



Integrated Science Assessment for Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter- Ecological Criteria 2nd External Review Draft

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Timeline for ISA

Call for information to initiate the review	August 2013
Kickoff workshop	March 2014
Peer-input workshop	August 2015
Draft Integrated Review Plan (IRP)	November 2015
CASAC/public consultation on draft IRP	February 2016
Integrated review plan public release	January 2017
1 st draft ISA public release	March 2017
CASAC review of 1 st draft ISA	May 2017
2nd draft ISA released	June 26, 2018
CASAC meeting to review 2nd draft	September 5-6, 2018
Final ISA targeted for public release	2019

ORD/NCEA and OAR/OAQPS Interactions: NAAQS Review

NAAQS Activity	ORD/NCEA	OAR/OAQPS
Workshop on science-policy issues	Co-lead development	Co-lead development
Integrated Review Plan	Lead development of chapter on the ISA	Lead development of other chapters (e.g., REA, PA)
Integrated Science Assessment	<u>Lead development</u>	Review draft materials with focus on identifying areas where clarification is needed
Risk/Exposure Assessment	Review draft materials and provide comments on interpretation of science	<u>Lead development</u>
Policy Assessment	Review draft materials and provide comments on interpretation of science	<u>Lead development</u>
Rule-making materials	Provide technical and scientific support	<u>Lead development</u>

Overview of Key Revisions in 2nd Draft

- ✓ Innovated new ISA structure to significantly reduce the length of the main document and focus on key messages
 - **Executive Summary:** concise synopsis of key findings targeted to a broad audience (19 pages)
 - **Integrative Synthesis (Chapter 1):** synthesis of key messages from the Appendices (111 pages)
 - **Appendices:** includes detailed information on each subject area (>1500 pages)

Overview of Key Revisions in 2nd Draft

- ✓ Revised literature base to:
 - Add additional references suggested by CASAC
 - Update literature through May 2017
 - Approximately 3000 publications in the 2nd draft (up ~500 from 1st draft)

- ✓ Improved cross-referencing among chapters on key topics

Key Revisions to Integrative Synthesis

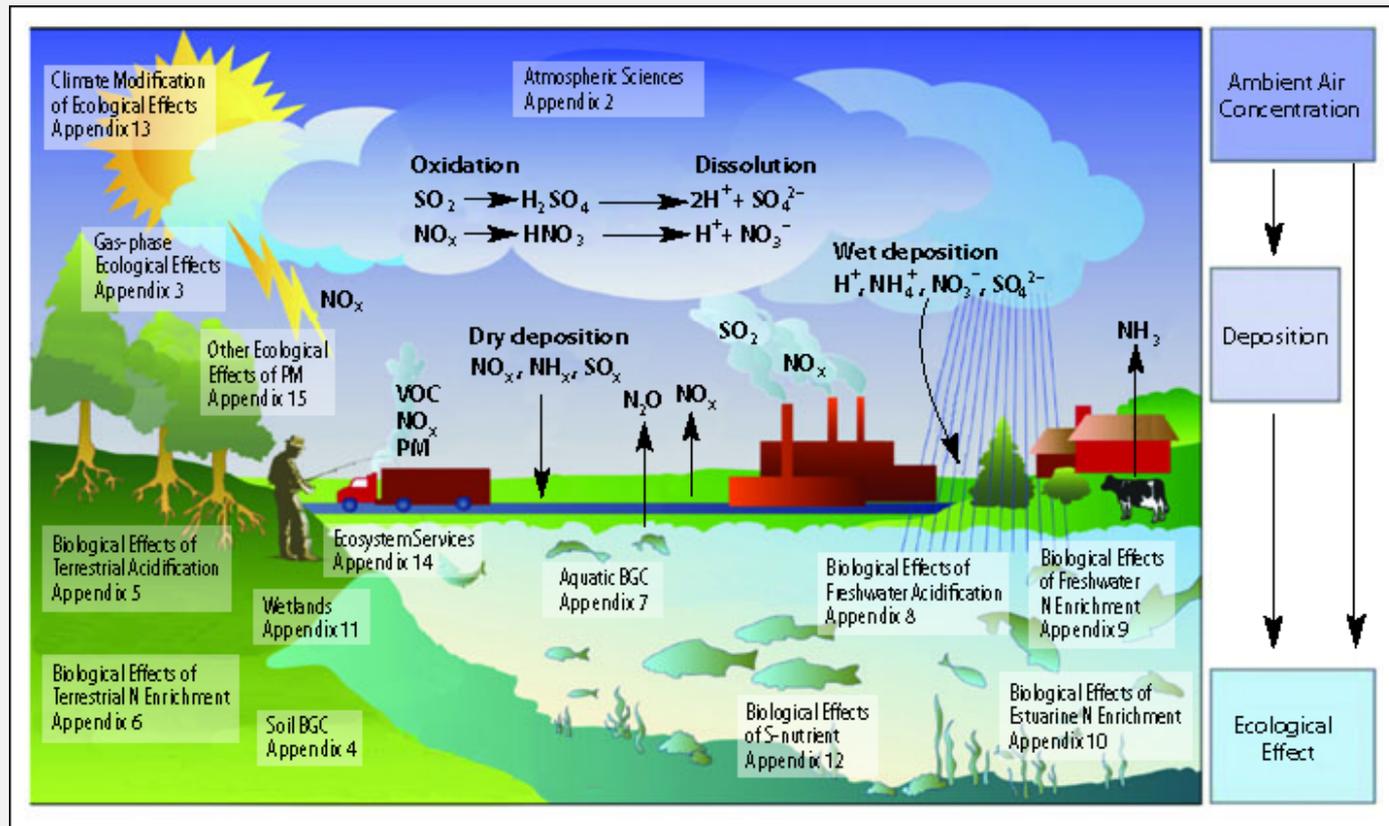
Integrative Synthesis Introduction (Chapter 1.1)

- Expanded discussion to clarify the purpose and scope of the ISA with respect to the REA
 - for example, new analyses with the goal of quantifying risk, such as new model runs, critical loads exceedance maps, and quantified uncertainties regarding modeled scenarios are not conducted in the ISA.
 - these types of analyses, if pursued, require scope-of-analysis decisions and are more appropriate for the Risk and Exposure Assessment (U.S. EPA, 2017b)

Key Revisions to Integrative Synthesis

New section “Connections, Concepts, and Changes” created in response to CASAC comments

- **Connections** (Chapter 1.2.1) includes new roadmap showing how subjects relate across the ISA



Key Revisions to Integrative Synthesis

New section “Connections, Concepts, and Changes”

- **Concepts** (Chapter 1.2.2) includes:
 - ecosystem scale, structure, and function
 - expanded discussion of deposition in the context of source apportionment to ecosystems
 - expanded discussion on critical loads (CL) including a discussion of the strengths and limitations of different critical load approaches (e.g., empirical, steady-state, and dynamic)
 - the importance of biodiversity
 - new section on the effects of reduced versus oxidized forms of N across ecosystems
 - new section on Scientific Advancements of the Aquatic Acidification Index (AAI), the metric developed in the previous secondary NAAQS review

Key Revisions to Integrative Synthesis

New section “Connections, Concepts, and Changes”:

- **Changes** (Chapter 1.2.3): Key conceptual changes since 2008 ISA
 - Atmospheric Sciences
 - » sources of N deposition
 - » the relationship between atmospheric concentration and deposition
 - Ecological Effects
 - » weight of evidence for ecological effects increased, confirming concepts previously identified
 - » improved quantification of dose (deposition)–response relationships
 - » stronger empirical evidence
 - » more species for N enrichment and acidification
 - » more links to biodiversity for N enrichment
 - » more information on N source apportionment in aquatic and wetland ecosystems
 - » new category of effects: Nutrient enhanced coastal acidification

Key Revisions to Emissions and Atmospheric Chemistry (Chapter 1.3 and Appendix 2)

- new information on emissions uncertainty estimates and methods
- new section on bidirectional exchange
- combined sections on geographic distribution of concentration and geographic distribution of deposition to allow side by side comparison of emissions, concentrations, deposition, by species group
- new section on modeling to replace first draft sections on transport and dry deposition, including definitive conclusions about transference ratios
- new material on ammonia emission estimate methods for livestock waste and fertilizer application
- a reorganized section on measurement to address comments about the federal reference method (FRM) adequacy, to explain roles of various networks in deposition estimates, to emphasize methods actually used for deposition modeling, to include deposition measurement, to categorize by species/groups of species

Causality Determinations

- **New causality determinations to the 2nd draft**
 - 1 new “likely causal” determination to this draft on the ecological effects of PM is the same likely causal determination as in the 2009 PM ISA
 - 3 causal determinations were expanded to include additional effects
 - 1 causal determination revised to improve clarity
- **There is no change in the main scientific conclusions in the ISA from 1st to 2nd draft**

Causality across Biological Scales of Organization

2018 NOx SOx PM Integrated Science Assessment for Ecological Effects*														
Indicator		Gases ‡	Nitrogen Deposition					Sulfur Deposition				Nitrogen and Sulfur Deposition		
Class of Pollutant Effect		Direct Phytotoxic	N-enrichment/Eutrophication				Eutrophication Driven Acidification	Sulfide Toxicity		Mercury Methylation		Acidification		
Ecosystem		Terrestrial	Terrestrial	Wetland	Fresh Water	Estuary	Estuary	Wetland	Fresh Water	Wetland	Fresh Water	Terrestrial	Fresh Water	
Scale of Ecological Response	Ecosystem	Productivity	Diagonal	Dark Green	Dark Green	Dark Green	Dark Green	Diagonal	Dark Green	Dark Green	Diagonal	Diagonal	Dark Green	Diagonal
	Community	Biodiversity	Diagonal	Dark Green	Dark Green	Dark Green	Light Green	Dark Green	Dark Green	Diagonal	Diagonal	Dark Green	Dark Green	
	Population Individual	Growth rate	Diagonal	Dark Green	Dark Green	Dark Green	Diagonal	Dark Green	Dark Green	Diagonal	Diagonal	Dark Green	Diagonal	
	Individual	Physiological alteration, stress or injury	Dark Green	Dark Green	Dark Green	Diagonal	Light Green	Dark Green	Dark Green	Diagonal	Diagonal	Dark Green	Dark Green	
	Geochemistry	Soil or sediment chemistry	Diagonal	Dark Green	Dark Green	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal	Dark Green	Dark Green	Dark Green	Diagonal
		Surface water chemistry	Diagonal	Diagonal	Dark Green	Dark Green	Dark Green	Light Green	Diagonal	Diagonal	Dark Green	Dark Green	Diagonal	Dark Green

Causality framework

Causal

Likely causal

Suggestive

Inadequate

Not likely

Not evaluated in causal framework

* A causal relationship is likely to exist between deposition of PM and a variety of effects on individual organisms and ecosystems, based on information from the previous review and limited new findings in this review

‡ Includes: NO, NO₂, HNO₃, SO₂, and PAN

Key Revisions to Soil Biogeochemistry (Chapter 1.4 and Appendix 4)

- expanded discussion of critical mechanisms that control dissolved organic carbon
- expanded discussion of biogeochemistry of soil recovery
- new section on effects of climate and N interactions on soil
- expanded discussion of differential ecological effects for oxidized vs. reduced deposition
- new section on calcium addition studies
- new section on applications of the PnET-BGC model
- new section on N-P dynamics

Key Revisions to Biological effects of N Enrichment and Acidification in Terrestrial Ecosystems

Biological effects of Terrestrial Acidification (Chapter 1.5 and Appendix 5)

- expanded linkages and cross-references to Appendix 4 and 6
- new section on climate modification of response to acidification
- an expanded discussion on uncertainty regarding the Bc (base cation):Al ratio for trees

Biological effects of Terrestrial Nitrogen Enrichment (Chapter 1.5 and Appendix 6)

- added expanded linkages/cross-references to Appendices 4 and 5
- new section on climate modification of ecosystem response to nitrogen
- new material on how N alteration of mycorrhizal communities might affect ecosystem function
- added expanded linkages/cross-references to Appendices 4 and 5

Key Revisions to Aquatic Biogeochemistry

Aquatic Biogeochemistry (Chapter 1.6, 1.7 and Appendix 7)

- a more balanced treatment of coastal vs. freshwater biogeochemistry, including more detail on estuarine biogeochemical processes affected by N and addition of sections on estuarine monitoring and water quality criteria for estuaries
- new information on dissolved organic carbon
- new information on recovery related to chemical indicators
- new information on trends for dissolved inorganic aluminum and nitrate in surface waters
- a new section on climate modification of ecosystem response to nitrogen

Key Revisions to Biological Effects of N Enrichment and Acidification in Freshwater

Biological effects of Freshwater Nitrogen Enrichment (Chapter 1.6 and Appendix 9)

- **the causal determination for this appendix has been expanded from the first draft to include productivity**
- a new section on increased atmospheric deposition of phosphorus
- freshwater harmful algal bloom discussion expanded
- incorporated new papers on critical loads
- a new section added on climate modification of ecosystem response to N

Biological effects of Freshwater Acidification (Chapter 1.6 and Appendix 8)

- added updated map of surface water ANC
- expanded discussion of biological recovery, mitigation responses and controls on biological response between glaciated and unglaciated regions
- a new section added on climate modification of ecosystem response to N and S

Key Revisions to Biological effects of N Enrichment in Near Coastal Ecosystems

Estuarine and Near Coastal Nitrogen Enrichment (chapter 1.7 and Appendix 10)

- **expanded the causal statement for this appendix to include the endpoints of total primary production and total algal community biomass as per recommendation from CASAC**
- additional information added on differential ecological effects for oxidized vs. reduced deposition
- expanded the scope of the appendix to include nutrient effects on coral reef ecosystems
- a new section on climate modification of ecosystem response to nitrogen
- a new map of eutrophic and hypoxic coastal areas

Key Revisions to Biological effects of N Enrichment in Wetland Ecosystems

Wetland Nitrogen Enrichment (Appendix 11)

- **the causal determination has been expanded from the first draft to include “growth and productivity” as endpoints**
- added information from the EPA 2011 National Wetlands Condition assessment, and the effects of oxidized vs. reduced N deposition
- Added new studies on N addition to European bogs, on invasive plants, and on marsh destabilization
- new section on climate modification of ecosystem response to nitrogen

Key Revisions to Biological Effects of S Enrichment on Wetlands and Freshwaters

Sulfur Enrichment (chapter 1.9 and Appendix 12)

- **the causal determination about sulfide phytotoxicity has been expanded from the first draft to include “growth and productivity” as endpoints**
- **the causal determination about mercury (Hg) has been reworded from the first draft : “The evidence is sufficient to infer a causal relationship between S deposition and increased methylation of Hg ~~where the value of other factors is within adequate range for methylation in wetland and aquatic ecosystems~~ in surface water, sediment, and soils in wetland and freshwater ecosystems”**
- new sulfide toxicity values for American wetland plant species
- new information on correlation between Hg and S deposition near sources, Hg methylation by sulfate-reducers in terrestrial forest soils, Hg and dissolved organic carbon interactions in soil and water, and correlations between algal blooms and Hg methylation

Uncertainty (Chapter 1.13)

- Introduction describes basic definitions and principles to create a common point of reference across disciplines
 - ontic uncertainty: inherent variability or randomness, and is an irreducible form of uncertainty
 - epistemic uncertainty: imperfections of knowledge, which may be reduced by further research and empirical investigation
- Focuses on key uncertainties and methods without quantification
- Includes atmospheric sciences (1.13.1)
 - Emissions uncertainty
 - Atmospheric measurement uncertainty
 - Atmospheric modeling uncertainty
- Includes ecological effects (Chapter 1.13.2)
 - Empirical critical loads
 - Modeled critical loads
 - Key considerations
 - » *empirical observation or application of a model*
 - » *spatial scale (e.g., site-specific, regional, or national)*
 - » *resources to be protected (e.g., stream, lake, soil, vegetation, aquatic biota)*
 - » *chemical indicator(s) of adverse effects (e.g., water ANC)*
 - » *critical level(s) for selected indicator(s)*
 - » *time frame of evaluation (i.e., ambient, 2050, long-term steady state)*

Key Revisions to Other Effects of PM and Ecosystem Recovery

Ecological effects of other components of PM (Chapter 1.10 and Appendix 15)

- **a likely causal determination (also in the 2009 PM ISA) was added:**
“The body of evidence is sufficient to infer a likely causal relationship between deposition of PM and a variety of effects on individual organisms and ecosystems, based on information from the previous review and limited new findings in this review”

Recovery of Ecosystems from Nitrogen (N) and Sulfur (S) (Chapter 1.11)

- New section in response to CASAC comments
- Overarching concepts of recovery
 - Recovery often modeled using chemical indicators
 - Recovery rates may differ among chemical pools
- Some evidence for acidification and S-nutrient recovery in the U.S. (northeastern U.S.)
- No evidence of recovery of N-driven nutrient enrichment

Key Revisions to Climate Modification of Ecosystem Response and Ecosystem Services

Climate Modification of Ecosystem Response (Chapter 1.12. and Appendix 13)

- new sections on this topic were added to all relevant Appendices, and these new sections are referenced in this Appendix.

Ecosystem Services (Chapter 1.14 and Appendix 14)

- new focus on ecosystem services that provide outcomes of ecological processes (biophysical or social)
- new discussion that defines ecosystem service analysis
- created several plain-spoken narratives (lichens and aquatic grasses)
- new information on economic impacts of ocean acidification
- new section on ecosystem services associated with N deposition classified using the new final ecosystem goods and services-classification system (FEGS-CS)

No Change in Main Conclusions of 2nd Draft

Current NO₂ & SO₂ Secondary Standards are based on foliar injury:

- No new evidence that foliar injury occurs at current concentrations in U.S.

N enrichment from atmospheric deposition alters many ecosystems:

- National N deposition rates have been broadly constant, with decreasing NO_y deposition offset by increased NH_x deposition
- New quantitative evidence that current rates of N deposition cause:
 - Decreases in lichen biodiversity and herbaceous plant biodiversity
 - Positive and negative effects on tree growth and mortality
 - Increases in algal growth, loss of sensitive aquatic species
- New thresholds of deposition (critical loads) are available for biological effects
- Surface waters receive N deposition and N inputs from agricultural and urban sources

No Change in Main Conclusions of 2nd Draft

Acidification from N & S deposition continues to affect ecosystems:

- Negative effects on fish, plants, plankton are well-documented
- S deposition has greatly declined over the past 25 years; driving decreases in total acidifying deposition observed in the East
- Some geochemical recovery has been documented in Northeast

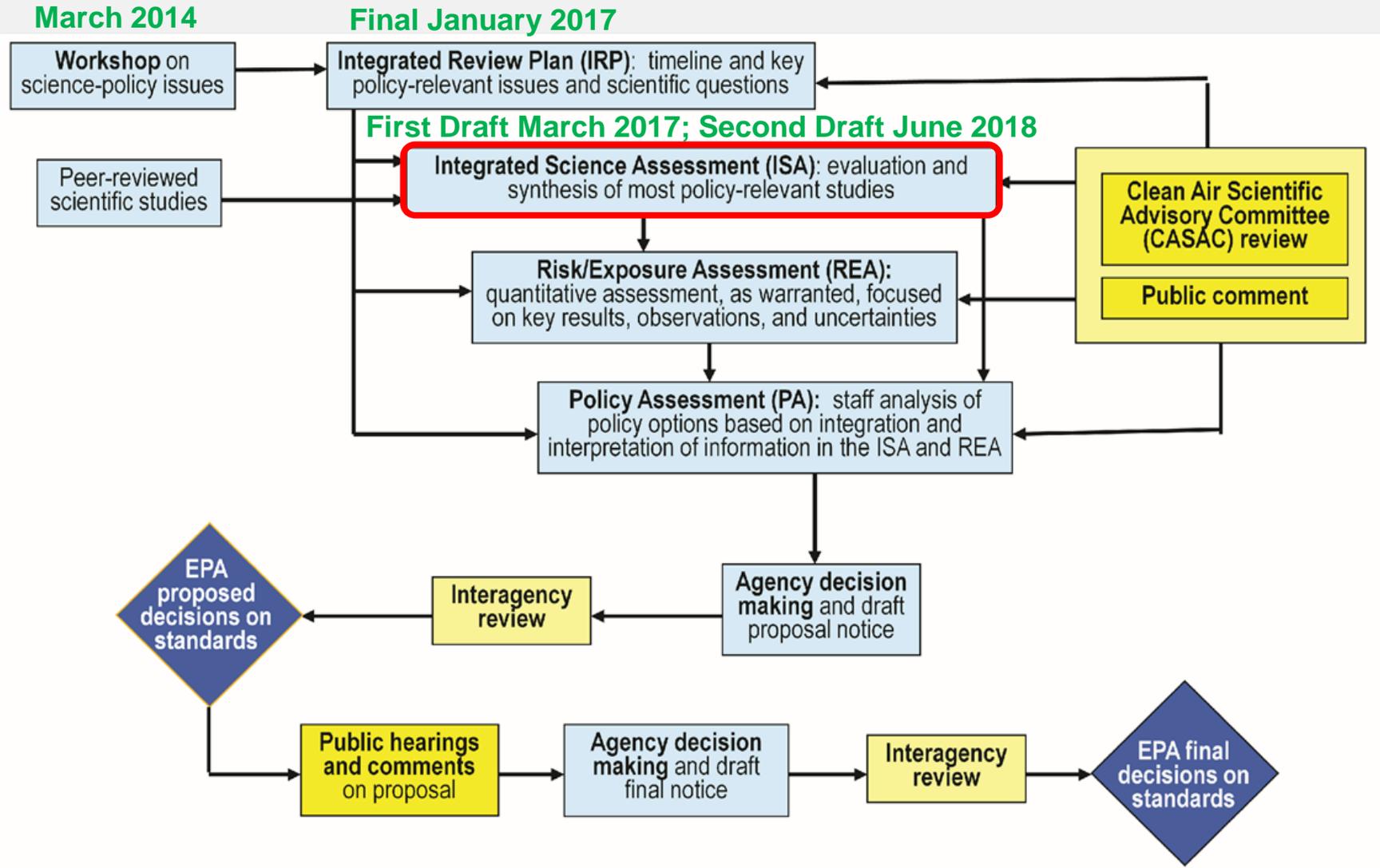
S enrichment from deposition alters aquatic and wetland ecosystems:

- New evidence that S deposition causes increases in sulfide toxicity and mercury methylation

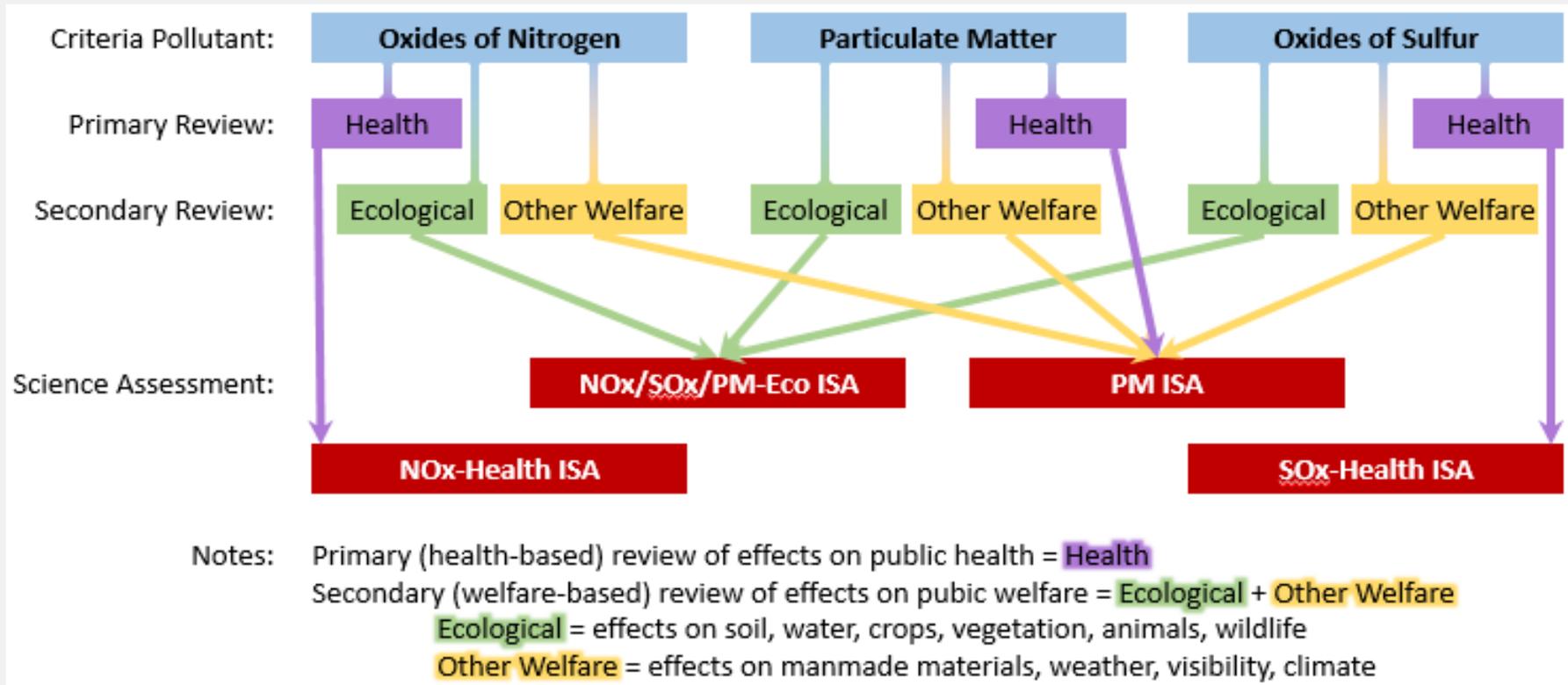
Next Steps

ISA Timeline	
Final ISA targeted for release	2019

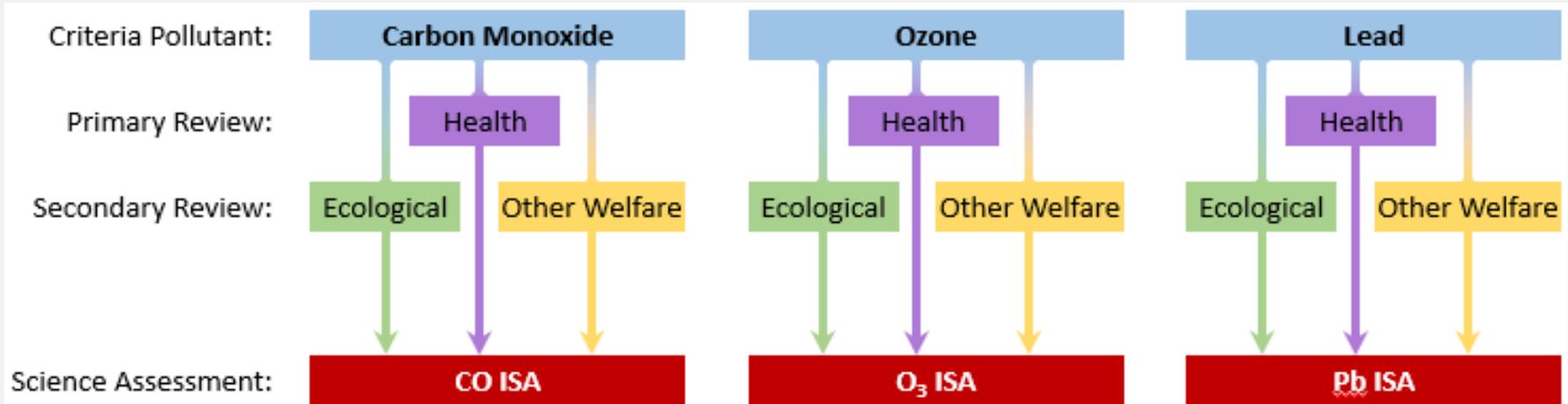
Overview of Review Process for National Ambient Air Quality Standards (NAAQS)



Relationship among Integrated Science Assessments



Relationship among Integrated Science Assessments



Notes: Primary (health-based) review of effects on public health = Health
 Secondary (welfare-based) review of effects on public welfare = Ecological + Other Welfare
 Ecological = effects on soil, water, crops, vegetation, animals, wildlife
 Other Welfare = effects on manmade materials, weather, visibility, climate