EPA United States Environmental Protection Agency

Draft Integrated Review Plan for the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur

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Draft Integrated Review Plan for the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur

U. S. Environmental Protection Agency
National Center for Environment Assessment
Office of Research and Development
and

Office of Air Quality Planning and Standards
Office of Air and Radiation
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DISCLAIMER

This Integrated Review Plan serves as a public information document and as a management tool for the U.S. Environmental Protection Agency's National Center for Environmental Assessment and Office of Air Quality Planning and Standards in conducting the review of the secondary national ambient air quality standards for oxides of nitrogen and oxides of sulfur. The approach described in this plan may be modified to reflect information developed during this review, and in consideration of advice and comments received from the Clean Air Scientific Advisory Committee and the public during the course of the review. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

List of Acronyms and Abbreviations

AAI	Aquatic Acidification Index
ADR	Adirondack Mountains of New York
Al^{3+}	aluminum
ANC	acid neutralizing capacity
AQCD	Air Quality Criteria Document
Bc/Al	Base cation to aluminum ratio, also Bc:Al
C	carbon
Ca/Al	calcium to aluminum ratio
Ca^{2+}	calcium
CAA	Clean Air Act
CASAC	Clean Air Scientific Advisory Committee
CASTNet	Clean Air Status and Trends Network
Chl *a*	chlorophyll *a*
CLE	critical load exceedance
CMAQ	Community Multiscale Air Quality model
CSS	coastal sage scrub
CWA	Clean Water Act
DIN	dissolved inorganic nitrogen
DO	dissolved oxygen
DOI	U.S. Department of Interior
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
FHWAR	fishing, hunting and wildlife associated recreation survey
FIA	Forest Inventory and Analysis National Program
FWS	Fish and Wildlife Service
GIS	geographic information systems
GPP	gross primary productivity
H^+	hydrogen ion
H_2O	water vapor
H_2SO_4	sulfuric acid
ha	hectare
HAB	harmful algal bloom
HFC	hydrofluorocarbon
Hg^{+2}	reactive mercury
Hg^0	elemental mercury
HNO_3	nitric acid
HONO	nitrous acid
HUC	hydrologic unit code
IMPROVE	Interagency Monitoring of Protected Visual Environments
IRP	Integrated Review Plan
ISA	Integrated Science Assessment
K^+	potassium
kg/ha/yr	kilograms per hectare per year
km	kilometer

LRMP	Land and Resource Management Plan
LTER	Long Term Ecological Monitoring and Research
LTM	Long-Term Monitoring
MAGIC	Model of Acidification of Groundwater in Catchments
MCF	Mixed Conifer Forest
MEA	Millennium Ecosystem Assessment
Mg^{2+}	magnesium
N	nitrogen
N_2	gaseous nitrogen
N_2O	nitrous oxide
N_2O_3	nitrogen trioxide
N_2O_4	nitrogen tetroxide
N_2O_5	dinitrogen pentoxide
Na^+	sodium
NAAQS	National Ambient Air Quality Standards
NADP	National Atmospheric Deposition Program
NAPAP	National Acid Precipitation Assessment Program
NAWQA	National Water Quality Assessment
NCEA	National Center for Environmental Assessment
NEEA	National Estuarine Eutrophication Assessment
NEP	net ecosystem productivity
NH_3	ammonia gas
NH_4^+	ammonium ion
$(NH_4)_2SO_4$	ammonium sulfate
NHx	category label for NH_3 plus NH_4^+
NO	nitric oxide
NO_2	nitrogen dioxide
NO_2^-	reduced nitrite
NO_3^-	reduced nitrate
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NO_y	total oxidized nitrogen
NPP	net primary productivity
NPS	National Park Service
NRC	National Research Council
NSWS	National Surface Water Survey
NTN	National Trends Network
NTR	organic nitrate
O_3	ozone
OAQPS	Office of Air Quality Planning and Standards
OAR	Office of Air and Radiation
ORD	Office of Research and Development
OW	Office of Water
PA	Policy Assessment
PAN	peroxyacyl nitrates
PFC	perfluorocarbons

pH	relative acidity
$PM_{2.5}$fine	particulate matter
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PSD	prevention of significant deterioration
REA	Risk and Exposure Assessment
REMAP	Regional Environmental Monitoring and Assessment Program
RIA	Regulatory Impact Analysis
S	sulfur
S_2O_3	thiosulfate
S_2O_7	heptoxide
SAV	submerged aquatic vegetation
SF_6	sulfur hexafluoride
SMP	Simple Mass Balance
SO	sulfur monoxide
SO_2	sulfur dioxide
SO_3	sulfur trioxide
SO_3^{2-}	sulfite
SO_4	wet sulfate
SO_4^{2-}	sulfate ion
SOM	soil organic matter
SO_x	sulfur oxides
SPARROW	SPAtially Referenced Regressions on Watershed Attributes
SRB	sulfate-reducing bacteria
STORET	STORage and RETrieval
TIME	Temporally Integrated Monitoring of Ecosystems
TMDL	total maximum daily load
TP	total phosphorus
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
µeq/L	microequivalents per liter
$\mu g/m^3$	micrograms per cubic meter

Key Terms used in the Secondary NO_2/SO_2 NAAQS Integrated Review Plan

Acidification: The process of increasing the acidity of a system (e.g., lake, stream, forest soil). Atmospheric deposition of acidic or acidifying compounds can acidify lakes, streams, and forest soils.

Air Quality Indicator: The substance or set of substances (e.g., PM2.5, NO_2, SO_2) occurring in the ambient air for which the National Ambient Air Quality Standards set a standard level and monitoring occurs.

Alpine: The biogeographic zone made up of slopes above the tree line, characterized by the presence of rosette-forming herbaceous plants and low, shrubby, slow-growing woody plants.

Acid Neutralizing Capacity: A key indicator of the ability of water to neutralize the acid or acidifying inputs it receives. This ability depends largely on associated biogeophysical characteristics, such as underlying geology, base cation concentrations, and weathering rates.

Arid Region: A land region of low rainfall, where "low" is widely accepted to be less than 250 mm precipitation per year.

Base Cation Saturation: The degree to which soil cation exchange sites are occupied with base cations (e.g., Ca^{2+}, Mg^{2+}, K^{+}) as opposed to Al^{3+} and H^{+}. Base cation saturation is a measure of soil acidification, with lower values being more acidic. There is a threshold whereby soils with base saturations less than 20% (especially between 10%–20%) are extremely sensitive to change.

Ecologically Relevant Indicator: A physical, chemical, or biological entity/feature that demonstrates a consistent degree of response to a given level of stressor exposure and that is easily measured/quantified to make it a useful predictor of ecological risk.

Critical Load: A quantitative estimate of exposure to one or more pollutants, below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge (UN ECE 1988, Nilsson and Grennfelt 1988). A critical load can be modeled or based on empirical relationships.

Denitrification: The anaerobic reduction of oxidized nitrogen (e.g., nitrate or nitrite) to gaseous nitrogen (e.g., N_2O or N_2) by denitrifying bacteria.

Dry Deposition: The removal of gases and particles from the atmosphere to surfaces in the absence of precipitation (e.g., rain, snow) or occult deposition (e.g., fog).

Ecological Risk: The likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors (U.S. EPA, 1992).

Ecological Risk Assessment: A process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors (U.S. EPA, 1992).

Ecosystem: The interactive system formed from all living organisms and their abiotic (i.e., physical and chemical) environment within a given area. Ecosystems cover a hierarchy of spatial scales and can comprise the entire globe, biomes at the continental scale, or small, well-circumscribed systems such as a small pond.

Ecosystem Benefit: The value, expressed qualitatively, quantitatively, and/or in economic terms, where possible, associated with changes in ecosystem services that result either directly or indirectly in improved human health and/or welfare. Examples of ecosystem benefits that derive from improved air quality include improvements in habitats for sport fish species, the quality of drinking water and recreational areas, and visibility.

Ecosystem Function: The processes and interactions that operate within an ecosystem.

Ecosystem Services: The ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are (1) supporting services, such as productivity or biodiversity maintenance; (2) provisioning services, such as food, fiber, or fish; (3) regulating services, such as climate regulation or carbon sequestration; and (4) cultural services, such as tourism or spiritual and aesthetic appreciation.

Eutrophication: The process by which nitrogen additions stimulate the growth of autotrophic biota, usually resulting in the depletion of dissolved oxygen.

Nitrogen Enrichment: The process by which a terrestrial system becomes enhanced by nutrient additions to a degree that stimulates the growth of plant or other terrestrial biota, usually resulting in an increase in productivity.

Nitrogen Saturation: The point at which nitrogen inputs from atmospheric deposition and other sources exceed the biological requirements of the ecosystem; a level beyond nitrogen enrichment.

Occult Deposition: The removal of gases and particles from the atmosphere to surfaces by fog or mist.

Semi-arid Regions: Regions of moderately low rainfall, which are not highly productive and are usually classified as rangelands. "Moderately low" is widely accepted as between 100- and 250-mm precipitation per year.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by NO_x and/or SO_x pollution (e.g., acidification, nutrient enrichment). The effect may be direct (e.g., a change in growth in response to a change in the mean, range, or variability of nitrogen deposition) or indirect (e.g., changes in growth due to the direct effect of nitrogen consequently altering competitive dynamics between species and decreased biodiversity).

Total Reactive Nitrogen: This includes all biologically, chemically, and radiatively active nitrogen compounds in the atmosphere and biosphere, such as NH_3, NH^{4+}, NO, NO_2, HNO_3, N_2O, NO_3–, and organic compounds (e.g., urea, amines, nucleic acids).

Valuation: The economic or non-economic process of determining either the value of maintaining a given ecosystem type, state, or condition, or the value of a change in an ecosystem, its components, or the services it provides.

Variable Factors: Influences which by themselves or in combination with other factors may alter the effects on public welfare of an air pollutant (section 108 (a)(2))

(a) Atmospheric Factors: Atmospheric conditions that may influence transformation, conversion, transport, and deposition, and thereby, the effects of an air pollutant on public welfare, such as precipitation, relative humidity, oxidation state, and co-pollutants present in the atmosphere.

(b) Ecological Factors: Ecological conditions that may influence the effects of an air pollutant on public welfare once it is introduced into an ecosystem, such as soil base saturation, soil thickness, runoff rate, land use conditions, bedrock geology, and weathering rates.

Vulnerability: The degree to which a system is susceptible to, and unable to cope with, the adverse effects of NO_x and/or SO_x air pollution.

Welfare Effects: The effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate; as well as damage to and deterioration of property, hazards to transportation, and the effects on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants (Clean Air Act Section 302[h]).

Wet Deposition: The removal of gases and particles from the atmosphere to surfaces by rain or other precipitation.

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1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is conducting a review of the existing air quality criteria for nitrogen oxides (NO_x) and sulfur oxides (SO_x) and secondary (welfare-based) national ambient air quality standards (NAAQS) for nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). The purpose of this Integrated Review Plan (IRP) document is to communicate the plan for the joint review of the criteria and secondary NAAQS for these pollutants.[1]

The review will provide an integrative assessment of relevant scientific information for oxides of nitrogen and oxides of sulfur and will focus on the basic elements of the secondary NAAQS; the indicator[2], averaging time[3], form[4], and level.[5] These elements, which serve to define each ambient air quality standard, must be considered collectively in evaluating the welfare protection afforded by the standards. The current secondary standards are a NO_2 standard set at a level of 0.053 ppm, annual arithmetic average, and a SO_2 standard set at a level of 0.5 ppm, 3-hour average, not to be exceeded more than once per year.

In this document, the terms NO_2 and SO_2, and NO_x and SOx are not interchangeable. The use of NO_2 and SO_2 refers to the specific chemical species whereas the more general terms NO_x and SO_x which include many more chemical species than just NO_2 and SO_2 are used in this plan when discussing the consideration of adequacy of the current standards and the need for revised standard(s).[6]

Although EPA generally considers criteria and standards for each of the six criteria pollutants individually, for this secondary NAAQS review, as in the last review completed in 2012, the reviews for nitrogen oxide and sulfur oxide compounds are being conducted together in recognition of linkages between these pollutants and their associated particulates with respect

[1] The reviews of the primary NAAQS for NO_2 and for SO_2 are addressed in separate plans – add references to final IRP documents.
[2] The “indicator” of a standard defines the chemical species or mixture that is measured in determining whether an area attains the standard.
[3] The “averaging time” defines the time period over which ambient measurements are averaged (e.g., 1-hour, 8-hour, 24-hour, annual).
[4] The “form” of a standard defines the air quality statistic that is compared to the level of the standard in determining whether an area attains the standard.
[5] The “level” defines the allowable concentration of the criteria pollutant in the ambient air.
[6] Consideration of potential revised standards would include consideration of the indicator for the standards, might include oxides of nitrogen and sulfur other than NO2 and SO2.

to acid deposition and atmospheric chemistry, as well as from an environmental effects perspective (most notably in the case of acidic deposition). Addressing the pollutants together will enable us to take a comprehensive look at the nature and interactions of both pollutants, which may provide for policy options that lead to more appropriate or efficient protection.

This review plan is organized into six chapters. Chapter 1 presents background information on the NAAQS review process, the nature of the environmental effects of NO_x and SO_x, the legislative requirements for the review of the NAAQS, past reviews of the NAAQS for NO_2 and SO_2, and the proposed review schedule. Chapter 2 presents a set of policy-relevant questions that will serve to focus the NAAQS review process on the critical scientific and policy issues. Chapters 3 through 5 discuss the science, exposure/risk, and policy assessment portions of the review. Chapter 6 contains cited references. As the assessments proceed, the plan described here may be modified to reflect information received during the review process.

1.1 LEGISLATIVE REQUIREMENTS

Two sections of the Clean Air Act (CAA) govern the establishment and revision of the NAAQS. Section 108 (42 U.S.C. 7408) directs the Administrator to identify and list "air pollutants" that "in his judgment, 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" and to issue air quality criteria for those that are listed. Air quality criteria are intended to "accurately reflect the latest scientific knowledge useful in indicating the kind and extent of identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in ambient air . . ."

Section 109 (42 U.S.C. 7409) directs the Administrator to propose and promulgate "primary" and "secondary" NAAQS for pollutants listed under section 108. Section 109(b)(1) defines a primary standard as one "the attainment and maintenance of which in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect the public health."[7] A secondary standard, as defined in Section 109(b)(2), must "specify a level of air quality the attainment and maintenance of which, in the judgment of the

[7] The legislative history of section 109 indicates that a primary standard is to be set at "the maximum permissible ambient air level . . . which will protect the health of any [sensitive] group of the population," and that for this purpose "reference should be made to a representative sample of persons comprising the sensitive group rather than to a single person in such a group" [S. Rep. No. 91-1196, 91st Cong., 2d Sess. 10 (1970)].

Administrator, based on such criteria, is required to protect the public welfare from any known or anticipated adverse effects associated with the presence of [the] pollutant in the ambient air."[8]

In setting standards that are "requisite" to protect public health and welfare, as provided in section 109(b), EPA's task is to establish standards that are neither more nor less stringent than necessary for these purposes. In so doing, EPA may not consider the costs of implementing the standards. See generally *Whitman v. American Trucking Associations*, 531 U.S. 457, 465-472, 475-76 (2001).

Section 109(d)(1) requires that "not later than December 31, 1980, and at 5-year intervals thereafter, the Administrator shall complete a thorough review of the criteria published under section 108 and the national ambient air quality standards . . . and shall make such revisions in such criteria and standards and promulgate such new standards as may be appropriate . . .". Section 109(d)(2) requires that an independent scientific review committee "shall complete a review of the criteria . . . and the national primary and secondary ambient air quality standards . . . and shall recommend to the Administrator any new . . . standards and revisions of existing criteria and standards as may be appropriate . . .". Since the early 1980s, this independent review function has been performed by the Clean Air Scientific Advisory Committee (CASAC).

1.2 OVERVIEW OF THE NAAQS REVIEW PROCESS

The current process for reviewing the NAAQS includes four major phases: (1) planning, (2) science assessment, (3) risk/exposure assessment, and (4) policy assessment and rulemaking. Figure 1-1 provides an overview of this process, and each phase is described in more detail below.[9] The planning phase of the NAAQS review process begins with a science policy workshop, which is intended to identify issues and questions to frame the review. Drawing from the workshop discussions, a draft IRP is prepared jointly by the EPA's National Center for Environmental Assessment (NCEA), within the Office of Research and Development (ORD), and the EPA's Office of Air Quality Planning and Standards (OAQPS), within the Office of Air

[8] Welfare effects as defined in section 302(h) [42 U.S.C. 7602(h)] include, but are not limited to, "effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being."

[9] The EPA maintains a website on which key documents developed for NAAQS reviews are made available (http://www.epa.gov/ttn/naaqs/). The EPA's NAAQS review process has evolved over time. Information on the current process is available at: http://www.epa.gov/ttn/naaqs/review.html.

and Radiation (OAR). The draft IRP is made available for CASAC review and for public comment. The final IRP is prepared in consideration of CASAC and public comments. This document presents the current plan and specifies the schedule for the entire review, the process for conducting the review, and the key policy-relevant science issues that will guide the review.

The second phase of the review, science assessment, involves the preparation of an Integrated Science Assessment (ISA) and, if appropriate, supplementary materials. The ISA, prepared by NCEA, provides a concise review, synthesis, and evaluation of the most policy-relevant science, including key science judgments that are important to the design and scope of exposure and risk assessments, as well as other aspects of the NAAQS review. The ISA (and any supplementary materials that may be developed) provides a comprehensive assessment of the current scientific literature pertaining to known and anticipated effects on public health and/or welfare associated with the presence of the pollutant in the ambient air, emphasizing information that has become available since the last air quality criteria review in order to reflect the current state of knowledge. As such, the ISA forms the scientific foundation for each NAAQS review and is intended to provide information useful in forming judgments about air quality indicator(s), form(s), averaging time(s) and level(s) for the NAAQS. The current review process generally includes production of a first and second draft ISA, both of which undergo CASAC and public review prior to completion of the final ISA. Chapter 3 below provides a more detailed description of the planned scope, organization, and assessment approach for the ISA and any supporting materials that may be developed.

In the third phase, the risk/exposure assessment phase, OAQPS staff considers information and conclusions presented in the ISA, with regard to support provided for the development of quantitative assessments of the risks and/or exposures for health and/or welfare effects. As an initial step, staff prepares a planning document (the Risk and Exposure Assessment or REA Planning Document) that considers the extent to which newly available scientific evidence and tools/methodologies warrant the conduct of quantitative risk and exposure assessments. As discussed in Chapter 4 below, the REA Planning Document focuses on the degree to which important uncertainties in the last review may be addressed by new information available in this review. Specifically, the document considers the extent to which newly available data, methods, and tools might be expected to appreciably affect the assessment results or address important gaps in our understanding of the exposures and risks associated with nitrogen oxides and sulfur oxides. To the extent warranted, this document outlines a general plan, including scope and methods, for conducting assessments. When an assessment is performed, one or more drafts of each REA document undergoes CASAC and public review. The REA provides concise presentations of methods, key results, observations, and related uncertainties. Chapter 4 below discusses consideration of potential quantitative and qualitative welfare-related assessments for this review.

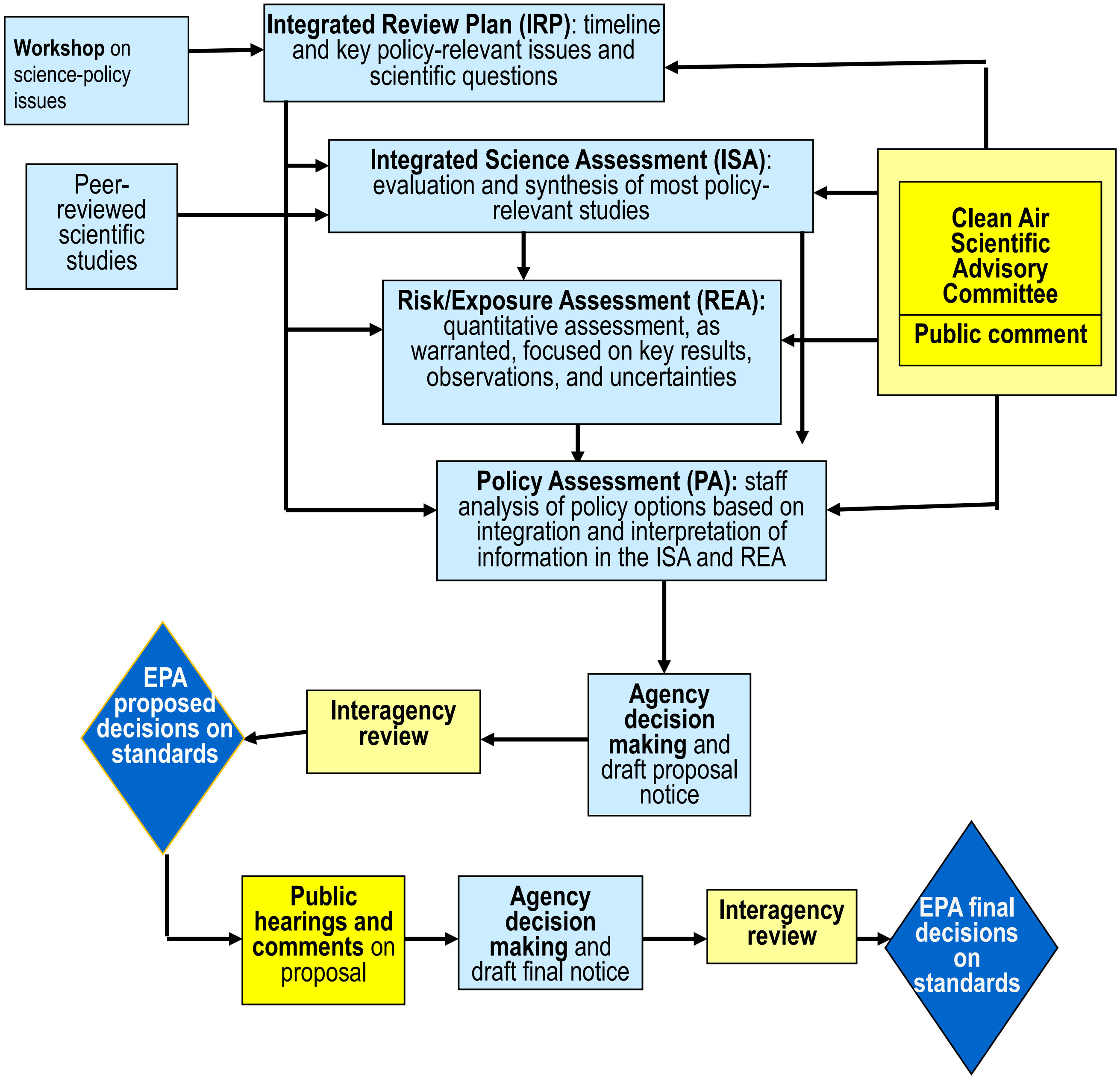


Figure 1-1. Overview of the NAAQS review process.

The review process ends with the policy assessment and rulemaking phase. The Policy Assessment (PA) is prepared prior to issuance of proposed and final rules. The PA provides a transparent presentation of OAQPS staff analyses and conclusions regarding the adequacy of the current standards and, if revision is considered, what revisions may be appropriate. The PA integrates and interprets the information from the ISA and REA to frame policy options for consideration by the Administrator. Such an evaluation of policy implications is intended to help ''bridge the gap'' between the Agency's scientific assessments, presented in the ISA and REA(s), and the judgments required of the EPA Administrator in determining whether it is appropriate to retain or revise the NAAQS. In so doing, the PA is also intended to facilitate CASAC's advice to the Agency and recommendations to the Administrator on the adequacy of the existing standards and, as pertinent, on revisions that may be appropriate to consider, as provided for in the CAA. In evaluating the adequacy of the current standards and, as appropriate, a range of potential alternative standards, the PA considers the available scientific evidence and, as available, quantitative risk and exposure analyses together with related limitations and uncertainties. The PA focuses on the information that is most pertinent to evaluating the basic elements of national ambient air quality standards: indicator, averaging time, form, and level. One or more drafts of a PA are released for CASAC review and public comment prior to completion of the final PA.

Following issuance of the final PA and consideration of conclusions presented therein, the Agency develops and publishes a notice of proposed rulemaking that communicates the Administrator's proposed decisions regarding the standards review. A draft notice undergoes interagency review involving other federal agencies prior to publication.[10] Materials upon which the proposed decision is based, including the documents described above, are made available to the public in the regulatory docket for the review.[11] A public comment period, during which public hearings are generally held, follows publication of the notice of proposed rulemaking. Taking into account comments received on the proposed rule,[12] the Agency develops a final rule which undergoes interagency review prior to publication to complete the rulemaking process. Chapter 5 below discusses the development of the PA and the rulemaking steps for this review.

1.3 REGULATORY HISTORY OF THE SECONDARY NAAQS FOR NO_2 AND SO_2

1.3.1 NO_2 NAAQS.

The first air quality criteria and standards for NOx were issued in 1971 (EPA, 1971; 36 FR 8186). Both the primary and secondary standards were set at 0.053 parts per million (ppm),

[10] Where implementation of the proposed decision would have an annual effect on the economy of $100 million or more (e.g., by necessitating the implementation of emissions controls), the EPA develops and releases a draft regulatory impact analysis (RIA) concurrent with the notice of proposed rulemaking. This activity is conducted under Executive Order 12866. The RIA is conducted completely independent of the rulemaking process and, by statute, is not considered in decisions regarding the review of the NAAQS.

[11] All documents in the docket are listed in the www.regulations.gov index. Publically available docket materials are available either electronically at www.regulations.gov or in hard copy at the Air and Radiation Docket and Information Center. The docket ID number for this review is EPA-HQ-OAR-2014-0128

[12] When issuing the final rulemaking, the Agency responds to all significant comments on the proposed rule.

as an annual arithmetic mean (36 FR 8186). In 1982, EPA published *Air Quality Criteria for Oxides of Nitrogen* (EPA, 1982), which updated the scientific criteria upon which the initial standards were based. On February 23, 1984, EPA proposed to retain these standards (49 FR 6866). After taking into account public comments, EPA published the final decision to retain the existing standards on June 19, 1985 (50 FR 25532).

In November 1991, EPA initiated another review and released an updated draft air quality criteria document (AQCD) for review and comment by CASAC and the public (56 FR 59285). The final AQCD was released later in 1993 (EPA, 1993). Staff of the OAQPS prepared a draft Staff Paper that summarized and integrated the key studies and scientific evidence contained in the revised air quality criteria document and identified the critical elements to be considered in the review of the NO_2 NAAQS. The Staff Paper was reviewed by the CASAC and the public in December 1994 and in September, 1995, EPA finalized the Staff Paper (EPA, 1995). On October 2, 1995, the Administrator announced her proposed decision not to revise either the primary or secondary NAAQS for NO_2 based on the information available in this review (60 FR 52874; October 11, 1995). After consideration of public comments, the Administrator made a final determination that revisions to neither the primary nor the secondary NAAQS for NO_2 were appropriate at that time (61 FR 52852, October 8, 1996).

The most recent review of the secondary NAAQS standards for oxides of nitrogen was performed jointly with a review of the secondary NAAQS for oxides of sulfur beginning in 2005 (described below).

1.3.2 SO_2 NAAQS.

Based on the 1970 sulfur oxides criteria document (DHEW, 1970), EPA promulgated the initial primary and secondary NAAQS for SO_2 on April 30, 1971 (36 FR 8186). The secondary standards were 0.02 ppm, as an annual arithmetic mean and 0.5 ppm, as a maximum 3-hr, not to be exceeded more than once per year. These secondary standards were established on the basis of vegetation effects evidence described in the 1970 criteria document. Based on additional data available in 1973, revisions were made to Chapter 5 "Effects of Sulfur Oxide in the Atmosphere on Vegetation" of the Air Quality Criteria for Sulfur Oxides (EPA 1973), which led the EPA to propose (38 FR 11355) and then finalize a revocation of the annual mean secondary standard (38 FR 25678). At that time, the EPA additionally considered welfare effects related to effects on materials, visibility, soils and water. However, the EPA concluded that either protection from such effects was afforded by the primary standard or that sufficient data were not then available to develop criteria for standards based on these effects (38 FR 25680).

In 1980, the EPA released a combined AQCD for sulfur oxides and particulate matter for CASAC review. Following its review of a draft revised criteria document in August, 1980, the CASAC concluded that acidic deposition was a topic of extreme scientific complexity, noting that a fundamental problem of addressing acid deposition in a criteria document is that acidic deposition is produced by several pollutants, including oxides of sulfur, oxides of nitrogen, and the fine particulate fraction of suspended particles (EPA, 1982, pp. 125-126). Following CASAC closure on the criteria document in December 1981, EPA released a final AQCD (EPA, 1982), and the OAQPS prepared a staff paper that was released in November, 1982 (USEPA, 1982). The issue of acidic deposition was not, however, assessed directly in the OAQPS staff paper because EPA followed the guidance given by CASAC.

In response to CASAC recommendations for a separate comprehensive discussion of acidic deposition as part of the criteria documents, EPA subsequently prepared the following documents: The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Review Papers, Volumes I and II (EPA, 1984), and The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Document (EPA, 1985) (53 FR 14935 -14936). Although these documents were not considered criteria documents and had not undergone CASAC review, they represented the most comprehensive summary of relevant scientific information completed by the EPA at that point (58 FR 21355).

At about the same time in 1980 as the CASAC recommendation for a comprehensive assessment of acidic deposition, Congress created the National Acid Precipitation Assessment Program (NAPAP). During the 10-year course of this program, a series of reports were issued and a final report was issued in 1990 (NAPAP, 1990).

On April 26, 1988, EPA proposed not to revise the existing primary and secondary standards. This proposal regarding the secondary SO_2 NAAQS was due to the Administrators conclusions that (1) based upon the then-current scientific understanding of the acidic deposition problem, it would be premature and unwise to prescribe any regulatory control program at that time, and (2) when the fundamental scientific uncertainties had been reduced through ongoing research efforts, EPA would draft and support an appropriate set of control measures (53 FR 14926). Subsequent to proposal, Congress took up consideration of acidic deposition.

On November 15, 1990, Amendments to the CAA were passed by Congress and signed into law by the President. In Title IV of these Amendments, Congress included a statement of findings that had led them to take this action, including that: "1) the presence of acidic compounds and their precursors in the atmosphere and in deposition from the atmosphere represents a threat to natural resources, ecosystems, materials, visibility, and public health; 2) the problem of acid deposition is of national and international significance; and that 3) current and future generations of Americans will be adversely affected by delaying measures to remedy the problem…". The goal of Title IV was to reduce emissions of SO_2 by 10 million tons and NO_x emissions by 2 million tons from 1980 emission levels in order to achieve reductions over broad geographic regions/areas. In envisioning that further action might be necessary in the long term, Congress included section 404 of the 1990 Amendments. This section requires the EPA to conduct a study on the feasibility and effectiveness of an acid deposition standard or standards to protect "sensitive and critically sensitive aquatic and terrestrial resources" and at the conclusion of the study, submit a report to Congress. Five years later EPA submitted to Congress its report titled *Acid Deposition Standard Feasibility Study: Report to Congress* (EPA, 1995) in fulfillment of this requirement. The Report to Congress concluded that establishing acid deposition standards for sulfur and nitrogen deposition might at some point in the future be technically feasible although appropriate deposition loads for these acidifying chemicals could not defined with reasonable certainty at that time.

The 1990 Amendments also added new language to sections of the CAA that pertain to the scope or application of the secondary NAAQS designed to protect the public welfare. Section 108 (g) specified that "the Administrator may assess the risks to ecosystems from exposure to criteria air pollutants (as identified by the Administrator in the Administrator's sole discretion)". The definition of public welfare in section 302 (h) was expanded to state that the welfare effects identified should be protected from adverse effects associated with criteria air pollutants"…whether caused by transformation, conversion, or combination with other air pollutants.

In response to these legislative initiatives, the EPA and other Federal agencies continued research on the causes and effects of acidic deposition and related welfare effects of SO_2 and implemented an enhanced monitoring program to track progress (58 FR 21357). In 1993, the EPA announced a decision not to revise the secondary standard, concluding that revision to address acidic deposition and related SO_2 welfare effects was not appropriate at that time (58 FR 21351). In reaching this decision, the EPA took into account the significant reductions in SO_2 emissions, ambient SO_2 concentrations and ultimately deposition expected to result from implementation of the title IV program, which was expected to significantly decrease the acidification of water bodies and damage to forest ecosystems and to permit much of the existing damage to be reversed with time (58 FR 21357). While recognizing that further action might be needed to address acidic deposition in the longer term, the EPA judged it prudent to await the results of the studies and research programs then underway, including those assessing the comparative merits of secondary standards, acidic deposition standards and other approaches to control of acidic deposition and related effects, and then to determine whether additional control measures should be adopted or recommended to Congress (58 FR 21358).

In 2000, the EPA announced receipt of two items related to acidic deposition and the NAAQS (65 FR 48699). The first was a petition submitted to the EPA in 1999 by representatives of seven northeastern states for the promulgation of revised secondary NAAQS for the criteria pollutants associated with the formation of acid rain (including NO_2, SO_2 and fine particulate matter, $PM_{2.5}$). The petition states that the language in section 302(h) of the CAA "clearly references the transformation of pollutants resulting in the inevitable formation of sulfate and nitrate aerosols and/or their ultimate environmental impacts as wet and dry deposition, clearly signaling Congressional intent that the welfare damage occasioned by sulfur and nitrogen oxides be addressed through the secondary standard provisions of Section 109 of the Act. The petition further stated that "recent federal studies, including the NAPAP Biennial Report to Congress: An Integrated Assessment, document the continued-and increasing-damage being inflicted by acid deposition to the lakes and forests of New York, New England and other parts of our nation, demonstrating that the Title IV program had proven insufficient." The petition also listed other adverse welfare effects associated with the transformation of these criteria pollutants, including visibility impairment, eutrophication of coastal estuaries, global warming, tropospheric ozone and stratospheric ozone depletion. The second item was a related request from the U.S. Department of Interior (DOI) that the EPA address many of the same adverse environmental effects associated with the same types of air pollutants, and with ozone that the DOI asserted were occurring in national parks and wilderness areas (65 FR 48699). Included among the effects of concern identified in the request were acidification of streams, surface waters and/or soils, eutrophication of coastal waters, visibility impairment, and foliar injury from ozone (65 FR 48701). The EPA requested comment on the issues raised by these requests, stating that it would consider any relevant comments and information submitted, along with the information provided by the petitioners and DOI, before making any decision concerning a response to these requests for rulemaking, which if commenced would include opportunity for public review and comment (65 FR 48701).

1.3.3 Most Recent Review of the NO_x and SO_x NAAQS

In 2005, EPA initiated a joint review of the air quality criteria for oxides of nitrogen and sulfur and the secondary NAAQS for NO_2 and SO_2. In so doing, the EPA assessed the scientific information, associated risks, and standards relevant to protecting the public welfare from adverse effects associated jointly with oxides of nitrogen and sulfur. Although EPA has historically adopted separate secondary standards for oxides of nitrogen and oxides of sulfur, EPA conducted a joint review of these standards because oxides of nitrogen and sulfur and their associated transformation products are linked from an atmospheric chemistry perspective, as well as from an environmental effects perspective. The joint review was also responsive to the National Research Council (NRC) recommendation for the EPA to consider multiple pollutants, as appropriate, in forming the scientific basis for the NAAQS (NRC, 2004).

The review was initiated in December 2005,[13] with a call for information (70 FR 73236) for the development of a revised ISA. A draft IRP was released in October 2007, reviewed by CASAC and the final IRP was released in December 2007 (U.S. EPA, 2007), as well as the ISA. The first and second drafts of the ISA were released in December 2007 and August 2008 (73 FR 10243) respectively for CASAC and public review. The final ISA (U.S. EPA, 2008) was released in December 2008 (73 FR 75716).

13 The review was conducted under a schedule specified by consent decree entered into by the EPA with the Center for Biological Diversity and four other plaintiffs. The schedule, which was revised on October 22, 2009 provided that the EPA sign notices of proposed and final rulemaking concerning its review of the oxides of nitrogen and oxides of sulfur NAAQS no later than July 12, 2011 and March 20, 2012, respectively.

Based on the scientific information in the ISA, the EPA developed a REA to further assess the national impact of the effects documented in the ISA. The Draft Scope and Methods Plan for Risk/ Exposure Assessment: Secondary NAAQS Review for Oxides of Nitrogen and Oxides of Sulfur outlining the scope and design of the future REA was released in March 2008 (U.S. EPA, 2008; 73 FR 10243). A first and second draft of the REA were released (August 2008 and June 2009) for CASAC review and public comment. The final REA (U.S. EPA, 2009) was released in September 2009. Drawing on the information in the final REA and ISA, a first and second draft PA were released in March 2010 and September 2010. The final PA was released in January 2011.

On August 1, 2011, based on consideration of the scientific information and quantitative assessments, the EPA published a proposal to retain the existing NO_2 and SO_2 secondary standards, and to also add secondary standards identical to the NO_2 and SO_2 primary 1-hour standards and not set a new multipollutant secondary standard in this review. After consideration of public comments on the proposed standards and on design of a new field pilot program to gather and analyze additional relevant data, the Administrator signed a final decision in this rulemaking on March 20, 2012. The Administrator's decision was that, while the current secondary standards were inadequate to protect against adverse effects from deposition of NO_x and SO_x, it was not appropriate under Section 109(b) to set any new secondary standards at this time due to the limitations in the available data and uncertainty as to the amount of protection the metric developed in the review would provide against acidification effects across the country (77 FR 20281). In addition, the Administrator decided that it was appropriate to retain the current NO_2 and SO_2 secondary standards to address direct effects of gaseous NO_2 and SO_2 on vegetation. Thus, taken together, the Administrator decided to retain and not revise the current NO_2 and SO_2 secondary standards: a NO_2 standard set at a level of 0.053 ppm, as an annual arithmetic average, and a SO_2 standard set at a level of 0.5 ppm, as a 3-hour average, not to be exceeded more than once per year (77 FR 20281).

The EPA's decision to not set a secondary NAAQS for NOx and SOx even though the Administrator had concluded that the existing standards are not adequate to protect against the adverse impacts of aquatic acidification on sensitive ecosystems was challenged by the Center for Biological Diversity and other environmental groups. The petitioners argued that having decided that the existing standards were not adequate to protect against adverse public welfare effects such as damage to sensitive ecosystems, the Administrator was required to identify the requisite level of protection for the public welfare and to issue a NAAQS to achieve and maintain that level of protection. The D.C. Circuit disagreed, finding that EPA acted appropriately in not setting a secondary standard given the EPA's conclusions that "the available information was insufficient to permit a reasoned judgment about whether any proposed standard would be 'requisite to protect the public welfare . . .'" Center for Biological Diversity, et al. v. EPA, 749 F.3d 1079, 1087 (2014). In reaching this decision, the court noted that EPA had "explained in great detail" the profound uncertainties associated with setting a secondary NAAQS to protect against aquatic acidification. Id. at 1088.

1.4 SCOPE OF THE CURRENT REVIEW

In the current review of the secondary NAAQS for NO_x and SO_x, EPA will assess the relevant scientific information regarding the welfare effects associated with NOx and SOx in ambient air, including those effects associated with the deposition of these pollutants and their transformation products. In addition to the deposition-related effects, the longstanding evidence has established there to be direct effects on vegetation associated with exposure to gas-phase oxides of nitrogen and sulfur in the ambient air. Protection against these effects that arise from direct contact with each of these pollutants separately in ambient air has been the focus in the setting of the current NO_2 and SO_2 secondary standards. As noted in the context of past review in section 1.3 above and summarized in more detail with regard to the most recent review in section 2.1 below, consideration of deposition-related processes and effects is appreciably more complex. Some key aspect are identified here.

- Oxides of nitrogen and sulfur are emitted into and occur in the air in both gaseous and particulate form.
- Processes associated with atmospheric chemistry and meteorology influence transformations, particle size, and transport, as well as deposition rates.
- Nitrogen and sulfur oxides differ with regard to their contribution to total nitrogen and sulfur deposition. While oxides of sulfur in ambient air account for nearly all sulfur deposition in the U.S., both oxides of nitrogen and also reduced nitrogen contribute to atmospheric deposition of nitrogen.
- Well recognized ecosystem effects to which deposition of nitrogen and sulfur oxides contribute, together or singly, include acidification, nutrient enrichment and facilitation of mercury methylation.

- Both nitrogen and sulfur contribute to ecosystem acidification.
- Deposition of nitrogen contributes to nitrogen-nutrient enrichment and eutrophication.
- Sulfate deposition affects mercury methylation in aquatic ecosystems.

- A multitude of factors contribute to a wide variation in ecosystem response to nitrogen and sulfur deposition.

1.5 REVIEW SCHEDULE

In August 2013, EPA's NCEA in Research Triangle Park, NC announced the official initiation of the current joint periodic review of air quality criteria for NO_x and SO_x. The Agency began by announcing in the Federal Register (78 FR 53452) the formal commencement of the review and a call for information. The projected schedule for the four phases of the review is shown in Table 1-1.

Table 1-1. Schedule for Review of Ambient Air Quality Criteria and NAAQS for NO_x and SO_x.

Stage of Review	Major Milestone	Target Dates
Integrated Plan	Literature Search	*Ongoing*
	Federal Register Call for Information	*August 2013*
	Workshop on science/policy issues	*March 4-6, 2014*
	Draft Integrated Review Plan (IRP)	November 2015
	CASAC consultation on IRP	December 1, 2015
	Final IRP	May 2016
Science Assessment	First draft of ISA	July 2016
	CASAC public meeting for review of first draft ISA	September 2016
	Second draft of ISA	June 2017
	CASAC/public review of second draft ISA	August 2017
	Final ISA	December 2017
Risk/Exposure Assessment	Planning document	November 2016
	CASAC public meeting for consultation on planning document	December 2016
	First draft of Risk and Exposure Assessment (REA)	July 2017
	CASAC/public review of first draft REA	August 2017
	Second draft of REA	January 2018
	CASAC/public review of second draft REA	March 2018
	Final REA	September 2018
Policy Assessment	First draft of Policy Assessment (PA)	February 2018
	CASAC/public review of first draft PA	March 2018
	Second draft of PA	September 2018
	CASAC/public review of second draft PA	October 2018
	Final PA	April 2019
Rulemaking	Notice of proposed rulemaking	May 2019
	Notice of final rulemaking	April 2020

2. KEY POLICY-RELEVANT ISSUES

In each NAAQS review, an initial step is to address the following overarching question:

- **Does the currently available scientific evidence and exposure/risk-based information support or call into question the adequacy of the protection afforded by the current standard(s)?**

As appropriate, reviews also address a second overarching question:

- **What alternative standards, if any, are supported by the currently available scientific evidence and exposure/risk-based information and are appropriate for consideration?**

To inform our evaluation of these overarching questions in the current review, we have identified key policy-relevant issues to be considered. These key issues reflect aspects of the welfare effects evidence, air quality information, and exposure/risk information that, in our judgment, are likely to be particularly important to inform the Administrator's decisions. They build upon the key issues that were important in previous reviews.

This combined review of the secondary standards for NO_x and SO_x allows for consideration of the combined as well as individual effects on atmospheric chemistry and public welfare, especially with respect to acid deposition. For example, acidification in an aquatic ecosystem depends on the total acidifying potential of the nitrogen and sulfur deposition resulting from oxides of nitrogen and sulfur as well as the inputs from other sources of nitrogen and sulfur such as reduced nitrogen and non-atmospheric sources. It is the joint impact of the two pollutants that determines the ultimate effect on organisms within the ecosystem, and critical ecosystem functions such as habitat provision and biodiversity.

Section 2.1 below describes the key considerations and conclusions from the last review with regard to the adequacy of the secondary standards for NO_x and SO_x (section 2.1), as well as some key areas of uncertainty in the last review for determining the elements for a revised standard judged to provide requisite public welfare protection (section 2.1.2). Section 2.2 summarizes our general approach for reviewing the secondary standards for NO_x and SOx in the current review and outlines the key policy-relevant issues. These issues are presented as a series of policy-relevant questions that will frame our approach and be addressed in detail in the science assessment, risk assessment, and policy assessment sections of the review.

2.1 CONSIDERATIONS AND CONCLUSIONS IN LAST REVIEW

Key policy-relevant aspects of the Administrator's decisions with regard to the adequacy of the secondary standards for SO2 and NO2, and her consideration of revised or additional standards, are described in section 2.1.1 below. Areas of uncertainty identified in the last review are summarized in section 2.1.2.

2.1.1 Adequacy of the Existing Standards and Consideration of Alternatives

The last review of the secondary NAAQS for NO_2 and SO_2 was completed in 2012 (77 FR 20218). In that review, the EPA considered the scientific evidence on deposition-related and other (direct) effects of oxides of nitrogen and sulfur in addition to the results of quantitative analyses of deposition-related effects. As described in section 1.3 above, this was the first time that the Agency had considered deposition-related information for these pollutants in such a manner. Taking into account all of this information, the Administrator's decision in the review was to retain the existing standards (53 ppb NO_2 as an annual average and 0.5 ppm SO_2, as a 3-hour average concentration not to be exceeded more than once per year) based on the conclusion that they are adequate to protect against the phytotoxic effects associated with direct contact of vegetation with NO_2 and SO_2 in ambient air.

With regard to deposition-related effects, the Administrator considered the full nature of ecological effects related to the deposition of ambient oxides of nitrogen and sulfur into sensitive ecosystems across the U.S. Based on such consideration, she concluded that the current secondary standards are neither appropriate nor adequate to protect from deposition-related effects such as those associated with acidification of aquatic and terrestrial ecosystems and nutrient enrichment of terrestrial and estuarine ecosystems (77 FR 20241-20242). However, after considering potential alternative standards, including such standards based on the AAI approach, the Administrator concluded that the current limitations in relevant data and the uncertainties associated with specifying the elements of the AAI are of such nature and degree as to prevent her from reaching a reasoned judgment as to what level and form of an AAI-based standard would provide the degree of protection from effects on the public welfare that the Administrator determined was requisite (77 FR 20262). With respect to the various elements of the AAI, uncertainties were generally related to limitations in available field data as well as uncertainties that are related to reliance on the application of ecological and atmospheric modeling at the ecoregion scale.

The Administrator additionally considered the option of setting new secondary standards identical to the current 1-hour NO_2 and SO_2 primary standards. She recognized, however, that the available information did not support a demonstrable linkage between 1-hour average concentrations of these pollutants in ambient air and the impact of longer-term deposition-related acidification associated with oxides of nitrogen and sulfur on sensitive aquatic ecosystems. As a result, the Administrator concluded there was no basis for a reasoned judgment as to what levels of 1-hour NO_2 and SO_2 standards would be requisite to protect public welfare. Accordingly, the overall decision for the review was to retain the existing secondary standards without revision or augmentation (77 FR 20264).

2.1.2 Key areas of uncertainty

In the previous review, the Agency recognized several key uncertainties including several important limitations in the available data. These limitations introduced significant uncertainty in understanding the representativeness of data particularly for areas of the country for which there was poor spatial coverage. With respect to air quality data, these uncertainties included limitations in air quality data specifically related to dry deposition and ammonia, as well as uncertainties in translating atmospheric concentrations to deposition.

Additional areas of uncertainty were also identified as they related to the five main effects categories: (1) aquatic acidification; (2) terrestrial acidification; (3) aquatic eutrophication; (4) terrestrial eutrophication; and (5) mercury methylation. These uncertainties generally related to limited information on: (1) the extent of sensitivity of the ecoregion to the effect, including response to long-term exposure of elevated deposition levels; (2) the relationship between the effect category and effects on ecosystem services; (3) the ability to characterize adverse effects across ecosystems and across multiple media. These are discussed in more detail in Section 4.1.

2.2 GENERAL APPROACH FOR THE CURRENT REVIEW

The approach for this review builds on the substantial body of information developed in the last review, taking into account the significant quantity and scope of recent scientific information and air quality data now available to inform our understanding of the key policy-relevant issues. The approach described below is most fundamentally based on using the EPA's assessment of the current scientific evidence and associated quantitative analyses to inform the Administrator's decisions regarding secondary standards for oxides of nitrogen and oxides of sulfur that are requisite to protect the public welfare from adverse effects. We recognize that the Administrator's decision will draw on the scientific evidence and quantitative analyses available in the review, as well as judgments about the appropriate weight to place on the range of uncertainties inherent in the evidence and analyses and public welfare policy judgments. To inform the Administrator's judgments, this approach involves translating scientific and technical information into the basis for addressing a series of key policy-relevant questions using both evidence- and exposure/risk-based considerations. Figure 2-1 summarizes the general approach, including consideration of the policy relevant questions which will frame the current review.

The ISA, REA and PA developed in this review will provide the basis for addressing the key policy-relevant questions and will inform the Administrator's judgments on the adequacy of the current secondary NO_2 and SO_2 standards and consideration, as appropriate, of alternative standards. This approach recognizes that the available ecosystem effects evidence generally reflects a broad and diverse set of endpoints and includes the consideration of critical loads developed for such endpoints across varying types of ecosystems. This approach is consistent with the requirements of the NAAQS provisions of the CAA and with how the EPA and the courts have historically interpreted the CAA. As discussed in section 1.1 above, these provisions require the Administrator to establish secondary standards that, in the Administrator's judgment, are requisite to protect public welfare. In so doing, the Administrator seeks to establish standards that are neither more nor less stringent than necessary for this purpose. The four basic elements of the NAAQS (i.e., indicator, averaging time, form, and level) are considered collectively in evaluating the public welfare protection afforded by the current and, as appropriate, potential alternative standards.

We note that the final decision on the adequacy of the current standards and, as appropriate, revision of these standards, is largely a public welfare policy judgment to be made by the Administrator. The Administrator's final decision must draw upon scientific information and analyses about ecosystem effects, exposure and risks, as well as judgments about how to consider the range and magnitude of uncertainties that are inherent in the scientific evidence and analyses. As in the previous review, as well as other recent NAAQS reviews, the EPA will consider the implications of placing more or less weight or emphasis on different aspects of the scientific evidence and exposure/risk-based information to inform the public welfare policy judgments that the Administrator will make in reaching final decisions on whether to retain or revise the current standards in this review. Evidence-based considerations include those related to the ecosystem effects evidence assessed and characterized in the ISA. Exposure/risk-based considerations draw from the results of the quantitative analyses.

This second joint review of the air quality criteria for NOx and SOx and the secondary NO_2 and SO_2 NAAQS will build off and expand the analyses and assessments conducted in the first review. This review will focus on welfare effects due to deposition rather than on the effects of particulate NO_x and SO_x in the atmosphere. Welfare effects associated with visibility will be addressed in the secondary PM NAAQS review. Additionally, the scope of this review will not include further discussion of acid deposition on man-made materials and structures. The current review will build on the last review's focus on sensitive ecosystems and species, and the linkages between ambient levels of nitrogen and sulfur and the critical loads of deposition that create adverse effects in those ecosystems and species.

2.2.1 Key considerations for the Current Review

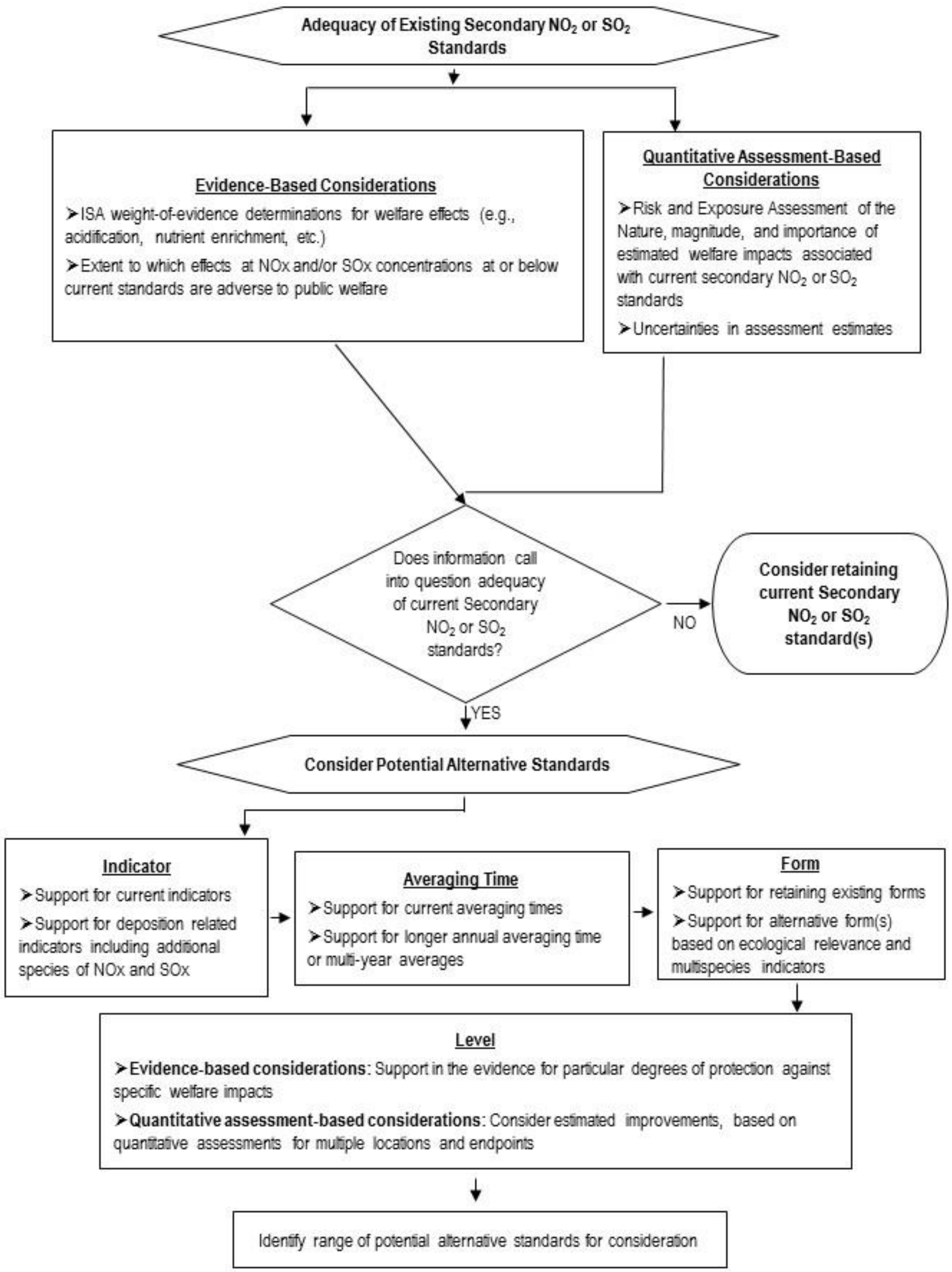
A key consideration for the review is the recognition that the effects of NO_x and SO_x compounds on aquatic and terrestrial ecosystems are diverse and occur over time as a result of deposition, include acidification and fertilization effects, are regionally specific, and occur through the atmospheric reactions, transport, and deposition of NO_x and SO_x compounds emitted from varied and ubiquitous sources. The links in the fate, transport, and deposition of the pollutants apply to both acidification and fertilization effects (which are understood to capture both eutrophication in aquatic systems and fertilization in terrestrial systems). While reviewing the pollutants together may incorporate a more holistic view of the effects of these compounds on the environment with regard to certain effects (particularly acidification), the issue of an appropriate indicator(s) is an important consideration especially with regard to effects other than acid deposition. Accordingly, the review will include particular consideration of the appropriate indicator(s) for secondary standards that protect the public welfare from adverse effects of NO_x and SO_x. In evaluating environmental responses to these pollutants, the review will consider the variability of environmental characteristics of ecosystems across the nation, including those related to ecosystem susceptibility and the relative importance of individual impacts versus combined impacts to a given ecosystem.

As described in section 1.1 above, secondary NAAQS “specify a level of air quality the attainment and maintenance of which, in the judgment of the Administrator, [based on the current scientific information], is required to protect the public welfare from any known or anticipated adverse effects associated with the presence of [the] pollutant in the ambient air.” Accordingly, the Administrator’s judgments regarding effects that are adverse to the public welfare is an important aspect of each secondary standard review. According to the Clean Air Act, welfare effects include: effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effect on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants (CAA, Section 302(h)). The Act provides no specific definition of public welfare or of adversity to public welfare, although the paradigm of adversity to public welfare as deriving from disruptions in ecosystem structure and function has been used broadly by EPA in prior reviews (e.g., the just completed review of the secondary standard for ozone). An evaluation of adversity to public welfare might consider the likelihood, type, magnitude, and spatial scale of the effect as well as the potential for recovery and any uncertainties relating to these considerations. Because oxides of nitrogen and sulfur are deposited from ambient sources into ecosystems where they affect changes to organisms, populations and ecosystems, the concept of adversity to public welfare as related to impacts on the public from alterations in structure and function of ecosystems would seem appropriate for this review. In addition, the Administrator in past NAAQS decisions has given particular consideration to ecological effects in areas with special federal protections, and lands set aside by states, tribes and public interest groups to provide similar benefits to the public welfare (e.g. 73 FR 16496, March 27, 2008). Such areas include

Class I areas[14] which are federally mandated to preserve certain air quality related values. Other information that may be helpful to consider includes the role of critical loads and ecosystem service impacts as benchmarks or measures of impacts on ecosystems that may be important to the public welfare.

Ecosystem services can be related directly to concepts of public welfare to inform discussions of societal impacts. Ecosystem services can be generally defined as the benefits individuals and organizations obtain from ecosystems. Ecosystem services can be classified as provisioning (food and water), regulating (control of climate and disease), cultural (recreational, existence, spiritual, educational), and supporting (nutrient cycling) (MEA 2005). Conceptually, changes in ecosystem services may be used to aid in considering the significance of particular effects on the public welfare. In the context of this review, ecosystem services may also aid in assessing the magnitude and significance to the public of a resource and in considering how oxides of nitrogen and sulfur concentrations and deposition may impact the public welfare through effects on that resource.

14 Areas designated as Class I include all international parks, national wilderness areas which exceed 5,000 acres in size, national memorial parks which exceed 5,000 acres in size, and national parks which exceed six thousand acres in size, provided the park or wilderness area was in existence on August 7, 1977. Other areas may also be Class I if designated as Class I consistent with the Act.



1 **Figure 2-1. Overview of General Approach for Review of Secondary NO_x and SO_x Standards**

2.2.1 Policy Relevant Questions

For the of the air quality criteria for NOx and SOx and the secondary NAAQS for NO_2 and SO_2, the most significant policy-relevant questions are:

I. To what extent has the new information altered the scientific support for the occurrence of effects related to exposure to oxides of nitrogen and oxides of sulfur in the ambient air?

II. To what extent is information available to improve our understanding of the scope of welfare effects of ambient NO_x and SO_x, including those from eutrophication, acidification, mercury methylation, and direct vegetative exposures?

   a. What information is available that can inform the nature and magnitude of ecosystem responses to NO_x and SO_x in the atmosphere and associated deposition? What is the variability associated with those responses (including ecosystem type, climatic conditions, environmental effects and interactions with other environmental factors and pollutants)? What information is available to inform our understanding of levels of deposition associated with effects of concern? What components of total reactive nitrogen deposition need to be considered?

   b. What types of ecological effects can be quantitatively related to NO_x and SO_x in ambient air and associated deposition? What metrics (e.g. particular ecosystems services) are available that can describe incremental changes in ecological function in a public welfare context? What information is available to inform judgments of adversity to public welfare?

   c. What exposure metrics for SO_x and NO_x have been established to quantitatively characterize ecosystem effects? Are there exposure metrics established for total reactive nitrogen (NO_x plus reduced forms of nitrogen)?

   d. To what extent do analyses suggest that exposures of concern for effects on public welfare are likely to occur under conditions that meet the current standards for oxides of nitrogen and sulfur? Are these risks/exposures of sufficient magnitude such that the welfare effects might reasonably be judged to be important to the public welfare? What are the important uncertainties associated with these risk/exposure estimates?

If the evidence suggests that revision of the current standards might be appropriate to consider, the review will consider a second overarching question. Specifically, we will evaluate how the scientific information and assessments inform decisions regarding the basic elements of the secondary NO_2 and SO_2 NAAQS: indicator, averaging time, level, and form. These elements will be considered collectively in evaluating the welfare protection afforded by the current or, as appropriate, potential alternative standards. With regard to consideration of potential alternative standards, specific policy-relevant questions include the following:

- To what extent does any new information provide support for consideration of a different *indicator* for oxides of nitrogen and oxides of sulfur in addition to or in place of NO_2 and SO_2?
- To what extent does the welfare effects evidence evaluated in the ISA and REA provide support for considering any different *averaging times and/or forms*?
- What range of alternative standard *levels* should be considered based on the scientific evidence and air quality analyses evaluated in the ISA and REA?
- What are the important uncertainties and limitations in the available evidence and assessments and how might those uncertainties and limitations be taken into consideration in identifying alternative standard *indicators, averaging times, forms and/or levels*?
- Based on the scientific evidence and air quality analyses evaluated in the ISA and REA, is it more appropriate to set a joint NO_x and SO_x standard or separate NO_x and SO_x standards?

These questions will frame the assessment of the evidence in the ISA, development of quantitative analyses for the REA and evaluation of policy options in the PA.

3. DEVELOPMENT OF THE INTEGRATED SCIENCE ASSESSMENT

The ISA comprises the science assessment phase of the NO_X and SO_X NAAQS secondary review. As described in section 1.4 above, this assessment focuses on updating the air quality criteria associated with ecological evidence to inform the review of the secondary NO_x and SO_X standard only.[15]

3.1 SCOPE

The ISA will critically evaluate and integrate the scientific information on the ecological effects associated with ambient air NO_x and SO_X and their deposition and other their products from the air. Discipline areas included will be atmospheric science, biogeochemistry, plant and animal physiology, ecotoxicology, population ecology and ecosystem services. The purpose is to synthesize the current state of knowledge on the most relevant issues pertinent to the review of the secondary NAAQS for NO_X and SO_X, to identify changes in the scientific evidence base since the previous review, and to describe remaining or newly identified uncertainties. The ISA discussions will be designed to focus on the key policy-relevant questions described in Section 3.4.

The current ISA will evaluate the literature published since the 2008 NO_X and SO_X ISA and incorporate this newer evidence with evidence considered in the last review. Key findings, and conclusions from the 2008 ISA for NO_X and SO_X will be briefly summarized at the beginning of the ISA and in individual sections. The results of recent studies will be integrated with previous findings. In evaluation of studies, emphasis will be placed on those that examine ecosystem effects in response to NO_X and SO_X concentrations and deposition.

[15]Note that evidence related to health effects of NO_X and SO_X will be considered separately in the science assessment conducted as part of the reviews of the primary NAAQS for NO_2 and SO_2.

3.2 ORGANIZATION

The organization of the ISA will begin with a discussion of major legal and historical aspects of prior review documents associated with NO_X and SO_X, as well as procedures for the assessment of scientific information. An integrative synthesis chapter will summarize the key information for each topic area, the causal determinations for relationships between NO_X and SO_X and ecological effects, information describing the extent to which ecological effects can be attributable specifically to NO_X and SO_X, and other uncertainties related to the interpretation of scientific information. The integrative synthesis chapter also will present a discussion of policy-relevant issues such as the concentration-response relationships, and the ecological significance of effects associated with NO_X and SO_X. Subsequent chapters are organized by subject area and contain the detailed evaluation of results of recent studies integrated with previous findings (see section 4.4 for specific issues to be addressed). Sections for each major ecological effect category conclude with a causal determination about the relationship with NO_X and SO_X, or an associated chemical indicator. The ISA will conclude with a chapter that examines ecological effects data to draw conclusions about potential at-risk species, ecosystem services and regions. The ISA may be supplemented with additional materials if required to support information contained within the ISA. These supplementary materials may include more detailed and comprehensive coverage of relevant publications and may accompany the ISA or be available in electronic form as output from the Health and Environmental Research Online (HERO) database developed by EPA (http://hero.epa.gov/). Supplementary information available in the HERO database will be presented as electronic links in the ISA.

3.3 ASSESSMENT APPROACH

The NCEA is responsible for preparing the ISA for NO_X and SO_X. In each NAAQS review, development of the science assessment begins with a "Call for Information" published in the *Federal Register*. This notice announces EPA's initiation of activities in the preparation of the ISA for the specific NAAQS review and invites the public to assist through the submission of research studies in the identified subject areas. This and subsequent key components of the process currently followed for the development of an ISA (i.e., the development process) are presented in Figure 3.1 and are described in greater detail in the Preamble to the ISA for NOx-

Human Health Criteria (U.S. EPA, 2015). How the ISA fits into the larger NAAQS review process is briefly described in Section 1.2, the Overview of the Review Process.

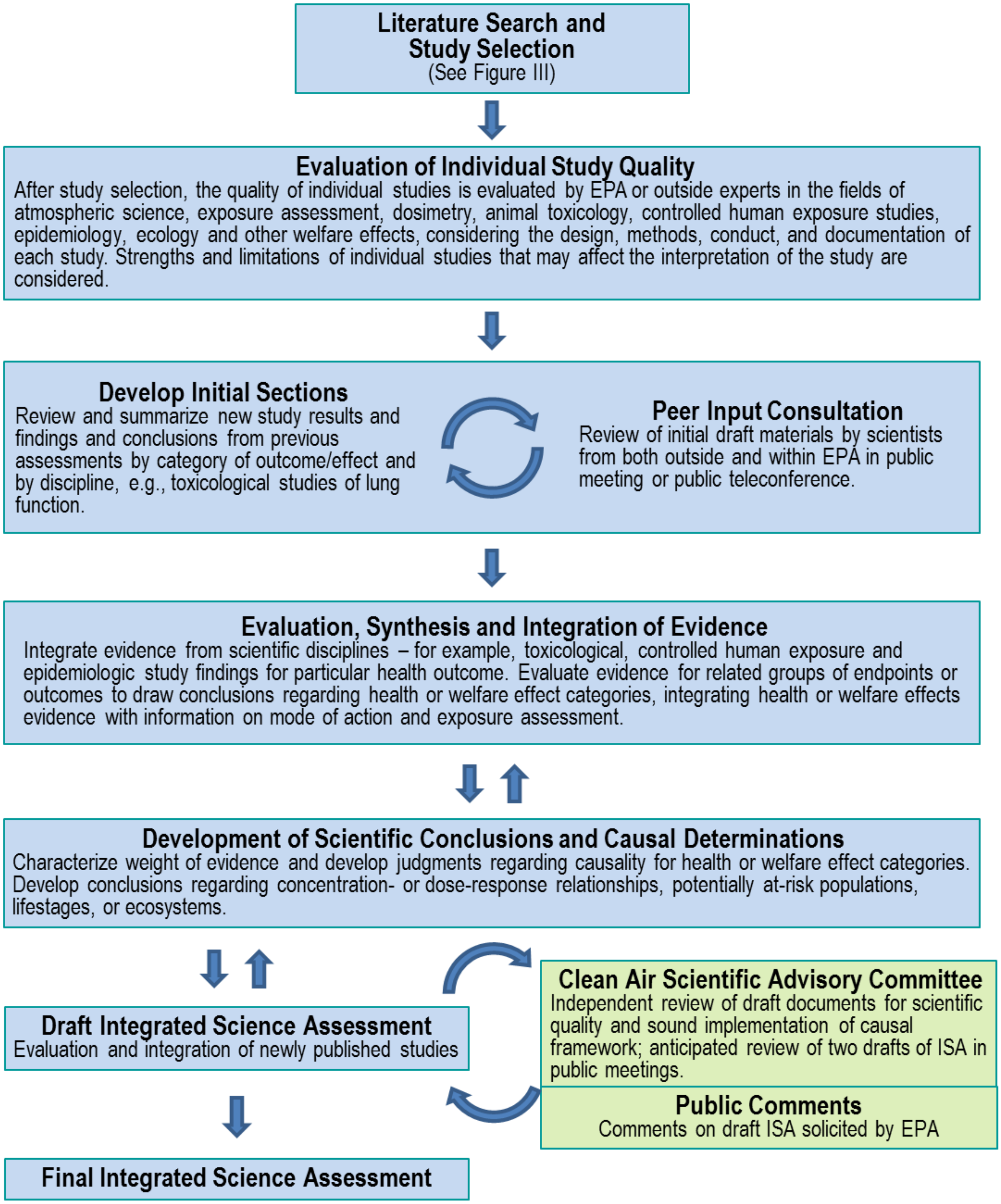


Figure 3.1. General Process for Development of Integrated Science Assessments (ISAs) (Modified from the Preamble to the ISA for NOx-Human Health Criteria, U.S. EPA, 2015)

Important aspects of the development of the ISA are described in the sections below, including the approach for searching the literature, identifying relevant publications, evaluating individual study quality, synthesizing and integrating the evidence, and developing scientific conclusions and causality determinations. These responsibilities are undertaken by subject-matter experts, who author ISA chapters. These experts include EPA staff with extensive knowledge in their respective fields and extramural scientists solicited by EPA for their expertise in specific fields. This section of the IRP also presents specific policy-relevant questions developed from input received at the NO_X and SO_X workshop on science policy issues. These questions are intended to guide the development of the ISA. The process for scientific and public review of drafts of the ISA is described in Section 3.4.

3.3.1 Literature Search and Selection of Relevant Studies

The NCEA uses a structured approach to identify relevant studies for consideration and inclusion in the ISA. As previously mentioned, a *Federal Register* Notice is published to announce the initiation of a review and to request information, including relevant literature, from the public. The EPA maintains an ongoing, multi-tiered literature search process that includes extensive manual and computer-aided citation mining of databases on specific topics in a variety of disciplines. The search strategies are designed a priori and iteratively modified to optimize identification of pertinent publications. In addition, papers are identified for inclusion in several other ways: specialized searches on specific topics; relational searches that identify recent publications that have cited references from previous assessments; identification of relevant literature by external scientific experts; recommendations from the public and CASAC during the call for information and external review process; and review of citations in previous assessments. The studies identified will include research published or accepted for publication from January 2008, which slightly precedes the publication end date for studies reviewed in the 2008 NO_X and SO_X ISA, through approximately two months before the release of the second external review draft of the ISA (target of summer 2016, see Table 2-1).

References identified through this multipronged search strategy are reviewed for relevance. Some publications are excluded based on screening of the title. Publications considered for inclusion in the ISA after reading the title are listed in the Health and Environmental Research Online (HERO) database (http://hero.epa.gov). Studies and reports that have undergone scientific peer review and have been published or accepted for publication are considered for inclusion in the ISA.

From the group of considered references, references are selected for inclusion in the ISA based on review of the abstract and full text. The references cited in the ISA include a hyperlink to the HERO database. The selection process is based on the extent to which the study is potentially informative, pertinent, and policy-relevant. These studies include those that provide a basis for or describe the relationship between the criteria pollutant and effects, in particular, those studies that offer innovation in method or design and studies that reduce uncertainty on critical issues. Uncertainty can be addressed, for example, by analyses of potential confounding or effect modification by co-pollutants or other factors, analyses of concentration-response or dose-response relationships, or analyses related to time between deposition and response. Evidence from previous studies (prior to January 2008) will be included to integrate with results from recent studies, and in some cases, characterize the key policy-relevant information in a particular subject area. Analyses conducted by the EPA using publicly available data, for example, air quality and emissions data, are also considered for inclusion in the ISA. The combination of approaches described above is intended to produce the comprehensive collection of pertinent studies needed to address the key scientific issues that form the basis of the ISA.

3.3.2 Evaluation of Individual Study Relevance and Quality

After selecting studies for inclusion, individual study quality is evaluated by considering the design, methods, conduct, and documentation of each study, but not the study results. This uniform approach aims to consider the strengths, limitations, and possible roles of chance, confounding, and other biases that may affect the interpretation of the results from individual studies. In assessing the scientific quality of studies, the following parameters are considered:

How clearly were the study design, study groups, methods, data, and results presented to allow for study evaluation?

To what extent are the air quality data and deposition metrics of adequate quality to serve as credible exposure indicators?

Were the study populations or model organisms adequately selected, and are they sufficiently well-defined to allow for meaningful comparisons between study or exposure groups?

Are the statistical analyses appropriate, properly performed, and properly interpreted?

Are likely covariates (i.e., potential confounding factors, modifying factors) adequately controlled for or taken into account in the study design or statistical analyses?

Are the ecological endpoint measurements meaningful, valid, and reliable?

Additional considerations specific to particular scientific disciplines are discussed below.

Atmospheric Science

Atmospheric science studies focus on sources, chemical transformations of emissions, transport of emitted pollutants and their reaction products, techniques for measuring concentrations and deposition of reactive nitrogen (N_r)and sulfur oxides using quality-assured field, experimental, and/or modeling techniques. The most informative measurement-based studies will include detailed descriptive statistics and include a clear and comprehensive description of measurement techniques and quality control procedures used. The most informative modeling-based studies will incorporate appropriate chemistry, transport, dispersion, and/or deposition modeling techniques with a clear and comprehensive description of model science, evaluation procedures, and metrics.

Ecological Effects Assessment

For ecological effects assessment, both laboratory and field studies (including field experiments and observational studies) can provide useful data for causality determination. Because conditions can be controlled in laboratory studies, responses may be less variable and smaller differences may be easier to detect. However, the control conditions may limit the range of responses (e.g., animals may not be able to seek alternative food sources) or incompletely reflect pollutant bioavailability, so they may not reflect responses that would occur in the natural environment. In addition, larger-scale processes are difficult to reproduce in the laboratory. Field observational studies measure biological changes in uncontrolled situations, and describe an association between a disturbance and an ecological effect. Field data can provide important information for assessments of multiple stressors or where site-specific factors significantly influence exposure. They are also often useful for analyses of larger geographic scales and higher levels of biological organization. However, because conditions are not controlled, variability is expected to be higher and differences harder to detect. Field surveys are most useful for linking stressors with effects when stressor and effect levels are measured concurrently. The presence of confounding factors can make it difficult to attribute observed effects to specific stressors.

Some studies are considered "intermediate" and are categorized as being between laboratory and field studies. Some use environmental media collected from the field to examine the responses in the laboratory. Others are experiments that are performed in the natural environment while controlling for some, but not all, of the environmental conditions (i.e., mesocosm studies). This type of study in manipulated natural environments can be considered a hybrid between a field experiment and laboratory study since some aspects are performed under controlled conditions but others are not. They make it possible to observe community and/or ecosystem dynamics, and provide strong evidence for causality when combined with findings of studies that have been made under more controlled conditions.

3.3.3 Integration of Evidence and Determination of Causality

EPA has developed a consistent and transparent basis for integration of scientific evidence and evaluation of the causal nature of air pollution-related welfare effects for use in developing ISAs, as described in the online Preamble to the ISA for NOx- Human Health Criteria (U.S. EPA, 2015). Evidence from across scientific disciplines for related ecological effects is evaluated, synthesized, and integrated to develop conclusions and causality determinations. This includes consideration of strengths and weaknesses in the overall collection of studies across disciplines. Confidence in the body of evidence is based on evaluation of study design and quality. The relative importance of different types of evidence to the conclusions varies by pollutant or assessment, as does the availability of different types of evidence for causality determination. Scientists will also evaluate uncertainty in the scientific evidence.

The ISA will evaluate the evidence for causal relationships between observed ecological outcomes and NO_X and SO_X exposures using a five-level hierarchy that classifies the weight of evidence for causation. Determination of causality involves the evaluation and integration of evidence across disciplines for major outcome categories (e.g., aquatic acidification) or groups of related endpoints. Key considerations in drawing conclusions about causality include consistency of findings for an endpoint across studies, biological plausibility, and coherence of the evidence across disciplines and across related endpoints. In discussing the causal determination, EPA characterizes the evidence on which the judgment is based, including strength of evidence for individual endpoints within the outcome category or group of related endpoints. EPA evaluates evidence relevant to understand the quantitative relationships between pollutant exposures and ecological effects. This includes evaluating the concentration-response or deposition-response relationships and, to the extent possible, drawing conclusions on the levels at which effects are observed.

3.3.4 Quality Management

The NCEA-RTP participates in the Agency-wide Quality Management System, which requires the development of a Quality Management Plan (QMP). Information on Quality Assurance may be found at www.epa.gov/QUALITY/qmps.html.

Implementation of the ORD-wide and NCEA QMP ensures that all data generated or used by NCEA scientists "have a degree of confidence in the quality of the data; and, are of the type and quality appropriate for their intended use" and that all information disseminated by NCEA adheres to a high standard for quality including objectivity, utility, and integrity. Quality assurance (QA) measures detailed in the QMP are being employed for the current NO_X and SO_X review, including the development of the ISA for NO_X and SO_X. The NCEA QA staff is responsible for the review and approval of quality-related documentation. NCEA scientists are responsible for the evaluation (and documentation) of all inputs to the ISA, including primary (new) analysis and secondary (existing) data and analysis, to ensure their quality is appropriate for their intended purpose. NCEA adheres to the use of Data Quality Objectives, which clarify project objectives, define the appropriate type of data used in the project, and specify tolerable levels of confidence in the data and tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to identify the most appropriate inputs to the science assessment. The approaches utilized to search the literature and criteria for study selection and evaluation were detailed in the two preceding subsections. Generally, NCEA scientists rely on scientific information found in peer-reviewed journal articles, books, and government reports. Where information is integrated, re-analyzed, modeled, or reduced from multiple sources to create new figures, tables, or summation, the data generated are considered to be new and are documented and subjected to rigorous quality assurance and quality control measures to ensure their accuracy, validity, and reproducibility.

3.4 SPECIFIC ISSUES TO BE ADDRESSED IN THE ISA

Policy-relevant questions that frame the entire review of the secondary NO_X and SO_X NAAQS also guide the development of the ISA. These policy-relevant questions are related to two overarching issues. The first issue is whether new evidence reinforces or calls into question the evidence presented and evaluated in the last NAAQS review with respect to factors such as the concentrations of NO_X and SO_X exposure associated with ecological effects and plausibility of ecological effects caused by NO_X and SO_X exposure. The second issue is whether uncertainties from the last review have been reduced and/or whether new uncertainties have emerged. Specific questions that will be addressed in the ISA are listed subsequently by topic area. In the ISA, these topic areas will be discussed in separate chapters or sections. The beginning of the ISA will include an integrative synthesis chapter that summarizes the key information for each topic area and the causal determinations. The integrative synthesis chapter also presents a discussion of policy-relevant issues such as the exposure metrics, averaging times, concentration/deposition-response relationship including threshold for effects, their ecological significance and ecosystem services.

Atmospheric Sciences: The ISA will present and evaluate data related to ambient concentrations of NO_X and SO_X; including sources and chemical reactions that determine the formation, degradation, and deposition of nitrogen and sulfur. The 2008 NO_X and SO_X ISA concluded that ambient annual NO_X and SO_X concentrations have decreased significantly as reported in the routine national networks, owing to controls enacted since the 1970s, and that deposition is spatially heterogeneous across the U.S. with mean S deposition in the U.S. greatest east of the Mississippi River and the highest mean N deposition totals in the Ohio River valley The current review will update and expand on these trends by reporting results from a number of recent publications on spatial and temporal concentration patterns based on national monitoring network data. It will also describe new advances in monitoring and modeling methods that reduce uncertainty in concentration estimates and improve understanding of NO_Y and SO_X speciation. In addition, it will summarize advances in our understanding of transport, transformation and deposition processes. Specific policy-relevant questions related to air quality and atmospheric chemistry that will be addressed include the following:

- What new information is available on spatial and temporal trends in ambient NO_Y and SO_X concentration, particularly in vulnerable areas?
- What new information is available on NO_Y and SO_X sources, transport, transformation, and deposition processes that impact exposure?
- What new information is available on speciation of NO_Y and SO_X components and their impact on deposition?
- What new measurement and modeling methods have been developed that improve our understanding and predictive capabilities?

Gas-phase Phytotoxic Effects: In the 2008 NO_X and SO_X ISA the evidence was sufficient to infer a causal relationship between exposure to SO_2, NO, NO_2, PAN, and HNO_3 and injury to vegetation. It was found that acute and chronic exposures to SO_2 have phytotoxic effects on vegetation which include foliar injury, decreased photosynthesis, and decreased growth. Acute exposures to NO_2, NO, PAN, and HNO_3 was found to cause plant foliar injury and decreased growth. However, the majority of studies had been performed at concentrations of these gas-phase species was above current ambient conditions observed in the U.S. Consequently, there was little evidence that current concentrations of gas-phase S or N oxides are high enough to cause phytotoxic effects. One exception was that some studies indicate that current HNO_3 concentrations may be contributing to the decline in lichen species in the Los Angeles basin.

- What new information is available to characterize the effects of SO_2, NO, NO_2, PAN, and HNO_3 on vegetation?
- What are the current concentration of these NO_X and SO_X gases and are they high enough to cause effects on vegetation?
- What new information is available on lichen decline related to exposure to NO_X and SO_X gases?

Terrestrial Nitrogen Enrichment: In the 2008 NO_X and SO_X ISA the evidence was sufficient to infer a causal relationship between N deposition (NO_X +NH_X) and the alteration of biogeochemical cycling of N and C in terrestrial ecosystems. It was found that N deposition alters the biogenic sources and sinks of two greenhouse gases (GHGs), CH_4 and N_2O, in terrestrial ecosystems, resulting in increased emissions to the atmosphere. N deposition increases the biogenic emission of N_2O in coniferous forest, deciduous forests and grasslands and N deposition resulted in a general stimulation of biogenic CH_4 from soils. Also it was found that N deposition thus often increases primary productivity, thereby altering the biogeochemical cycling of C. A limited number of studies suggested that N deposition may increase C-sequestration in some forests, but has no apparent effect on C-sequestration in non-forest ecosystems.

A causal relationship was also inferred between N deposition and the alteration of species richness, species composition and biodiversity in terrestrial ecosystems. It was found that, in terrestrial ecosystems, N deposition can accelerate plant growth and change C allocation patterns (e.g., shoot:root ratio), which can increase susceptibility to severe fires, drought, and wind damage. The alteration of primary productivity can also alter competitive interactions among plant species. The increase in growth is greater for some species than others, leading to possible shifts in population dynamics, species composition, community structure, and in few instances, ecosystem type. There were numerous sensitive terrestrial biota and ecosystems identified that were affected by N deposition including acidophytic lichens, grasslands in Minnesota and pine ecosystems in the Rocky Mountains.

In the current review, specific policy-relevant questions related to N enrichment of terrestrial ecosystems will be addressed:

- What new information is available on the changes in ecosystem services resulting from N addition to terrestrial ecosystems?
- What new information is available to characterize nitrogen critical loads for U.S. ecosystems?
- What new evidence and models exists to characterize the effects of nitrogen addition on biodiversity and invasive species? What new evidence exists to improve characterization the link between nitrogen addition changes in biodiversity to alteration of fire regimes, faunal communities, etc.? What new information exists to characterize adverse effects in Class I areas?
- What new information is available to characterize the effects of N addition on ecosystem carbon cycling, carbon budgets and other greenhouse gas fluxes?
- What new information exists to characterize terrestrial N deposition links to ecosystem services?
- What new information is available to characterize the causal relationship between oxidized nitrogen deposition (apart from NHx) specifically and the effects described above?

Terrestrial Acidification: In the 2008 NO_X and SO_X ISA**, t**he strongest evidence for a causal relationship came from studies of terrestrial systems exposed to elevated levels of acidifying deposition that showed reduced plant health, reduced plant vigor, and loss of terrestrial biodiversity. In multiple studies, consistent and coherent evidence showed that acidifying deposition can affect terrestrial ecosystems by causing direct effects on plant foliage and indirect effects associated with changes in soil chemistry. Biological effects of acidification on terrestrial ecosystems were generally attributable to aluminum toxicity, decreased ability of plant roots to take up nutrient cations and elevated leaching of Ca^{2+} from conifer needles. There are several indicators of stress to terrestrial vegetation, including percent dieback of canopy trees, dead tree basal area (as a percent), crown vigor index, and fine twig dieback. Forests of the Adirondack Mountains of New York (ADR), Green Mountains of Vermont, White Mountains of New Hampshire, the Allegheny Plateau of Pennsylvania, and high-elevation forest ecosystems in the southern Appalachians are the regions which are most sensitive to terrestrial acidification effects from acidifying deposition. There are widespread measurements of ongoing depletion of exchangeable base cations in forest soils in the northeastern U.S. despite recent decreases in acidifying deposition.

In the current review specific policy-relevant questions related to acidification in terrestrial ecosystems that will be addressed include the following:

- What new information is available on the changes in ecosystem services resulting from acidifying deposition to terrestrial ecosystems?
- What new information is available on plant species or other biotic endpoints vulnerable to terrestrial acidification? What new information is available to characterize dose response relationships between deposition and these endpoints?
- What new information or models are available to characterize terrestrial acidification? Specifically, what new information is available to characterize critical loads?
- What new information is available to scale up site-specific data to address regional sensitivity to terrestrial acidification?
- What new evidence exists to characterize ecosystem services related to terrestrial acidification

Aquatic Nitrogen Enrichment: In the 2008 NO_X and SO_X ISA the evidence was sufficient to infer a causal relationship between N deposition and biogeochemical cycling of N and C in freshwater aquatic and coastal marine systems. A causal relationship was also inferred between N deposition at current levels and species richness, species composition, and biodiversity in freshwater aquatic and coastal marine systems. N deposition was found to alter species assemblages and cause eutrophication of aquatic systems to the extent that N is the growth-limiting nutrient. Species assemblages may also be changed when N is added to the freshwater ecosystem. In estuarine systems, N from atmospheric and non-atmospheric sources contributes to increased phytoplankton and algal productivity leading to eutrophication. Estuary eutrophication is an ecological problem indicated by water quality deterioration, resulting in numerous adverse effects including hypoxic zones, species mortality and harmful algal blooms. The contribution of atmospheric deposition to total N loads varies in these systems.

In the current review specific policy-relevant questions related to N nutrient enrichment to aquatic systems that will be addressed include the following:

- Are there new endpoints available for assessing effects of eutrophication, especially on ecological populations (i.e., size and structure) or biodiversity (e.g., species richness, abundance, and composition) in freshwater and coastal systems? What new information is available on the changes in ecosystem services resulting from N addition to aquatic ecosystems?
- What new empirical data or modeling results are available that would enhance our understanding of the biogeochemistry of eutrophication in freshwater and/or coastal systems?
- What resources or evidence are available from other monitoring agencies which may aid in the assessment of N nutrient enrichment in aquatic systems? What new information exists to characterize adverse effects of eutrophication in protected areas (e.g., Class I areas, National Parks, Wilderness Areas)?
- What new information is available to characterize the causal relationship between oxidized nitrogen deposition (apart from NHx) specifically and the effects described above?

Aquatic Acidification: In the 2008 NO_X and SO_X ISA there was sufficient evidence to infer a causal relationship between the exposure to NO_X and SO_X, aquatic acidification and the loss of acid-sensitive species. In general, more species are lost with greater acidification. These effects are linked to changes in surface water chemistry, including concentrations of SO_4^{2-}, NO_{3-}, inorganic Al and Ca, surface water pH, sum of base cations, ANC and base cation surplus. Decreases in ANC and pH and increases in inorganic Al concentration contribute to declines in zooplankton, macroinvertebrates and fish species richness. These effects on species richness may also affect ecosystem services, such as biodiversity and cultural services such as fishing and tourism.

In the current review specific policy-relevant questions related to acidifying deposition to aquatic systems that will be addressed include the following:

- What new information is available on biotic endpoints that may be vulnerable to aquatic acidification?
- What new information is available to characterize the relationship between ANC and biotic endpoints?
- What new information is available on the changes in ecosystem services resulting from N addition to aquatic ecosystems?
- What new evidence exists to characterize the relationship between ANC and pH? How do we reliably relate ANC in the field to pH thresholds of biotic toxicity developed in the lab?
- What new information is available to characterize the best models of aquatic acidification? What are the data requirements? Are those models appropriate for a regional scale?
- What new data exists to better characterize the current condition of water bodies and critical loads nationwide?
- What new evidence exists to characterize ecosystem services related to aquatic acidification

Wetland Nitrogen Enrichment: In the 2008 NO_X and SO_X ISA the evidence was sufficient to infer a causal relationship between N deposition and the alteration of biogeochemical N and C cycling in freshwater and coastal wetland systems. There was strong evidence on N deposition increasing N_2O emissions and CH_4 emissions. Additional responses to N deposition in wetlands were NO_3^- leaching, increased N mineralization, and higher denitrification rates, although the extent of these responses depended on season, climate, hydrology, vegetation type, and geography. Impacts of N deposition upon C cycling included increased plant productivity coupled with increased decomposition rates in bogs, and increased plant productivity in intertidal wetlands.

The evidence was also sufficient to infer a causal relationship between N deposition and the alteration of species richness, composition, and biodiversity in wetland ecosystems. The ISA identified rare North American plant species adapted to the low-N environment historically common in freshwater wetlands and thus vulnerable to N deposition, including three federally endangered species in the genus *Isoetes*, the endangered insectivorous green pitcher *Sarracenia* *oreophila*, the state-listed endangered insectivore *Drosera rotundifolia*, and 15 state-listed endangered *Spagnum* species.

In the current review, specific policy-relevant questions related to N enrichment of wetland ecosystems will be addressed:

- What new evidence exists to characterize relative NO_Y loading contributions to wetland ecosystems that also receive N in surface water from other anthropogenic sources?
- What new empirical data or modeling results are available that would enhance our understanding of the biogeochemistry of eutrophication in wetlands?
- What are appropriate ecological endpoints in wetlands affected by nitrogen deposition?
- What new information is available on the changes in ecosystem services resulting from N addition to wetland ecosystems?
- Should restored or built wetlands be included and is evidence of effects of N deposition on these systems available?
- What new evidence exists to quantify the effect of N deposition upon rare wetland species?
- What new information is available to characterize the effects of N addition on wetland carbon cycling, carbon budgets and other greenhouse gas fluxes?
- What new evidence, models, or analyses exist that address how wetland ecosystem services are impacted by N deposition?
- What new information is available to characterize the causal relationship between oxidized nitrogen deposition (apart from NHx) specifically and the effects described above?

Sulfur-driven Mercury Methylation: In the 2008 NO_X and SO_X ISA evidence was sufficient to infer a causal relationship between S deposition at current levels and increased Hg methylation in aquatic environments. Hg is highly neurotoxic and once methylated principally by S-reducing bacteria, it can be taken up by microorganisms, zooplankton and macroinvertebrates**,** and concentrated in higher trophic levels, including fish eaten by humans. In 2006, 3,080 fish consumption advisories were issued because of methylmercury (MeHg), and as of July 2007, 23 states had issued statewide advisories. The production of meaningful amounts of MeHg requires the presence of SO_4^{2-} and Hg, and where Hg is present, increased availability of SO_4^{2-} results in increased production of MeHg. The amount of MeHg produced varies with oxygen content, temperature, pH, and supply of labile organic C. Watersheds with conditions known to be conducive to Hg methylation can be found in the northeastern U.S. and southeastern Canada, but significant biotic Hg accumulation has been widely observed in other regions that have not been studied as extensively, and where a different set of conditions may exist. In the current review specific policy-relevant questions related to sulfur-driven mercury methylation that will be addressed include the following:

- What new evidence exists to characterize the geographic extent of mercury methylation induced by sulfur deposition? Is there new evidence to characterize the effects of abiotic factors (e.g., pH) on the dose response between sulfur deposition and mercury methylation?
- What new evidence exists of the identity and distribution of organisms that methylate mercury? What new evidence exists of the trophic interactions by which methylated mercury moves through the food chain?

3.5 SCIENTIFIC AND PUBLIC REVIEW

Drafts of the ISA will be made available for review by the CASAC NO_X and SO_X secondary NAAQS review panel and the public as indicated in Figure 3-1 above; availability of draft documents will be announced in the Federal Register. The CASAC panel will review the draft ISA documents and discuss their comments in public meetings that will be announced in the Federal Register. EPA will take into account comments, advice, and recommendations received from the CASAC panel and from the public in revising the ISA. EPA has established a public docket for the development of the ISA. After appropriate revision based on comments received from CASAC and the public, the final document will be made available on an EPA website and in hard copy. A notice announcing the availability of the final ISA will be published in the Federal Register.

4. RISK AND EXPOSURE ASSESSMENT

In addition to this integrated review plan, we will develop a Planning Document that will more specifically outline the scope, methods, and tools that will be used in the Risk and Exposure Assessment. The Risk and Exposure Assessment will provide a concise presentation of the conceptual model, scope, methods, key results, observations, and related uncertainties associated with the quantitative analyses performed in support of the NO_X SO_X secondary NAAQS review. This assessment will build upon the scientific information presented in the Integrated Science Assessment (as described in Chapter 3). The results of the Risk and Exposure Assessment will be used in the Policy Assessment, along with the evidence provided in the Integrated Science Assessment to inform policy options for consideration by the Administrator.

In general, the Risk and Exposure Assessment is intended to address several questions described in Chapter 3, including the following:

- What is the nature and magnitude of negative ecosystem responses to NO_X and SO_X (including atmospheric concentrations and deposition)?
- What is the variability associated with those responses, including across ecosystem types, climatic conditions, environmental effects and interactions with other environmental factors and pollutants?
- Are there specific levels of atmospheric concentrations and deposition associated with adverse effects of concern?

4.1 SUMMARY OF PREVIOUS RISK AND EXPOSURE ASSESSMENT

The Risk and Exposure Assessment (U.S. EPA, 2009) conducted for the previous review described the potential risk from deposition of oxides of nitrogen and sulfur to sensitive ecosystems. Specifically, it evaluated the relationships between atmospheric concentrations, deposition, biologically relevant exposures, targeted ecosystem effects, and, to the extent possible, associated ecosystem services. In order to link these effects, the previous Risk and Exposure Assessment examined various ways to quantify the relationships between air quality indicators, deposition of biologically available forms of nitrogen and sulfur, ecologically relevant indicators relating to deposition, exposure and effects on sensitive receptors, and related effects resulting in changes in ecosystem structure and services. The previous Risk and Exposure Assessment also evaluated the contributions of atmospheric NO_X and SO_X relative to deposition as well as the contribution of NO_X to total reactive nitrogen in the atmosphere, relative to the contributions of reduced forms of nitrogen (e.g., ammonia, ammonium).

The previous Risk and Exposure Assessment assessed the ecological effects and ecosystem service effects associated with deposition of total reactive nitrogen and sulfur (S), focusing on four main targeted ecosystem effects on terrestrial and aquatic systems: (1) aquatic acidification; (2) terrestrial acidification; (3) aquatic nutrient enrichment, including eutrophication; and (4) terrestrial nutrient enrichment. In addition, the previous Risk and Exposure Assessment also qualitatively addressed the influence of sulfur oxides deposition on methylmercury production; nitrous oxide effects on climate; nitrogen effects on primary productivity and biogenic greenhouse gas fluxes; and phytotoxic effects on plants.

To evaluate each of these targeted effects, the previous Risk and Exposure Assessment selected eight case study areas and two supplemental study areas based on ecosystem characteristics, indicators, and ecosystem service information. The selected case study areas are shown in Figure 4-1. For aquatic acidification effects, the previous Risk and Exposure Assessment estimated the percentage of lakes and streams that exceeded critical loads for alternative Acid Neutralizing Capacity levels of 0, 20, 50, and 100 in the Adirondack Mountains and Shenandoah National Park and the associated effects on ecosystem services such as recreational fishing. For terrestrial acidification effects, effects on tree growth and associated ecosystem services were evaluated using base cations to aluminum ratios of 0.6, 1.2, and 10 in the Kane Experimental Forest and the Hubbard Brook Experimental Forest, with effects on sugar maple and red spruce extrapolated to 17 states. For aquatic nutrient enrichment effects, changes in the eutrophication index were evaluated for the Potomac River Basin and the Neuse River Basin. For terrestrial nutrient enrichment effects, nitrogen deposition was compared to existing benchmarks for ecological effects in the coastal sage scrub communities in southern California and the mixed conifer forest communities in the San Bernardino and Sierra Nevada Mountains. In addition, two supplemental areas were examined (i.e., Rocky Mountain National Park and Little Rock Lake, Wisconsin).

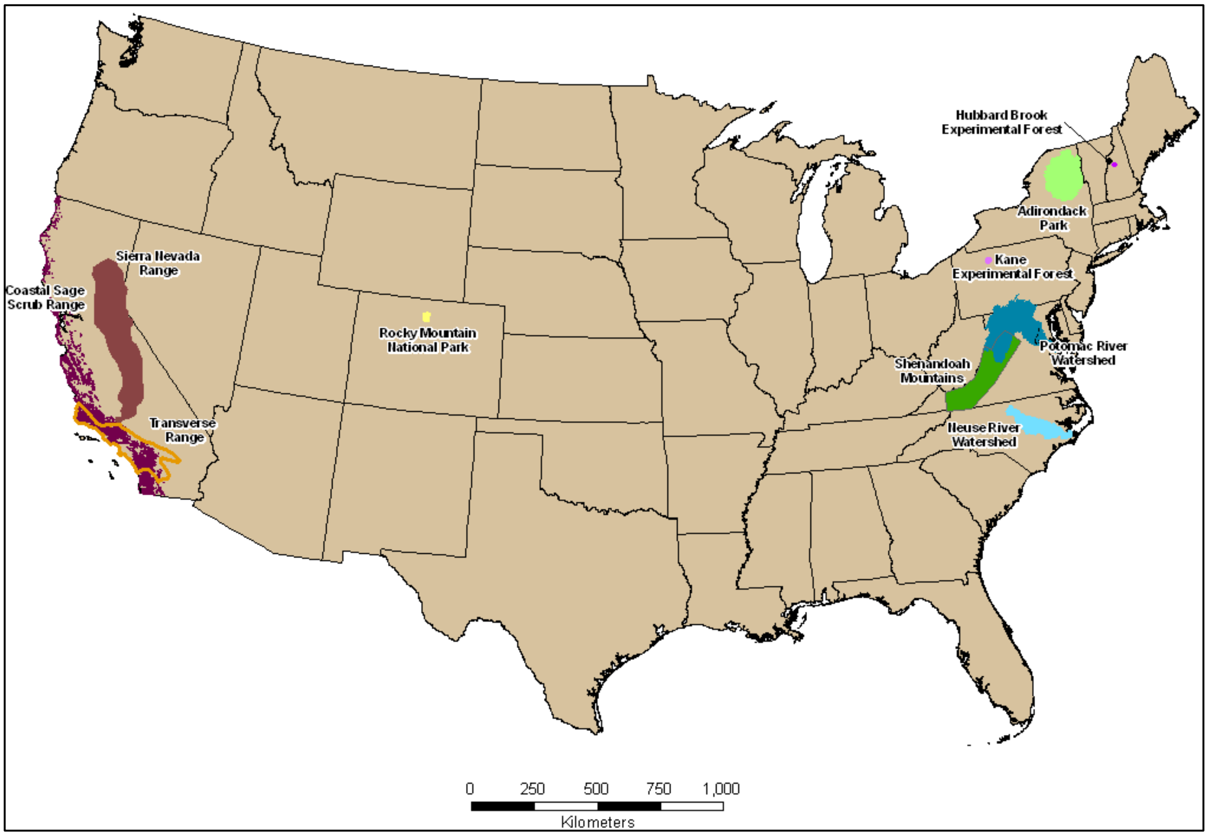


Figure 4-1. Eight Case Study Areas and One Supplemental Area in Previous Risk and Exposure Assessment (Source: U.S. EPA, 2009, Figure ES-3).

In summary, based on case study analyses, the previous Risk and Exposure Assessment concluded that known or anticipated adverse ecological effects were occurring under recent conditions and that these adverse effects would continue into the future. The air quality analyses found that deposition of nitrogen and sulfur was higher in the East than the West, regional deposition corresponded with emissions and ambient concentrations, reduced nitrogen deposition exceeded oxidized nitrogen deposition in the vicinity of local ammonia sources, spatial variation in deposition exists within case study areas, and seasonal patterns of deposition varied in the case study areas. Key findings from the case studies are outlined below.

- **aquatic acidification** -- despite recent improvements in deposition, both the Adirondacks and Shenandoah have higher deposition and acidity relative to modeled conditions for 1860, between 18 to 58 percent of modeled lakes in the Adirondacks and 52 to 93 percent of modeled streams in Shenandoah had nitrogen and sulfur deposition in 2002 exceeding Acid Neutralizing Capacity levels of 0 to 100, and modeling constant 2002 emissions yielded no improvement in water quality in the Adirondacks by 2050.

- **terrestrial acidification** -- 3 to 75 percent of all sugar maple plots and 3 percent to 36 percent of all red spruce plots exceeded base cation to aluminum ratios of 0.6 to 10.
- **aquatic enrichment** -- a decrease of 78 percent of atmospheric nitrogen deposition would be required to improve the eutrophication index for the Potomac from Bad to Poor, that the eutrophication index could not be improved for the Neuse with only decreases in atmospheric deposition, and that decreasing nitrogen deposition does not always decrease loading to the estuary linearly.
- **terrestrial enrichment** -- 93 percent of coastal sage scrub areas and 38 percent of mixed conifer forest areas in California exceeded ecological benchmarks for nitrogen deposition.

The Agency recognized that there were key uncertainties in the previous review, which included several important data limitations. Many of these uncertainties were related to air quality information and included limited ambient measurements of NOx and reduced forms of N (ammonia and ammonium), limited dry deposition data, and uncertainties in relating atmospheric concentration to deposition. Other key areas of uncertainty were also identified as they related to the five main effects categories: (1) aquatic acidification; (2) terrestrial acidification; (3) aquatic eutrophication; (4) terrestrial eutrophication; and (5) mercury methylation. These key uncertainties are listed in Table 4-1 below.

Table 4-1: Key Uncertainties identified in the Previous Review

Effect Category	Key Uncertainties
Aquatic Acidification	• Lack of nationwide soil weathering rates, especially weathering rates for aquatic ecosystems sensitive to acidification • Limited information about the uncertainty in critical loads for acidity and reported exceedance values • Lack of methods for calculating critical loads for surface water acidity when data are absent or of poor quality • Lack of a method for combining multiple critical load estimates for surface waters and soils on a national scale • Lack of methods to combine critical loads across media and across effects • Limited information on the relationship between critical loads for aquatic acidity and effects on ecosystem services, especially due to incremental changes in an ecological indicator such as ANC
Terrestrial Acidification	• Limitations in the base cation weathering models available to estimate terrestrial critical acid loads nationwide • Limited information on the relationship between tree growth, critical load exceedances, and nitrogen and sulfur deposition for most tree species • Limited information on the relationships between critical loads for terrestrial acidity and effects on ecosystem services
Aquatic Eutrophication	• Limited ability to broadly predict effect of changing nitrogen inputs on water quality indicators. • Difficulty predicting effect of changing air loads to waterbodies with other major inputs of nitrogen from land based sources. • Model and data uncertainty • Limited ability to extrapolate relationships between ecological indicators and atmospheric deposition outside of specific case study locations • Limited relationships between ecological indicators of nitrogen enrichment and ecosystem services for most areas
Terrestrial Eutrophication	• Uncertainties regarding the interactions between elevated levels of atmospheric nitrogen, fire intensity and frequency, and invasive grasses • Limited information on ecological communities long-term response to elevated nitrogen and how benchmarks may change • Lack of clearly defined indicators of ecosystem health for some impacted communities • Limitations in the resolution of modeled air quality data • Limited relationships between ecological indicators of nitrogen enrichment and ecosystem services
Mercury Methylation	• Lack of information on variation in methylation rates and correlation with sulfur deposition • Limited information on the extent of sensitivity in most waterbodies

The previous Risk and Exposure Assessment also noted that the uncertainties in the modeling did not have an obvious directional bias that would suggest a clear under- or over-estimation of risks. As discussed in the remainder of this chapter and in more detail in the forthcoming Planning Document, the current Risk and Exposure Assessment will aim to better characterize these uncertainties and attempt to address them through the use of new and expanded datasets, models, and tools, as available.

4.2 APPROACH FOR THE CURRENT RISK AND EXPOSURE ASSESSMENT

Although the Planning Document will provide more specific information, we provide some preliminary ideas regarding the scope of the current Risk and Exposure Assessment here. First, as discussed in Chapter 1, the Risk and Exposure Assessment will not focus on visibility, materials damage, and ozone effects that might be associated with NO_X and SO_X as these are addressed in other NAAQS reviews. Second, the analyses will focus on ecological effects determined to have a causal or likely causal relationship with NO_X and SO_X in the Integrated Science Assessment, which may reflect multiple chemical species of nitrogen and sulfur. Third, these analyses will likely include a combination of national and local-scale analyses reflecting various policy scenarios, such as recent ambient conditions, the existing standards, and potential alternative standards. Lastly, we anticipate that the analyses will likely focus on areas in the contiguous U.S. due to the greater availability of data.

There have been numerous advances in the science and data available for assessing the impacts of ambient concentration and deposition of NOx and SOx and associated ecological responses. Furthermore, there have been significant advances in characterizing and valuing ecosystem services. These will be covered in the Integrated Science Assessment. EPA will review that information to determine whether or not to pursue an REA and if so, what is appropriate to be addressed in the design of the REA which will be described in more detail in the forthcoming Planning Document. At this time, EPA anticipates conducting an assessment similar to that carried out in the previous assessment – addressing aquatic acidification, terrestrial acidification, aquatic nutrient enrichment, terrestrial nutrient enrichment, and effects of SO2 on mercury methylation. We anticipate that advances in science since the past review will allow us to evaluate these im ore detail. Overall, we anticipate the assessment to utilize an integrated assessment approach to characterize the ecological effects, enhanced use of ecosystem services as a framework for characterizing impacts, and the use of case studies and national assessments.

4.2.1 Integrated Assessment Approach

The Risk and Exposure Assessment plans to use an integrated assessment approach which involves several steps and combines various analytical and modeling tools as a means to assess ecological impacts. Section 4.3 discusses the various components of the assessment and types of data and tolls that could potentially be used for conducting integrated assessments. Section 4.3.1 (Air Quality Information) discusses tools and data that will potentially be used to provide information on emissions, air quality concentrations, and amount of deposition for current conditions, as well as for different policy scenarios. Section 4.3.2 (Ecological / Environmental Process Effects) includes tools and data that would assess intermediate ecological process effects. Section 4.3.3 (Ecosystem Goods and Services) discusses how end products could be potentially linked to changes in direct uses (e.g., recreation) and direct users (households), which affect public welfare.

To illustrate briefly the overall approach we outline one pathway – aquatic acidification - as an example of this approach. In the first step we would assess alternative NOx and SOx standards using changes in emissions associated with varying policy scenarios using emissions inventories (e.g., NEI) that serve as inputs for air quality models (e.g., CMAQ). These would be used to estimate atmospheric concentrations and deposition of pollutants to land and water surfaces. In subsequent steps, we would assess intermediate ecological process effects; for example, linking changes in deposition to changes in the surface water chemistry of lakes and streams. These linkages may include algorithms based on observed relationships between ecosystem chemical parameters (e.g., acid neutralizing capacity) and biological indicators of ecosystem health (e.g., fish species richness). In some circumstances, the biological indicators themselves (e.g., fish) are also final ecosystem goods and services, but sometimes additional linkages are needed. In the final steps, these end products are linked to changes in direct uses (e.g., recreation) and direct users (households), which affect public welfare.

The stepwise pathway for aquatic acidification outlined above is an example of an analysis that can be completely quantified from deposition through economic valuation of affected ecosystem services for different policy scenarios. Other endpoints are more likely to have gaps in the pathway. In the previous Risk and Exposure Assessment, we found that in many cases the ecological studies linking nitrogen and sulfur deposition to an ecological effect could not quantify the impact of a small change in deposition from a policy scenario (i.e., an incremental analysis), and instead these analyses quantified only whether or not an effect occurred without relating the severity of the effect to a known gradient of nitrogen and sulfur deposition. Another common gap identified in the previous review occurred in the translation step between the evidence of an ecological effect and the evidence of an effect on a defined ecosystem service. In many cases, incremental changes to ecosystem services based on changes in ecological condition, function, or processes have not been quantified. Although a wealth of economic data and research are available to quantify the total value of many ecosystem services, less information is available for incremental analysis. For the current Risk and Exposure Assessment, we intend to proceed down the analytical pathway as far as the available data, methods, and resources will allow for each of the endpoints identified in the Integrated Science Assessment. Even without completing the pathway to economic valuation, valuable conclusions can be drawn from the analyses of impacts on components of public welfare as defined in the CAA. For example, we may be able to quantify a loss in biodiversity in a forest or grassland due to nitrogen deposition (an effect on an ecosystem condition), but we may not have the data available to quantify the associated change in ecosystem services. Although we would not have the data to provide an incremental analysis of the change in economic value due to the loss of biodiversity, we could still provide evidence regarding whether and how much people consider biodiversity loss to be important to them.

4.2.2 Ecosystem Services Framework

In the previous review of the secondary standards for NO_X and SO_X, the EPA introduced using ecosystem services as a tool for framing the discussion of the ecological effects of nitrogen and sulfur deposition on public welfare. Ecosystem services can be generally defined as the benefits that individuals and organizations obtain from ecosystems. The EPA has defined ecological goods and services as the "outputs of ecological functions or processes that directly or indirectly contribute to social welfare or have the potential to do so in the future. Some outputs may be bought and sold, but most are not marketed" (U.S. EPA, 2006). Conceptually, changes in ecosystem services may be used to aid in characterizing a known or anticipated adverse effect on public welfare. In the context of this review, ecosystem services may also aid in assessing the magnitude and significance of a resource and in assessing how NO_X and SO_X may affect that resource.

In the previous Risk and Exposure Assessment, we qualitatively described many of the ecosystem services potentially affected by nitrogen and sulfur deposition. As shown in Figure 5-3, the ultimate goal of the ecosystem services framework is to quantify each step in the process from policy change through the environmental processes to the resulting change in public welfare. In this manner, alternative policy scenarios, such as existing and potential alternative standards, can also be evaluated and compared. However, it may not be possible to fully quantify each of these steps due to data gaps, thus some portions may be qualitative.

4.2.3 National and Case Study Assessments

The Risk and Exposure Assessment will likely include a combination of national and regional scale assessments as well as smaller scale site specific case studies. In general, case study assessments can provide high confidence estimates of localized or regional effects for a specific endpoint, potentially through the entire integrated assessment process from changes in ambient concentrations and deposition to changes in ecosystem services and human welfare. National assessments potentially allow consideration of multiple endpoints across broad geographic scales, but many areas of the country may have limited data. Because neither ecosystems nor ecosystem effects from the N and S deposition are uniformly distributed across the U.S., conducting both types of assessments provides balance and breadth to the Risk and Exposure Assessment.

As in the previous review, identifying sensitive ecosystems is likely to be an important component of the current Risk and Exposure Assessment. To aid in evaluating which ecosystems are sensitive to nitrogen and sulfur deposition, it may be useful to group or cluster ecosystems (where data are available) based on a set of underlying similar characteristics relevant to the ecological effect of interest. Clustering ecosystems can reduce the number of locations modeled while still adequately characterizing the variability in ecosystem responses to changes in nitrogen and sulfur deposition. In the previous Policy Assessment (U.S. EPA, 2011), staff recommended that consideration be given to Omernik Ecoregions (level III).[16] Other potential grouping characteristics may include (but are not limited to): (1) potential nitrogen and sulfur retention rates, (2) potential nitrogen and sulfur uptake rates, which might include vegetative uptake, potential denitrification, and potential mobilization of nitrogen and sulfur, (3) potential residence time based on local hydrology (precipitation rates, conductivity) and geology (bedrock type, pervious surfaces, soil type and characteristics), (4) total supply of nitrogen and sulfur including atmospheric deposition, and other non-atmospheric sources (such as fertilization, sewer leaks, point sources, etc.). In national or case study assessments, we may also apply ecosystem-specific characteristics to help assess sensitivities, such as Class I areas or critical habitat for threatened and endangered species (where data are available).

We intend to develop detailed criteria for selecting case study areas in the Planning Document for the Risk and Exposure Assessment. In general, priority is given to case study areas for which adequate models and data are available to assess changes in ecological and ecosystem service effects associated with changes in deposition with minimal gaps in the integrated assessment approach. For some endpoints, we may choose to assess the same case study areas as the previous Risk and Exposure Assessment based on the availability of additional data and tools. In addition, we will consider the case studies developed for the Integrated Science Assessment.

4.3 POTENTIAL TOOLS AND MODELS FOR RISK AND EXPOSURE ASSESSMENT

The Integrated Assessment approach and the enhanced focus on ecosystem services will require the use of a wide range of assessment components and tools. Some of the available analytical tools considered for conducting the current assessment are summarized below. In the forthcoming Planning Document, these tools will be evaluated for how well they can inform the Risk and Exposure Assessment regarding the appropriate endpoint(s)/indicator(s), geographic level/scale of protection, national or case-study modeling, and ecosystem services to assess. This list of tools is not intended to be comprehensive, but rather, this list is intended to provide

[16] Ecoregions are areas of similarity regarding patterns in vegetation, aquatic, and terrestrial ecosystem components. Available ecoregion categorization schemes include EPA's Omernik classifications (Omernik, 1987, http://www.epa.gov/wed/pages/ecoregions.htm), the National Ecological Observatory Network (NEON, http://www.neoninc.org/) domains, and Baily's ecoregions developed for the United States Forest Service.

information regarding potential tools we are considering and to solicit comment on additional tools that might be appropriate to consider.

4.3.1 Air Quality

Total atmospheric deposition is the sum of wet (i.e., precipitation), dry and occult (i.e., fog and clouds) deposition. For all practical purposes, observations only provide estimates of precipitation-based deposition. Dry deposition estimates rely on models that account for the heat, mass transfer, and thermodynamic processes influenced by meteorology, land and water surface properties and atmospheric species of interest. Occult deposition is not modeled explicitly, but it is generally assumed to be incorporated in models through mass conservation principles (i.e., removal through precipitation, dry deposition, transformation, or transport). Consequently, deposition often is discussed in terms of wet and dry components, both of which are significant contributors to total deposition.

Characterizing ambient air quality is technically necessary to estimate dry deposition. Comprehensive chemical transport models (CTMs) were relied on in the previous review and have emerged as preferred tools to estimate dry deposition based on their ability to integrate multiple physical and chemical processes relevant to dry deposition.[17] CTMs also estimate wet deposition (precipitation-based), and it has become a relatively common practice to optimize the use of observed wet deposition with modeled dry and wet deposition to generate total deposition estimates.

Monitoring Networks

A key data source for the Risk and Exposure Assessment is the National Trends Network (NTN) within the National Atmospheric Deposition Network (NADP). This network provides weekly averaged observations of precipitation based nitrate, sulfate and ammonium covering a variety of ecoregions at 360 sites across the U.S. (see Figure 5-4). In addition, the ammonia monitoring network (AMoN) within the NADP provides weekly integrated observations of ammonia gas at 50 sites.

[17] The Community Multiscale Air Quality Model (CMAQ) and the Community Air Quality Model with Extensions (CAMx) are two "state-of-the-science" CTMs for simulating air quality and deposition on local, regional, and national scales.

Most of the routine gaseous and particulate air quality monitoring sites operated by state and local agencies and tribes (SLTs) are weighted strongly toward high population areas, but the areas of interest for secondary standards are often relatively pristine and rural areas. The Clean Air Status and Trends Network (CASTNET), managed by EPA and NPS, is the most relevant source of ambient air quality data in rural locations and provides weekly integrated observations of total inorganic nitrate (i.e., nitric acid and particulate nitrate), particulate ammonium, and total inorganic sulfur (i.e., gas phase sulfur dioxide and particulate sulfate) at 91 sites. CASTNET does not provide observations of organic nitrates (e.g., peroxy and alkyl nitrates) and NO_2, which are significant components of the NO_Y budget. The NCore network, operated by the SLTs, provides continuous NO_Y measurements reported at hourly intervals at 78 sites (15 are rural) (see Figure 5-5). Routine networks (wet and dry phases) do not provide observations of organic nitrogen, which can approach 20% or more of the total nitrogen budget (Jickells et al., 2013; Benedict et al., 2013).The relative contributions to the organic nitrogen budget from anthropogenic and natural fractions and atmospheric transformation processes are not well characterized. Routine measurements of organic-nitrogen generally are not available, although the NADP has conducted periodic analyses of total precipitation nitrogen, allowing an estimate of total organic-nitrogen through difference.

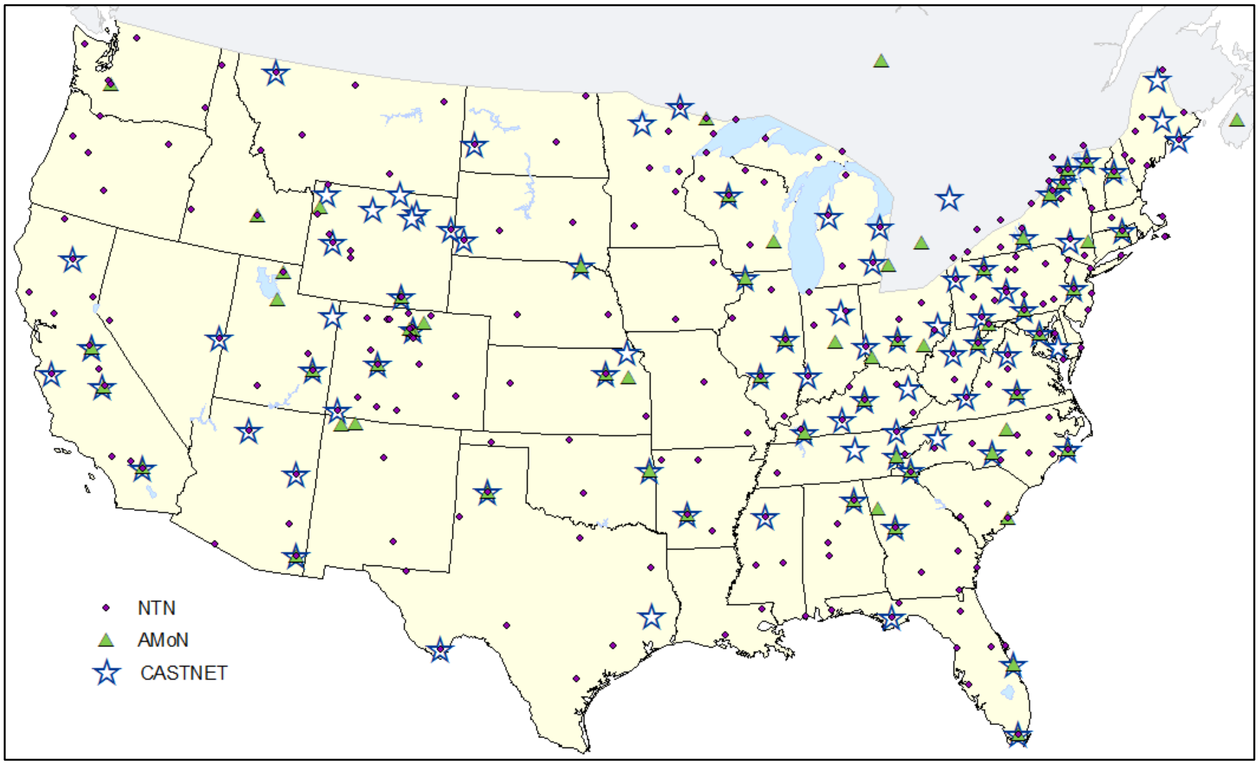


Figure 4-4. Location of NADP-NTN, AMoN and CASTNET monitoring sites

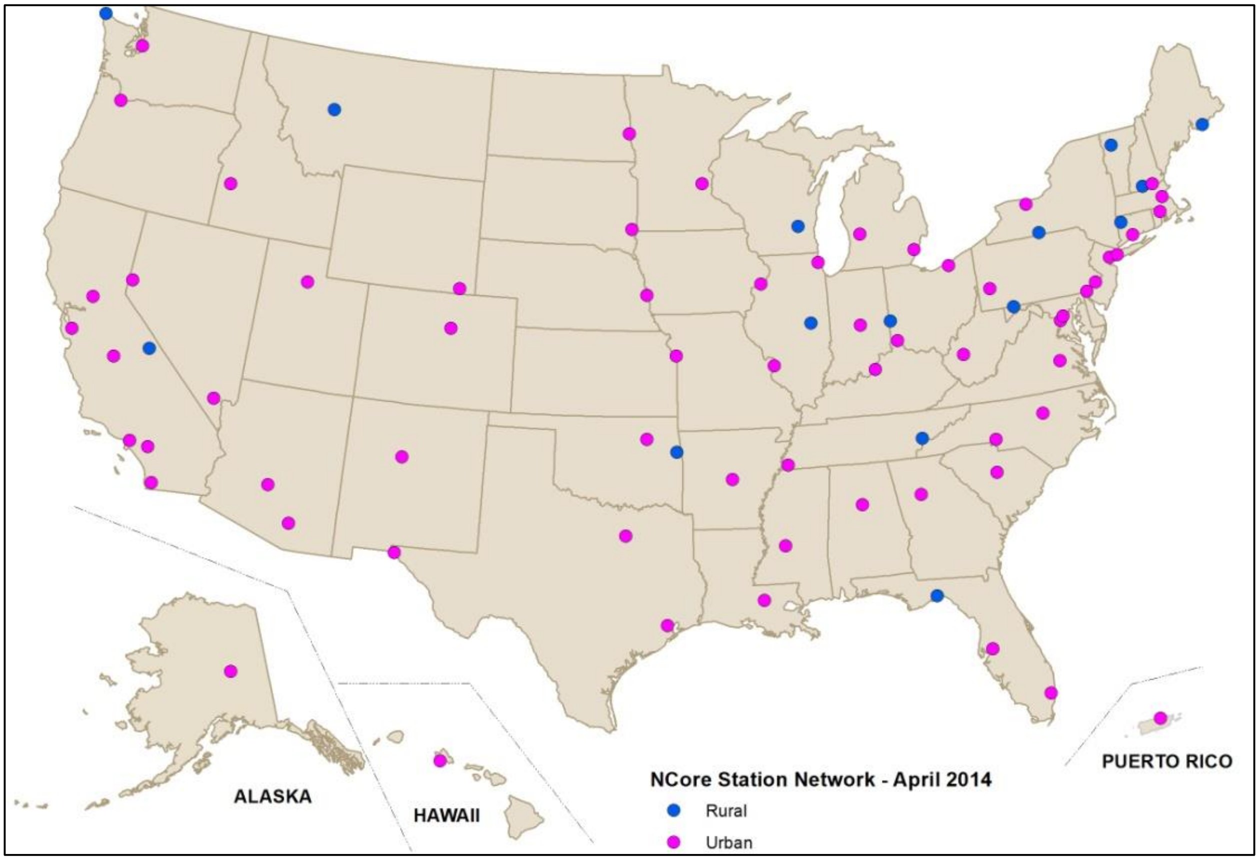


Figure 4-5. Location of NCore sites with NO_Y instruments

Emissions

We intend to use emissions information from the 2011 National Emission Inventory[18] in the Risk and Exposure Assessment. In general, nitrogen and sulfur emissions estimates are dominated by well-characterized combustion processes from power generation (using high confidence continuous emissions monitoring systems), and the transportation sector. The dominant roles of single sources for SO_2 (power generation) and NO) (transportation) simplifies source measurement and emissions estimation practices. Greater uncertainty exists in NO_X emissions from natural sources such as lightning and soil-based generation, but these are generally accounted for in modeling applications. Considerable uncertainty exists regarding emissions of organic nitrogen, which are not accounted for in emissions inventories and have not been a focus of treatment in air quality models. In addition, estimates of ammonia emissions generally present significant challenges given the variety of agricultural practices related to animal feeding operations and fertilizer applications across different regions and meteorological

[18] http://www.epa.gov/ttn/chief/net/2011inventory.html

regimes. Ammonia generation through motor vehicle catalytic reduction of NO_X can be substantial in some urban areas.

Community Multi-Scale Air Quality (CMAQ) Model

We intend to use the CMAQ modeling platform as a tool for estimating deposition and supporting the development of transference ratios (Sickles and Shadwick, 2012) that convert ambient concentrations of NO_Y and SO_x to deposition of nitrogen and sulfur. The CMAQ modeling system is a comprehensive three-dimensional grid-based Eulerian air quality model designed to estimate the formation, transport, and fate of oxidant precursors, primary and secondary PM concentrations and deposition, and air toxics, over regional and urban spatial scales (e.g., over the contiguous U.S.) (U.S. EPA et al., 1999; Byun and Schere, 2006; Dennis et al., 1996; Carlton et al., 2010). The CMAQ model is a well-known and well-established tool and is commonly used by EPA for regulatory analyses, for instance the recent Regulatory Impact Analysis for Particulate Matter NAAQS (U.S. EPA, 2012), and by States in developing attainment demonstrations for their State Implementation Plans. The CMAQ model version 5.0 was peer-reviewed (CMAS, 2011).

CMAQ includes many modules that simulate the emission, production, decay, deposition and transport of organic and inorganic gas-phase and particle-phase pollutants in the atmosphere. The most recent multi-pollutant CMAQ code reflects updates to version 5.0 to improve the underlying physical/chemical process algorithms as well as include new diagnostic/scientific modules.[19] Figure 5-6 shows the geographic extent of the modeling domain that could be used for air quality modeling in this analysis. The domain covers the 48 contiguous states along with the southern portions of Canada and the northern portions of Mexico. This modeling domain contains 25 vertical layers with a top at about 17,600 meters, or 50 millibars, and a horizontal resolution of 12 x 12 km.

[19] CMAQ version 5.0.2; multipollutant version, which was released on July 2012. It is available from the Community Modeling and Analysis System (CMAS) website: http://www.cmascenter.org. See also RELEASE_NOTES for CMAQv5.0 - February 2012 and RELEASE_NOTES for CMAQv5.0.1 - July 2012.

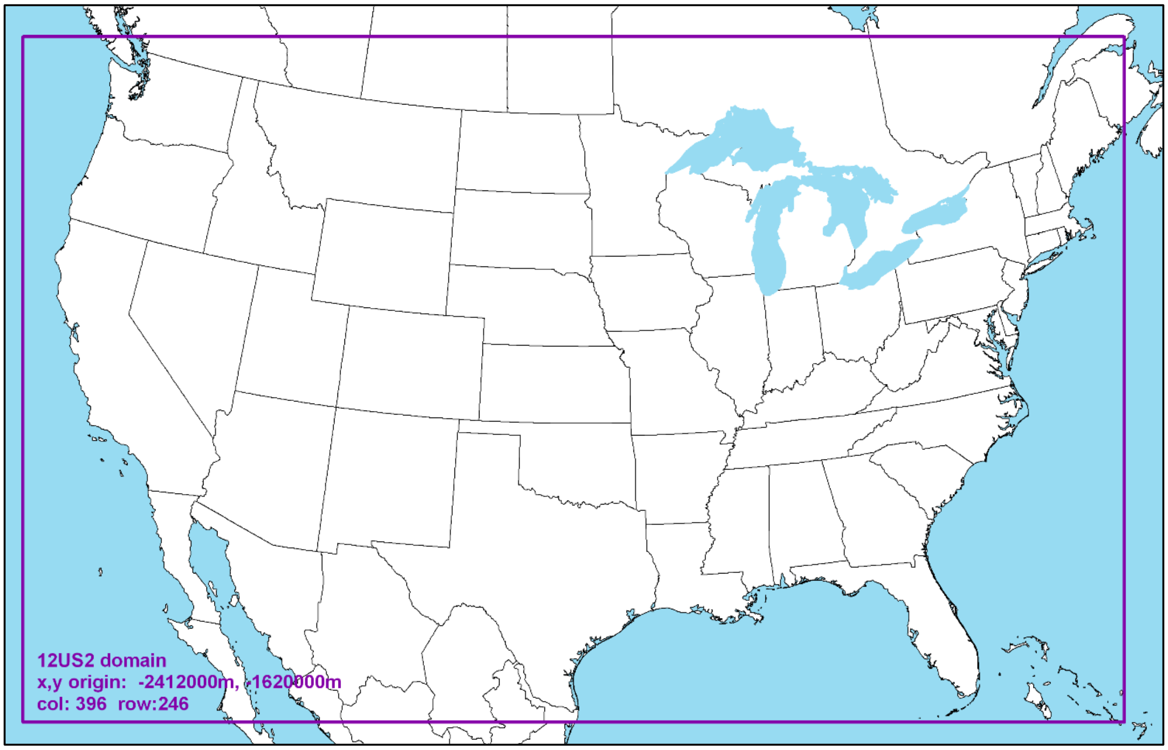


Figure 4-6. Map of the CMAQ 12-km US Modeling Domain

The key inputs to the CMAQ model include emissions from anthropogenic and biogenic sources, meteorological data, and initial and boundary conditions. The CMAQ meteorological inputs will be derived from Version 3.4 of the Weather Research Forecasting Model (WRF) (Skamarock et al., 2008). These inputs include hourly-varying horizontal wind components (i.e., speed and direction), temperature, moisture, vertical diffusion rates, and rainfall rates for each grid cell in each vertical layer. Details of the 2011 annual meteorological model simulation and evaluation will be described in more detail as appropriate in technical support documents. The lateral boundary and initial species concentrations are provided by a three-dimensional global atmospheric chemistry model, the GEOS-CHEM model (Yantosca et al., 2012).[20] The global GEOS-CHEM model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from the NASA's Goddard Earth Observing System.[21] This model was run for 2011 with a grid resolution of 2.0 degrees x 2.5 degrees (latitude-longitude). The predictions were used to provide one-way dynamic boundary conditions at one-hour intervals and an initial concentration field for the CMAQ simulations. A successful GEOS-

[20] Standard version 8-03-02 with 8-02-01 chemistry

[21] GEOS-5; additional information available at: http://gmao.gsfc.nasa.gov/GEOS/ and http://wiki.seas.harvard.edu/geos-chem/index.php/GEOS-5

Chem evaluation was conducted for the purpose of validating the 2011 GEOS-Chem simulation for predicting selected measurements relevant to their use as boundary conditions for CMAQ (Henderson et al., 2014).[22]

Recently, total deposition estimates based on combining monitoring observations and CMAQ estimates were developed under the NADP's Total Deposition science committee[23] and likely will be used for estimates of recent conditions and potentially for various scenarios. Deposition estimates based on this hybrid approach attempt to utilize the broad spatial and chemical composition coverage afforded by CMAQ with the confidence instilled by using observations where available in order to provide estimates of deposition in areas without monitoring sites.

4.3.2 Environmental / Ecological Effects

4.3.2.1Critical Loads Databases

In the previous Risk and Exposure Assessment, a critical loads approach was used to connect deposition of nitrogen and sulfur to the acid-base condition of lakes and streams for which data were available. A critical load is the level of input of a pollutant below which no harmful ecological effects occur over the long term based on the current scientific knowledge (UBA, 2004). For this Risk and Exposure Assessment, critical loads can be used in two ways: first, as a screening tool to identify regions or ecosystems where critical loads are being exceeded under changing deposition levels of NOx and SOx; second, for some ecological endpoints (e.g., Acid Neutralizing Capacity) data are available to assess critical loads associated with varying levels of ecological effect, which provides more information regarding the potential effect of policy change.

In general, critical loads are developed in three ways: empirical, simple mass balance, and dynamic modelling. Empirical approaches are based on observations of ecological responses in relation to observed deposition levels. These can be generated from one or more sites and then are applied to ecologically similar sites where data are not available. Simple mass balance models generally use steady-state assumptions that involve estimating fluxes of pollutants in and

[22] More information is available about the GEOS-CHEM model and other applications using this tool at: http://www-as.harvard.edu/chemistry/trop/geos.
[23] http://nadp.sws.uiuc.edu/committees/tdep/tdepmaps/

out of the system to calculate time invariant critical load estimates which may take decades to impart an associated effects response. Dynamic models generally incorporate more explicit treatment of biogeochemical processes and allow for solutions matching effects and loads as a function of time.

In the previous review, only the critical loads data for aquatic acidification were determined to be adequate for the Risk and Exposure Assessment. To support the current review, in addition to new data on aquatic acidification (such as the Critical Loads Database (CLAD)[24]), new critical loads will be considered that address terrestrial acidification, aquatic and terrestrial eutrophication, and loss of terrestrial plant biodiversity. The U.S. Forest Service has published a review of new critical loads data, which assesses critical loads nationally by ecosystem (USDA, 2011; Pardo et al., 2012). Additionally, several multi-agency collaborations (i.e., EPA, USFS, USHS) are contributing to additional information on critical loads, and are finalizing several peer reviewed publications on losses of terrestrial plant biodiversity (Simkin et al. in review, Stevens et al., in review, Clark et al., in preparation). These, as well as other new databases will be evaluated for inclusion and analysis in the Risk and Exposure Assessment.

4.3.2.2 Models Used in Conjunction with Critical Loads Steady-State Water Chemistry (SSWC) Model

Critical loads were derived from present-day water chemistry and are based on the principle that excess base cation production within a catchment area should be equal to or greater than the acid anion input, thereby maintaining the ANC above a pre-selected level (Reynolds and Norris, 2001). The SSWC model assumes a mass balance and that all SO42– in runoff originates from sea salt spray and anthropogenic deposition. Given a critical ANC protection level, the critical load of acidity is simply the input flux of acid anions from atmospheric deposition (i.e., natural and anthropogenic) subtracted from the natural (i.e., pre-industrial) inputs of base cations in the surface water.

In the SSWC model, a critical load of acidity, CL (A), is calculated for the principle that the acid load should not exceed the non-marine, non-anthropogenic base cation input and sources and sinks in the catchment minus a buffer to protect selected biota from being damaged.

[24] http://nadp.sws.uiuc.edu/committees/clad/db/ Accessed January, 2015.

Model of Acidification of Groundwater in Catchments (MAGIC)

MAGIC is a lumped-parameter model of intermediate complexity, developed to predict the long-term effects of acidic deposition on surface water chemistry (Cosby et al. 1985a,b,c, 2001). The model simulates soil solution and surface water chemistry to predict average concentrations of the major ions. MAGIC calculates for each time step the concentrations of major ions under the assumption of simultaneous reactions involving sulphate adsorption, cation exchange, dissolution-precipitation-speciation of aluminium and dissolution-speciation of inorganic and organic carbon. MAGIC accounts for the mass balance of major ions in the soil by bookkeeping the fluxes from atmospheric inputs, chemical weathering, net uptake in biomass and loss to runoff.

MAGIC reflects the size of the pool of exchangeable base cations in the soil. As the fluxes to and from this pool change over time owing to changes in atmospheric deposition, the chemical equilibria between soil and soil solution shift to give changes in surface water chemistry. The degree and rate of change of surface water acidity thus depend both on flux factors and the inherent characteristics of the affected soils. Data inputs required for calibration of MAGIC comprise lake and catchment characteristics, soil chemical and physical characteristics, input and output fluxes for water and major ions, and net uptake of base cations by vegetation.

Photosynthetic / Evapo-Transpiration Model - Biogeochemical (PnET – BGC)

PnET-BGC is a comprehensive forest-soil-water model developed by linking a monthly carbon, nitrogen and water balance model (PnET) (Aber et al., 1997) with a soil model (BGC) to allow for comprehensive simulations of element cycling within forest and the interconnected aquatic ecosystems (Gbondo-Tugbawa et al., 2001). The model is able to simulate both abiotic and biotic processes. The representation of biomass accumulation and the associated element cycling enable the evaluation of land disturbance and climatic events on soil and water chemistry (Gbondo-Tugbawa et al., 2001). The model uses relatively simple formulations and requires a moderate number of inputs to quantify the acid-base status of soil and surface waters under various levels of atmospheric deposition. Its simplicity also makes it a good candidate for regional applications.

4.3.2.3 Water Quality Models and Data Sources

Spatially Referenced Regressions on Watershed attributes (SPARROW)

The U. S. Geological Survey (USGS) developed the SPARROW model[25] as a tool that relates in-stream water quality measurements to characteristics of watersheds using a steady-state, nonlinear regression formulation that follows the rules of mass balance. The model empirically estimates the fate and transport of contaminants in river networks. It can track nutrient delivery locally to outlets of inland waterways and regionally to coastal waters. This model was used in the previous Risk and Exposure Assessment to estimate changes in estuary eutrophication, and is being evaluated for application in the current review.

Soil and Water Assessment Tool (SWAT)

SWAT[26] is a public domain model supported by USDA with components for weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, and water transfer at the watershed level. SWAT is a physically-based, continuous time simulation model designed to estimate long-term landscape processes. It can be considered a watershed hydrologic transport model. This model is being evaluated for application in the current review.

Hydrologic and Water Quality System (HAWQS)

HAWQS[27] applies the SWAT water quality model on a national scale with a user interface used to support EPA analyses. It is a total water quantity and quality modeling system with databases, interfaces, and models to evaluate the impacts of management alternatives, pollution control scenarios, and climate change scenarios. HAWQS is capable of supporting a wide variety of national and regional scale economic and policy analyses by simulating baseline and alternative water quality conditions with respect to the following water quality constituents:

[25] USGS http://water.usgs.gov/nawqa/sparrow/ Accessed January, 2015.
[26] Texas A&M University http://swat.tamu.edu/ Accessed January, 2015.
[27] Texas A&M University https://epahawqs.tamu.edu/. Accessed January, 2015.

nutrients, sediments, biological oxygen demand, dissolved oxygen, pathogens, and pesticides. This model is being evaluated for application in the current review.

Nitrogen and Phosphorus Pollution Data Access Tool (NPDAT)

U.S. EPA developed NPDAT[28] to help states, other partners, and stakeholders prioritize watersheds on a statewide basis for nitrogen and phosphorus loading reductions, and set watershed load reduction goals based upon best available information. The NPDAT leverages the common code base used by the EPA's Recovery Mapper, MyWATERS Mapper, and Beaches Mapper Web mapping applications. The NPDAT aggregates data available elsewhere at a single location. For example, the available data layers include nitrogen loading for major river basins from SPARROW and water quality monitoring sites for nitrogen.

4.3.3 Ecosystem Services

Since the previous review, there have been significant advances in the field of ecosystem goods and services. EPA is considering a two-part classification system to estimate the flow of goods and services impacted by NOx and SOx to the human economy. For this review we will move forward with a more refined system of categorizing ecosystem services based on the concept of "final ecosystem goods and services" as described in Landers and Nahlick (2013). Final Ecosystem Goods and Services (FEGS) are "components of nature, directly enjoyed, consumed or used to yield human well-being". EPA is considering using the National Ecosystem Services Classification System (NESCS) (U.S. EPA, 2014) which identifies FEGS as the "supply side" input into the "demand side" human economy as shown in Figure 4-2. NESCS classification system is based on a conceptual framework that provides a way to systematically link ecological systems that produce ecosystem services and human systems that directly use these services (i.e., market production systems and households).

[28] http://www2.epa.gov/nutrient-policy-data/nitrogen-and-phosphorus-pollution-data-access-tool Accessed January, 2015.

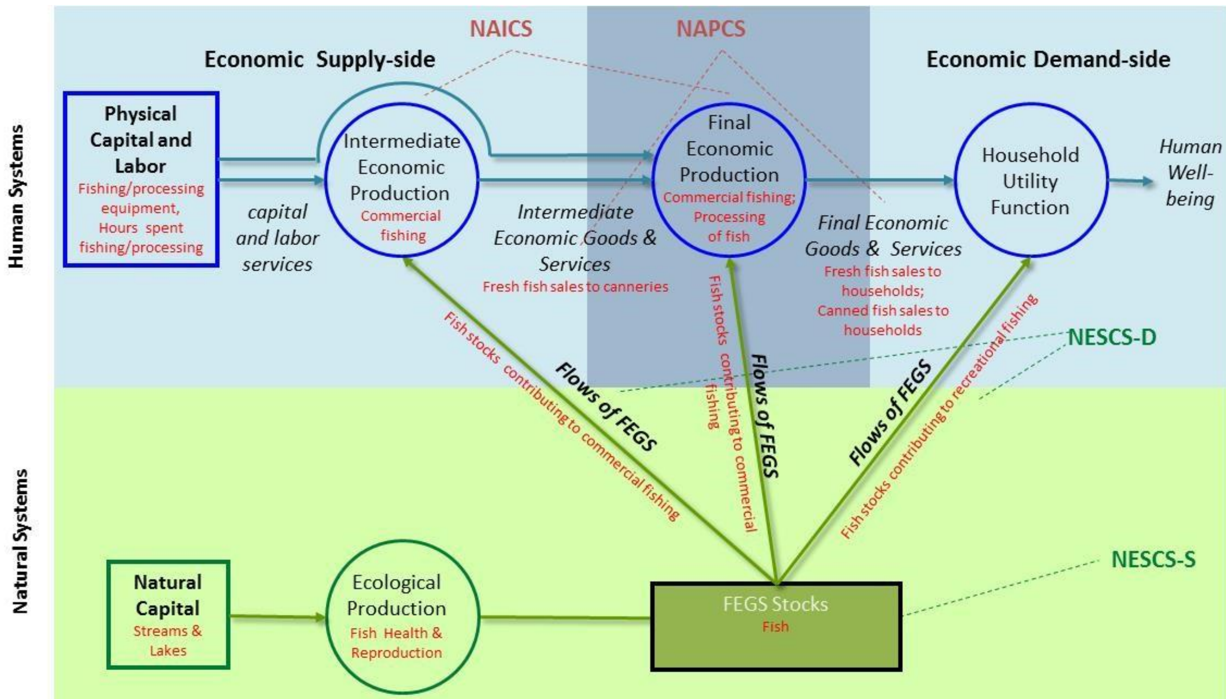


Figure 4-2. NESCS Conceptual Framework with Illustrative Example (Source: NESCS draft report)

We will consider developing specific tables for the Risk and Exposure Assessment that will allow a more complete description of the ecosystem services affected. Where we are not able to provide a quantitative analysis of the links between intermediate and final services, this system will allow us to map the possible pathways of effects to the final services that flow directly to households and contribute to public welfare. This detailed classification structure will allow a more inclusive description of the myriad economic impacts of the effects of nitrogen and sulfur deposition and will assist us in identifying additional areas where economic valuation may be possible.

Integrated Valuation of Environmental Services and Tradeoffs (InVEST)

Developed by the Natural Capital Project, InVEST is a suite of models that map and value ecosystem services.[29] InVEST has been used to inform land use decisions because it allows decision makers to assess the tradeoffs of ecosystem services in alternative scenarios. In considering the usefulness of this tool for the Risk and Exposure Assessment, we are aware that this suite of tools cannot be used to assess the marginal changes in ecosystem services affected by changes in air quality due to policy changes; however, it may be useful in describing the total

[29] http://www.naturalcapitalproject.org/InVEST.html Accessed January, 2015.

array of services in a location that may be affected by changes in NO_X and SO_X and the total value of those services.

Ecosystem Valuation Toolkit

The ecosystem valuation toolkit (Earth Economics, 2014) provides a set of tools for assessing the value of ecosystem services affected by policy decisions.[30] The toolkit includes a database of ecosystem service values managed by ecological economists, a web-based model for calculating ecosystem service values called SERVES (Simple, Effective Resource for Valuing Ecosystem Services), and a set of general materials on ecosystem services and links to other resources.

Artificial Intelligence for Ecosystem Services (ARIES)

ARIES is a web-based model developed with a grant from the National Science Foundation by the University of Vermont, Earth Economics, and Conservation International.[31] It provides a mapping tool that uses relevant ecological and socioeconomic information to track the provision, use, and flows of services to beneficiaries.

Recreation Use Values Database

Housed at Oregon State University, the recreation use values database consists of 352 economic studies that focused on recreation values in the U.S. and Canada from 1958 to 2006.[32] These studies are estimates of net willingness to pay for a particular activity and not marginal values for changes in resource quantity or quality. This database may be useful for estimating total value of particular recreation activities affected by nitrogen and sulfur deposition. A weakness in the database is its age – no studies later than 2006 are included. This database is being updated in a project led by USGS. Completion expected spring 2015.

National Survey on Recreation and the Environment (NSRE)

The NSRE is an ongoing effort by the U.S. Forest Service to track participation and trends in outdoor recreation.[33] The survey has been conducted on a regular basis since 1960 and

[30] http://esvaluation.org/ Accessed January, 2015.
[31] http://www.ariesonline.org/ Accessed January, 2015.
[32] http://recvaluation.forestry.oregonstate.edu/ Accessed January, 2015.
[33] http://www.srs.fs.usda.gov/trends/nsre-directory/ Accessed January, 2015.

contains participation rates for a wide range of outdoor activities and includes questions that gauge respondent's attitudes regarding the importance of various ecosystem attributes and functions. The latest survey was published in 2010 (USDA, 2010).

National Fishing, Hunting, and Wildlife-Associated Recreation (FHWAR)

The FHWAR has been conducted every 5 years since 1955 by the U.S. Fish and Wildlife Service.[34] In partnership with the U.S. Census Bureau and at the request of state fish and wildlife agencies with assistance from the state agencies, conservation groups, and related industries, the survey tracks participation and expenditures for fishing, hunting and other wildlife-associated recreation. The latest survey was completed in 2012.

4.4 CHARACTERIZING UNCERTAINTY AND VARIABILITY

An important issue associated with any Risk and Exposure 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. In contrast, *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). In any risk assessment, uncertainty is ideally reduced by the maximum extent practical, 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. Sources of variability that are not fully reflected in the risk assessment can consequently introduce uncertainty into the analysis.

The goal in designing a Risk and Exposure Assessment is to reduce uncertainty to the extent practical and to incorporate the sources of variability into the analysis approach to ensure 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 ecological effects of NO_X and SO_X. We are considering using

[34] http://wsfrprograms.fws.gov/Subpages/NationalSurvey/National_Survey.htm Accessed January, 2015.

recent guidance from the World Health Organization (WHO, 2008), which presents a four-tiered approach for characterizing uncertainty. With this four-tiered approach, the WHO framework provides a means for systematically linking the characterization of uncertainty to the sophistication of the underlying risk assessment, where the decision to proceed to the next tier is based on the outcome of the previous tier's assessment. Ultimately, the decision as to which tier of uncertainty characterization to include in a risk assessment will depend both on the overall sophistication of the risk assessment and the availability of information for characterizing the various sources of uncertainty.

4.5 PUBLIC AND SCIENTIFIC REVIEW

Drafts of this integrated review plan, the Planning Document for the Risk and Exposure Assessment, and the Risk and Exposure Assessment itself will be reviewed by the Clean Air Science Advisory Committee (CASAC) of EPA's Science Advisory Board (SAB) and the public. CASAC members and consultants will review the draft document and discuss their comments in a public meeting announced in the Federal Register. Based on CASAC's past practice, EPA expects that key CASAC advice and recommendations for revision of these documents will be summarized by the CASAC Chair in a letter to the EPA Administrator. In revising these drafts, EPA will take into account any such recommendations. EPA will also consider comments received, from CASAC and from the public, at the meeting itself and any written comments. EPA anticipates preparing a second draft of the Risk and Exposure Assessment for CASAC review and public comment. After appropriate revision, the final document will be made available on an EPA website, with its public availability being announced in the Federal Register.

5. POLICY ASSESSMENT AND RULEMAKING

5.1 POLICY ASSESSMENT

The PA provides a transparent staff evaluation and staff conclusions regarding policy considerations related to reaching judgments about the adequacy of the current standards and potential alternatives. The PA integrates and interprets the information from the ISA and REA to frame policy options for consideration by the Administrator. When final, the PA is intended to help "bridge the gap" between the Agency's scientific assessments presented in the ISA and REA and the judgments required of the Administrator in determining whether it is appropriate to retain or revise the NAAQS.

The development of the PA is also intended to facilitate CASAC's advice to the Agency and recommendations to the Administrator on the adequacy of the existing standards or revisions that may be appropriate to consider, as provided for in the CAA. Staff conclusions in the PA are based on the information contained in the ISA and REA and any additional staff evaluations and assessments discussed in the PA. In so doing, the discussion in the PA is framed by consideration of a series of policy-relevant questions drawn from those outlined in section 2.2 above, including the fundamental questions associated with the adequacy of the current standards and, as appropriate, consideration of alternative standards in terms of the specific elements of the standards: indicator, averaging time, level, and form.

The PA for the current review will identify conceptual evidence-based and risk/exposure-based approaches for reaching public welfare policy judgments. It will discuss the implications of the science and quantitative assessments for the adequacy of the current secondary standards and for any alternative standards under consideration. The PA will also describe a broad range of policy options for standard setting, identifying the range for which the staff identifies support within the available information. The PA will describe the underlying interpretations of the scientific evidence and risk/exposure information that might support such alternative policy options that could be considered by the Administrator in making decisions for the secondary NO_x and SO_x standards. Additionally, the PA will identify key uncertainties and limitations in the underlying scientific information and in our assessments. The PA will also highlight areas for future welfare-related research, model development, and data collection.

In identifying a range of secondary standard options for the Administrator to consider, it is recognized that the final decision will be largely a public welfare policy judgment. A final decision must draw upon scientific information and analyses about welfare effects and risks, as well as judgments about how to deal with the range of uncertainties that are inherent in the scientific evidence and analyses. This approach is consistent with the requirements of the NAAQS provisions of the CAA and with how the EPA and the courts have historically interpreted the CAA. These provisions require the Administrator to establish secondary standards that are requisite to protect public welfare from any known or anticipated adverse effects associated with the presence of the pollutant in the ambient air. In so doing, the Administrator seeks to establish standards that are neither more nor less stringent than necessary for this purpose. As discussed in section 1.1 above, the provisions do not require that secondary standards be set to eliminate all welfare effects, but rather at a level that protects public welfare from those effects that are judged to be adverse.

Staff will prepare at least one draft of the PA document for CASAC review and public comment. The draft PA document will be distributed to CASAC Oxides of Nitrogen and Oxides of Sulfur NAAQS Review Panel for their consideration and made available to the public for review and comment, with notice of availability announced in the *Federal Register*. Review by CASAC will be discussed at a public meeting that will be announced in the *Federal Register*. Based on past practice by CASAC, the EPA expects that CASAC will summarize key advice and recommendations for revision of the document in a letter to the EPA Administrator. In revising the draft PA document, the EPA will take into account any such recommendations and also consider comments received from CASAC and from the public, including those received at the meeting itself. The final document will be made available on an EPA website, with its public availability announced in the *Federal Register*.

5.2 RULEMAKING

Following issuance of the final PA and the EPA management consideration of staff analyses and conclusions presented therein, and taking into consideration CASAC advice and recommendations, the Agency will develop a notice of proposed rulemaking. The proposed rulemaking notice conveys the Administrator’s proposed conclusions regarding the adequacy of the current standards and any revision that may be appropriate. As specified by Executive Order, the EPA will submit a draft notice of proposed rulemaking to the Office of Management and

Budget (OMB) for interagency review, to provide OMB and other federal agencies the opportunity for review and comment. After the completion of interagency review, the EPA will publish the notice of proposed rulemaking in the *Federal Register*. Monitoring rule changes associated with review of the secondary NO_x and SO_x standards will, as appropriate, be developed and proposed in conjunction with this NAAQS rulemaking.

At the time of publication of the notice of proposed rulemaking, all materials on which the proposal is based are made available in the public docket for the rulemaking.[35] Publication of the proposal notice is followed by a public comment period, generally lasting 60 to 90 days, during which the public is invited to submit comments on the proposal to the rulemaking docket. Taking into account comments received on the proposed rule, the Agency will then develop a notice of final rulemaking, which again undergoes OMB-coordinated interagency review prior to issuance by the EPA of the final rule. At the time of final rulemaking, the Agency responds to all significant comments on the proposed rule. Publication of the final rule in the *Federal Register* completes the rulemaking process.

35 The rulemaking docket for the current secondary NO_x/SO_x NAAQS review is identified as EPA-HQ-OAR-2014-0128. Dockets are publicly accessible at www.regulations.gov. The EPA requests that comments from the public on the PA, REA and rulemaking documents be submitted to this docket. A separate docket for the ISA will be established and specified in the notice of availability of the first draft ISA. Public comments on drafts of the ISA may be submitted to that docket.

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