_3 for the various welfare effects evaluated?
- Given recognition in the last review that the significance of O_3-induced effects to the public welfare depends in part on the intended use of the plants or ecosystems on which those effects occurred, to what extent has new scientific evidence become available to suggest additional locations where the vulnerability of sensitive species or ecosystems would have special significance to the public welfare and should be given increased focus in this review?
- To what extent do risk and/or exposure analyses suggest that exposures of concern for O_3-related welfare effects are likely to occur with current ambient levels of O_3 or with levels that just meet the O_3 standard? Are these risks/exposures of sufficient magnitude such that the welfare effects might reasonably be judged to be important from a public welfare perspective? What are the important uncertainties associated with these risk/exposure estimates?
- To what extent have important uncertainties identified in the last review been addressed and/or have new uncertainties emerged?

1.3 Overview of Current Assessment Plan

Since the 2008 review, new scientific information on the direct and indirect effects of O_3 on vegetation and ecosystems, respectively, has become available. With respect to mature trees and forests, the information regarding O_3 impacts to forest ecosystems has continued to expand, including limited new evidence that implicates O_3 as an indirect contributor to decreases in stream flow through direct impacts on whole tree level water use. Newly published results from the Long-term FACE (Free Air CO_2 enrichment) studies provide additional evidence regarding chronic O_3 exposures in closed forest canopy scenarios including interspecies interactions such as decreased growth of branches and root mass in sensitive species. Also, lichen and moss communities on trees monitored in FACE sites have been shown to undergo species shifts when exposed to O_3. In addition, it is expected that as in the previous review, recent available data from annual field surveys conducted by the USFS to assess foliar damage to selected tree species will again be available. In light of this new scientific information, we will consider whether additional analyses are warranted, such as combining the USFS data with recent county level air quality data to determine the incidence of visible O_3 damage occurring across the U.S. at air quality levels that meet or are below the current standard, as was done in the last review. To the extent warranted, based on new information regarding O_3 effects on forest trees, both qualitative and quantitative assessments may be considered in an effort to place both the estimates of risk from more recent long-term studies and historic shorter-term studies in the context of ecosystem services.

Additional information relevant to vegetation risk assessments expected to be available includes that regarding the interactions between elevated O_3 and CO_2 with respect to plant growth and how these interactions might be expected to be modified under different climatic conditions, and potential reactions of O_3 with chemicals released by plants to attract pollinators that could decrease the distance the floral "scent trail" travels and potentially change the distance pollinators have to travel to find flowers. To the extent warranted, staff also plans to consider any available information regarding potential risks to threatened or endangered species.

To the extent warranted, qualitative and/or quantitative assessments of ecosystem services impacted by O_3 will be considered to inform the current review. For example, the ecosystem services evaluation in this review may include tree biomass and crop analyses, and when possible include impacts on ecosystem services such as impacts on biodiversity, biological community composition, health of forest ecosystems, aesthetic values of trees and plants and the nutritive quality of forage crops. CO_2 sequestration is another important ecosystem service (regulating) that may be affected by O_3 damage to vegetation. New preliminary evidence of O_3 effects on the ability of pollinators to find their target is also of special interest with respect to the possible implication for ecosystem services. Impairment of the ability of pollinators to locate flowers could have broad implications for agriculture, horticulture and forestry.

If resources are available, we will consider using the Forest and Agricultural Sector Optimization Model (FASOM) to assess the economic impacts of O_3 damage to forests and agricultural crops jointly. FASOM is a dynamic, non-linear programming model designed for use by the EPA to evaluate welfare and market effects of carbon sequestration in trees, understory, forest floor, wood products and landfills that would occur under different agricultural and forestry scenarios. It may be possible to use FASOM to model damage by O_3 to the agriculture and forestry sectors and quantify how O_3-exposed vegetation affects the ecosystem service of carbon sequestration.

A conclusion in the last review was that the science continued to support a change in the form of the secondary standard for O_3 to better reflect the effects of cumulative O_3 exposures on plants. The current form of the secondary standard may not protect sensitive species that are chronically exposed to elevated O_3 concentrations. In light of new information on exposures, risks, non-plant effects, and ecosystem services, we will consider whether additional analyses are warranted to evaluate the relative risks associated with both the current and potentially alternative secondary standards seasonal forms, including the impact of using different length diurnal windows (e.g., 12, 16 or 24 hrs) or different seasonal periods (e.g., 3, 5, or 7 months).

2 AIR QUALITY CONSIDERATIONS

Air quality analyses are necessary to inform and support welfare-related assessments. The planned air quality analyses for this review will build upon those of the ISA and will include consideration of: (1) summaries of recent ambient air quality data, (2) estimation approaches to extrapolate air quality values for rural areas without monitors as well as federally designated Class I natural areas important to welfare effects assessment, (3) estimates of Policy-Relevant Background (PRB) concentrations, (4) air quality simulation procedures that modify recent air quality data to reflect changes in the distribution of air quality estimated to occur at some unspecified time in the future when an area just meets a given set of NAAQS. In this review, air quality analyses are being planned to support quantitative exposure and risk assessments that we may consider in light of the new scientific information available for specific locations, as well as at regional and national scales.

In addition to updating air quality summaries since the last review, these air quality analyses will include summaries of the most currently available ambient measurements for the current and potential alternate secondary standard forms, and comparisons among them . These air quality analyses will use monitor data from the AQS database (which includes National Park Service monitors) and the CASTNET network. In addition, staff may explore the suitability of using other sources of O_3 concentration information that might be available, such as from portable monitors or satellites.

In the last review, the vegetation exposure analysis used a spatial interpolation technique to create an interpolated air quality surface to fill in the gaps in ambient monitoring data, especially those left by a sparse rural monitoring network in the western United States. In this review, additional approaches that potentially could be used to fill in the gaps in the rural monitoring network, as well as opportunities for enhancing the fusion of monitoring and modeled O_3 data, may be explored.

Estimates of the risks in excess of PRB remaining upon meeting the current or potential alternative standards require EPA to estimate PRB. EPA will be evaluating alternative definitions of PRB and the implications of those definitions for estimates of risk, and will use a definition of PRB that is consistent with the health risk and exposure assessment. This type of risk estimate is considered relevant to inform the EPA Administrator's decision on the adequacy of a given standard.

As part of the air quality analyses supporting the assessments, it will be necessary to adjust recent O_3 air quality data to simulate just meeting the current standard and any alternative O_3 standards. In the last review, EPA used a quadratic air quality rollback approach (U.S. EPA, 2007), but staff may consider alternative air quality simulation procedures.

2.1 National Ozone Exposure Surface

Since the last review, little has changed in terms of the extent of monitoring coverage in non-urban areas. We are planning to consider both past and alternative approaches for generating estimates of national O_3 exposures in an effort to continue enhancing our ability to characterize exposures in these non-monitored areas. It is expected that any vegetation exposure assessments that may be conducted will again include assessments of recent air quality, air quality associated with just meeting the current standard and any alternative standards that might be considered.

In addition, given the importance of providing protection for sensitive vegetation in areas afforded special protections, such as in federally designated Class I natural areas, we may also consider alternative sources of O_3 exposure information for those types of sites. For example, portable O_3 monitors are being deployed in some national parks and a current exploratory study is underway to measure O_3 concentration variations with gradients in elevation.[2] Information from these monitors could potentially inform our understanding of uncertainties associated with assessing O_3 distribution patterns in complex terrain and high elevations. New exposure data that would inform this assessment will be considered where appropriate.

To generate a national ozone exposure surface, staff plans to consider several interpolation methods. One option is to use a previously modeled ozone surface generated by the CMAQ model based on 2005 emissions at a 12 km grid resolution in conjunction with monitor data

[2] For more information on portable ozone monitors in National Parks, please see http://www.nature.nps.gov/air/studies/porto3.cfm

(2004-2006) to create a fused surface with the Modeled Attainment Test Software (MATS).[3] Another option is to use the Voronoi Neighbor Averaging (VNA) interpolation method in the BenMAP model (Abt Associates, Inc., 2008) to create a national ozone surface from more recent monitor data (e.g., 2008-2010).[4] Staff will also evaluate alternate interpolation methods and sources of air quality data to assess which option is most appropriate given the analysis requirements, desire for consistency with the health risk assessment, and available resources.

In order to generate the national ozone surface in terms of a particular index, the monitored data and CMAQ model outputs that form the basis for the interpolation need to be characterized in terms of that index. At a minimum, staff plans to generate the national surface in terms of the current secondary standard. Staff recognizes that additional indices may be selected for further evaluation upon review of the information contained in the ISA and may perform additional air quality analyses based on those indices. Any expanded evaluation of additional indices would be contained and discussed in the Policy Assessment.

In conjunction with the health risk assessors, staff is currently considering various approaches to simulate just meeting the current and alternative standards, including the quadratic air quality "rollback" adjustment that was used in the last review (Johnson, 1997) and variations of the proportional adjustment method. In addition, staff is currently investigating methods for generating adjusted air quality in non-monitored areas.

The national ozone surface, depicted as a GIS layer, provides the exposures needed as input to the crop and tree seedling risk and ecosystem service assessments described in sections 3 and 4.

[3] More information on CMAQ is available at http://www.epa.gov/amad/CMAQ/index.html. More information on MATS is available at http://www.epa.gov/scram001/modelingapps_mats.htm.

[4] More information on the VNA method in BenMAP is available at http://www.epa.gov/air/benmap/models/BenMAPManualAugust2010.pdf

3 ECOLOGICAL EFFECTS OF EXPOSURE

3.1 National Scale Assessment

3.1.1 Tree Seedling Concentration-Response Functions

Staff plans to analyze the 11 OTC tree seedling C-R functions identified and assessed in the 2007 O_3 Staff Paper in terms of the current exposure metrics. This analysis will enable staff to directly evaluate estimated seedling biomass loss values expected to occur under air quality exposure scenarios expressed in terms of the current and alternate secondary standards. Currently, the ISA does not provide any information that would substantially change these C-R functions, but Staff would evaluate any new information that becomes available in the ISA.

3.1.2 Estimation of Biomass Loss for Tree Seedlings

In the 2007 O_3 Staff Paper, information on tree species growing regions was derived from the USDA Atlas of United States Trees (Little, 1971). Staff plans to consider using more recent information from the USDA Forest Service FIA database in order to update growing ranges for the 11 tree species studied by NHEERL-WED. Staff plans to combine the national ozone surface (from section 2.1) with the C-R function for each of the tree seedling species and information on each tree species growing region to produce estimates of biomass loss for each of the 11 tree seedling species. From this information, staff plans to generate GIS maps depicting biomass loss for each species for each air quality scenario.

3.2 Ecosystem Level Case Study Areas

In order to assess the ecological effects of ozone staff will analyze ecosystem level effects in several case study areas. These areas will be selected to allow a more refined assessment of the extent of foliar injury, biomass loss and welfare related services. Criteria that may be used to select case study areas include:

- Occur in areas expected to have elevated levels of ozone where ecological effects might be expected to occur.
- Availability of vegetation mapping including estimates of species cover.

- Geographic coverage representing a cross section of the nation, including urban and natural settings.
- Occurrence of ozone sensitive species and/or species for which ozone concentration-response curves have been generated.

3.2.1 Estimation of Vegetation Effects in National Parks

The National Parks provide several potential case study areas. The United States Geological Survey (USGS) in conjunction with the National Park Service (NPS) is actively creating maps of the vegetation communities within the National Parks (http://biology.usgs.gov/npsveg/index.html). This provides a consistent vegetation map to compare across park units, which includes species coverage data. The NPS has also generated a comprehensive list of plant species that are known to exhibit foliar injury at ambient ozone levels (Porter, 2003).

Potential National Park units to be included are Great Smoky Mountains National Park, Rocky Mountain National Park, and Sequoia/Kings National Park. All three of these park units occur in areas with elevated ambient ozone levels, have vegetation maps, and have species that are considered ozone sensitive.

The NPS vegetation maps would be compared, using GIS, to the national ozone surface to provide an overall estimate of foliar damage and total biomass loss. The NPS units also have GIS data for park trails and recreational areas, which can be compared to the areas of foliar damage. Potential ecological metrics that will be calculated include:

- Percent of vegetation cover affected by foliar injury.
- Percent of trails affected by foliar injury.
- Estimate of species specific biomass loss within the case study area.
- Percent of wetland areas affected by foliar injury or biomass loss.

3.2.2 Estimation of Vegetation Effects in Urban Areas

Several urban areas nationally have extensive habitat management plans that include resource and vegetation mapping. These data are not as consistent or as readily available as the

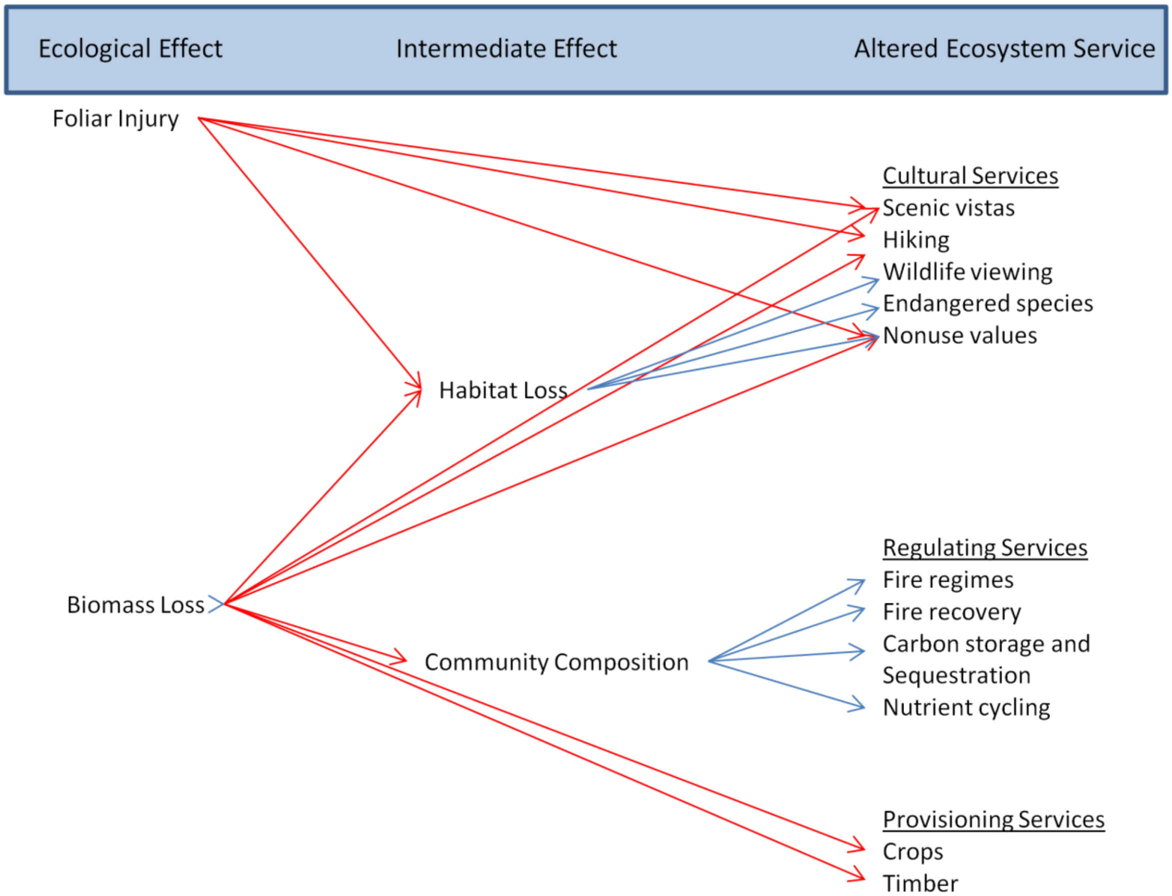
NPS units but in some cases can provide adequate vegetation maps in regions where ozone sensitive species occur. Two examples which are currently available are the city of Boulder, Colorado, which has a range of resource mapping available (http://www.bouldercounty.org/find/maps/pages/gisdldata.aspx) and San Diego County, where there is a large scale Multiple Species Conservation Plan (MSCP) in place (http://www.sandiego.gov/planning/mscp/). Both urban areas occur in areas with elevated ozone and both have some species in common with species occurring on the NPS ozone sensitive species list (Porter, 2003).

Similar to the National Park case study areas, vegetation maps in urban areas would be compared, using GIS, to the national ozone surface to provide an overall estimate of foliar damage and total biomass loss. When available, GIS data for public trails and recreational areas will be compared to aerial extent of foliar damage. Ecological metrics that may be calculated for urban case studies will be similar to those calculated for National Parks depending on data availability.

4 ECOSYSTEM SERVICES EVALUATION

One of the requirements of the risk assessment for a secondary NAAQS is to quantify the risks to public welfare. The Risk and Exposure Assessment for Review of the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur (U.S. EPA, 2009) has detailed discussions of how ecosystem services and public welfare are related and how a services framework may be employed to evaluate effects on welfare. We plan to identify the ecosystem services associated with the ecological effects described in Section 4 of this document for the national scale assessment and the more refined case study areas. These services may be characterized as: supporting services that are necessary for all other services (e.g., primary production); cultural services including existence and bequest values, aesthetic values, and recreation values, among others; provisioning services (e.g., food and timber); and regulating services such as climate regulation or flood control. Figure 4.1 illustrates the relationships between the ecological effects of ozone and the anticipated ecosystem services impacts. Specific services to be evaluated are discussed in the following sections.

Figure 4.1 Schematic of Ecological Effects and Ecosystem Service Impacts*



***Illustrative only. Not intended to be comprehensive.**

4.1 National Scale Assessment

Depending on data and resource availability, we will attempt to develop an estimate of ecosystem service impacts broadly across the United States for selected cultural, regulating, and provisioning services.

4.1.1 Cultural Services

We plan to use GIS mapping developed for the ecological effects analysis to illustrate where effects may be occurring and relate those areas to national scale statistics for recreational use available through the National Survey of Fishing, Hunting, and Wildlife-Associated

Recreation (U.S. DOI, 2007). The resulting estimates of service provision can then be scaled to the current population and values assigned using existing meta-data on willingness to pay from Kaval and Loomis (2003). We are aware that these estimates will be limited to current levels of service provision and will provide a snapshot of the overall magnitude of services potentially affected by ozone exposure. At this time estimates of service loss due to ozone exposure is beyond the available data and resources; however, estimates of the current level of services would have embedded within them the current losses in service due to ozone exposure.

4.1.2 Regulating Services

The regulating services associated with ozone exposure include fire regimes, fire recovery, and carbon storage and sequestration due to ozone effects on community composition and diversity. Changes in community composition may increase fire frequency and/or intensity in certain ecosystems. Additionally, selection pressure due to ozone exposure may affect the timing of ecosystem recovery and the ecological succession as well as the composition of the succession communities. We will conduct a literature and data search for information available to estimate the impact of current levels of these services. There is data available through the U.S. Forest Service on fire incidence and expenditures related to wildland fires.

4.1.3 Provisioning Services

The scope of the national-level provisioning services assessment will depend on data and resource availability. Below we outline potential methods for assessing the provisioning services associated with crop yield loss and tree biomass loss, which are consistent with the methods from the previous review.

4.1.3.1 Estimation of Yield Loss for NCLAN Crops

County-level crop planting data will be obtained from USDA-NASS (National Agricultural Statistics Service; http://www.nass.usda.gov/) for each NCLAN crop for the most recent year available. This information will be used to create GIS maps containing the planting data for each species/cultivar of commodity crop. Staff plans to overlay the national ozone surface (as discussed in section 2.1) with GIS maps of the crop growing regions and crop specific planting and harvesting data to calculate yield loss using the relevant C-R functions. Staff will evaluate this data to calculate which months to use for the exposure of crops. This combination of data will result in an estimate of county-level percent yield loss for each NCLAN crop. Staff plans to create GIS maps of percent yield loss of each crop for the counties in which they were planted. This analysis will also be performed for just meeting the current standard and other alternative standards. The change in crop county-level percent yield loss estimates between ‚as is' air quality and meeting various standards will serve as inputs to the AGSIM© agricultural economic impacts model.

4.1.3.2 Economic Valuation Associated with Crop Yield Loss

The peer-reviewed AGSIM© model (Taylor et al., 1993) has been utilized recently in many major policy evaluations. AGSIM© is an econometric-simulation model used to calculate agricultural impacts of changes in O_3 exposure and is based on a large set of statistically estimated demand and supply equations for agricultural commodities produced in the United States. Initially, AGSIM© will be used to calculate the economic impacts of yield changes between the ‚as is' and ‚just meet' scenarios for a base year to be determined. This approach will also be used to calculate the economic valuation of alternative standards under consideration. If data are available, the same analysis will be performed using air quality data from other years.

In addition, as mentioned in a previous section, given sufficient resources we will consider using the FASOM model either as a complement to or in place of AGSIM©.

4.1.3.3 Modeling of Tree Growth and Economics

In the 2007 O_3 Staff Paper, the tree growth simulation model (TREGRO) was used as a tool to evaluate the effect of O_3 effects on mature tree growth. TREGRO (Weinstein et al, 1991) has been used to evaluate the effects of a variety of O_3 scenarios on several species of trees in different regions of the U.S. However, in order to examine tree growth rates over long time periods, competition among tree species must also be taken into account. Some researchers have linked TREGRO to the stand growth model, ZELIG (Urban et al., 1991), to simulate succession in mixed stands (Laurence et al., 2000; Weinstein et al., 2005). The linked TREGRO and ZELIG modeling system can be modified to predict the effects of O_3 on basal area and other growth parameters of some species. As mentioned previously the FASOM model may be substituted for the above linked models provided resources are available.

There are many uncertainties and limitations in the modeling framework outlined above. For example, the TREGRO model is currently only parameterized for a subset of the 11 tree species for which seedling biomass C-R functions were available at the time of the last review. This subset includes ponderosa pine, loblolly pine, tulip poplar, red oak, sugar maple, and red spruce. Though TREGRO could potentially be parameterized for other tree species for which CR functions exist, this has not yet been done. Second, there is evidence that seedlings and mature trees may respond differently to O_3 exposure (Hanson et al, 1994). Third, when modeling growth of trees into the future, many simplifying assumptions must be used with respect to environmental factors that may be changing along with O_3 such as carbon dioxide concentrations, temperatures, and rainfall patterns. Consequently, these models provide only a framework for scientists and policy-makers to investigate questions about how factors such as O_3 may affect forest growth.

4.2 Case Study Analysis

4.2.1 National Park Areas

We plan to use GIS mapping produced for the ecological effects analysis to illustrate where effects may be occurring as a starting point to illustrate and, if possible, quantify the ecosystem services at potential risk. These are primarily, in national parks, cultural values that include existence, bequest and recreational values. Where we have data available we will overlay maps of critical habitat for threatened or endangered species and, if possible, assign values for the preservation of those species. We will also overlay the ecological effects maps with data on where hiking trails, campgrounds, or other park amenities are found to intersect potentially affected areas. We can then relate those areas to case study specific statistics for recreational use available through the National Park Service. In addition, we will, if possible, describe the other nonuse values associated with national parks including existence and bequest values. The resulting estimates of service provision values can then be assigned using existing meta-data on willingness to pay from Kaval and Loomis (2003). We are aware that these estimates will be limited to current levels of service provision. At this time estimates of service loss due to ozone exposure may be beyond the available data and/or resources for many if not all ecosystem services listed above.

4.2.2 Urban Areas

Where data are available, we plan to follow the same methodology for the urban case as the national park studies with the possible addition of the use of the i-Tree model to assess effects on ecosystem services provided by urban forests, including VOC emissions, building energy use, leaf area/biomass, pollution removal, and carbon storage and sequestration. The i-TREE model is a publicly available peer-reviewed software suite developed by the U.S. Forest Service and its partners to assess the ecosystem service impacts of urban forestry (available here: http://www.itreetools.org/). We will collaborate with the U.S. Forest Service to vary the tree growth metric in the model, which will allow us to assess the effects of ozone exposure on the ability of the forests in the selected case study area to provide the services enumerated by the model.

5 UNCERTAINTY AND VARIABILITY

Table 5-1. Potential Sensitivity Analyses

Component of the Risk Assessment	Sensitivity Analysis
Air Quality	A sensitivity analysis of the effect of different assumptions about background ozone levels on estimated risks associated with "as is" levels of ozone above background levels
Air Quality	A sensitivity analysis of the effect of different air quality adjustment procedures on the estimated risk reductions resulting from just meeting the current secondary standard and alternative standards
Concentration-Response	A sensitivity analysis of the effects of variability in the C-R functions on the estimates of tree and crop biomass loss.
Baseline Effects	A comparison of using larger-scale baseline ecological data (national, state, etc) versus more detailed community specific information in the case study areas.

5.1 Differentiating Between Uncertainty and Variability

An important issue associated with any ecological risk assessment is the characterization of uncertainty and variability. Variability refers to the heterogeneity in a variable of interest that is inherent and cannot be reduced through further research. For example, there may be variability among C-R functions describing the relation between ozone and vegetation injury across selected study areas. This variability may be due to differences in ecosystems (e.g., diversity, habitat heterogeneity, and rainfall), levels and distributions of ozone and/or co-pollutants, and/or other factors that vary either within or across ecosystems.

Uncertainty refers to the lack of knowledge regarding both the actual values of model input variables (parameter uncertainty) and the physical systems or relationships (model uncertainty – e.g., the shapes of concentration-response functions). In any risk assessment, uncertainty is, ideally, reduced to the maximum extent possible, through improved measurement of key parameters and ongoing model refinement. However, significant uncertainty often remains and emphasis is then placed on characterizing the nature of that uncertainty and its impact on risk estimates. The characterization of uncertainty can include both qualitative and quantitative analyses, the latter requiring more detailed information and often, the application of sophisticated analytical techniques such as 2-stage Monte Carlo simulation.

While the goal in designing a quantitative risk assessment is to reduce uncertainty to the extent possible, with variability the goal is to incorporate the sources of variability into the analysis approach to insure that the risk estimates are representative of the actual response of an ecosystem (including the distribution of that adverse response across the ecosystem). An additional aspect of variability that is pertinent to this risk assessment is the degree to which the set of selected case study areas provide coverage for the range of ozone-related ecological risk across the U.S.

We plan to more fully differentiate variability and uncertainty in the design of the risk assessment to more clearly address (a) the extent to which the risk estimates represent the distribution of ecological impacts across ecosystems, including impacts on more sensitive species, and (b) the extent to which risk estimates are impacted by key sources of uncertainty which could prevent a clear differentiation between regulatory alternatives based on risk estimates.

The remainder of this section discusses how we are planning to address variability and uncertainty within the ozone NAAQS risk assessment. The treatment of variability is discussed first (section 5.2) by identifying sources of variability associated with the modeling of ozone-related risk and noting which of those sources are reflected in the risk modeling approach presented here. Next, the treatment of uncertainty is addressed, which will include both a qualitative and quantitative component. The qualitative component is described first (section 5.3.1), including plans for identifying and describing key sources of uncertainty, and noting whether those sources of uncertainty are addressed quantitatively in the risk assessment model. A preliminary list of key sources of uncertainty for the risk assessment is provided as part of this discussion. The quantitative component of the uncertainty characterization approach, which is structured around single-factor and multi-factor sensitivity analysis methods, is then described (section 5.3.2).

5.2 Addressing Variability

Key sources of variability associated with the modeling of ecological risk associated with ozone exposure are presented below, including whether, and to what extent, we plan to address each source of variability:

- Spatial gradients in ozone concentrations: We plan to provide a national ozone surface that reflects the variation in ozone concentrations across the country. However, this source of variability is likely to be less well captured in the risk assessment primarily because the majority of studies providing effect estimates are themselves limited in reflecting more detailed patterns of ozone exposure among populations. More specifically, the studies typically use an average ambient concentration developed across regionally oriented monitors as a surrogate for exposure.
- Community composition (i.e., greater concentrations of sensitive species in certain locations): We plan to include multiple case study areas reflecting differences in species composition in different regions of the country to address this issue. In addition, we plan to provide a list the O_3 sensitive species by state and Class 1 area.
- Longer-term temporal variability in ambient ozone levels (reflecting meteorological trends, as well as future changes in the mix of ozone sources and regulations affecting ozone): This is more difficult to incorporate into the analysis and reflects a combination of variability as well as uncertainty.

5.3 Uncertainty Characterization

5.3.1 Qualitative Assessment

We plan to include a qualitative discussion of uncertainty in the risk assessment which will include: (1) identification and description of key sources of uncertainty, noting whether they are addressed quantitatively in the risk assessment model and (2) a qualitative assessment of those sources of uncertainty in terms of their potential impact on risk using a "high," "medium," and "low" designation. A preliminary list of potentially important sources of uncertainty has been developed for this plan and is presented below (note, some of these sources may be addressed in the quantitative uncertainty analysis, when feasible):

- Statistical uncertainty associated with the fit of the exposure or concentration response functions.
- Potential role of co-pollutants.
- Transferability of C-R functions from study locations to case study area locations: this reflects variation in (a) ozone distributions, (b) the possible role of co-pollutants in influencing risk, and (c) differences in population characteristics, (d) climatic or growing condition differences.
- Procedures for adjusting air quality to simulate alternate standard levels: There is uncertainty in developing the method for adjusting current ambient ozone levels (at individual monitors used in the risk assessment) to simulate just attaining alternative standard (methods available are likely to include both retrospective empirical monitor-based trend analysis and forward-looking model-based predictions.
- Estimates of policy-relevant background ozone levels in a particular location. There is uncertainty associated with characterizing PRB for individual locations.
- Limited monitoring coverage in rural areas. There is uncertainty associated with extrapolating a national exposure surface from limited monitoring sites, which is potentially greater in rural areas where the nearest monitor is often more distant.

5.3.2 Quantitative Analysis

The quantitative uncertainty analysis for the ozone risk assessment will be determined by the data that are available and used in the assessment. Staff will consider using a deterministic sensitivity analysis-based approach, Monte Carlo style analyses, and other methods that are relevant to the final data and analyses used in the assessment. The uncertainty analyses will provide the decision maker with a reasonable alternative set of risk estimates to supplement the set of core risk estimates that are generated. This set of additional risk estimates will provide insights into the impact of uncertainty on the initial set of core risk estimates.

6 SCHEDULE AND MILESTONES

Table 7-1 below includes the key milestones for the exposure analysis and welfare/vegetation-based risk assessment that will be conducted as part of the current ozone NAAQS review. A consultation with the CASAC Ozone Panel is planned for May 19-20, 2011 to obtain input on this draft Scope and Methods Plan. Staff will then proceed to develop welfare risk estimates associated with recent ozone levels and levels adjusted to just meet the current and alternate ozone standards. These estimates and the methodology used to develop them will be discussed in the first draft ozone Risk and Exposure Assessment and in separate exposure analysis and risk assessment technical support documents. These draft reports will be released for CASAC and public review in conjunction with the release of second draft ozone Policy ISA in October 2011. EPA will receive comments on these draft documents from the CASAC Ozone Panel and general public at a meeting in November 2011. The revised exposure analysis and risk assessment reports will include estimates associated with just meeting any alternative standards that may be recommended by staff for consideration. The revised analyses will be released in May 2012 in conjunction with the first draft ozone Policy Assessment for review by CASAC and public at a meeting to be held in July 2012. Staff will consider these review comments and prepare final exposure analysis and risk assessment reports by October 2012.

Table 7 1. Key Milestones for the Welfare Risk Assessment for the ozone NAAQS Review

Milestone	Date
Release 1st draft ozone ISA	March 2011
Release draft Scope and Methods Plan	April 2011
CASAC/public review and meeting on 1st draft ozone ISA	May 19-20, 2011
CASAC consultation on draft Scope and Methods Plan	May 2011
Release 2nd draft ozone ISA	September 2011
Release 1st drafts of the ozone Exposure Analysis and Risk Assessment reports	October 2011
CASAC/public review and meeting on 2nd draft ozone ISA and 1st drafts of the ozone Exposure Analysis and Risk Assessment reports	November 2011
Final ozone ISA	February 2012
Release 2nd drafts of the ozone Exposure Analysis and Risk Assessment reports and 1st draft of the Policy Assessment	May 2012
CASAC/public review and meeting on 2nd drafts of the ozone Exposure Analysis and Risk Assessment reports and 1st draft of the Policy Assessment	June 2012
Final ozone Policy Assessment, Exposure Analysis, and Risk Assessment	October 2012

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