Comments from members of the SAB Integrated Nitrogen Committee on the February 18, 2009 draft report, *Reactive Nitrogen in the United States; An Analysis of Inputs, Flows, Consequences, and Management Options*

Table showing comments received

Comments from Dr. Ellis Cowling

Comments on the Executive Summary

> Jim -- Tom -- Angela --
>   As requested by Jim in a phone conversation on Monday, I have
> concentrated my attention (in part together with Paul Stacey) on two
> very important parts of our Report -- the Executive Summary and the
> statements of recommendations -- including the three "Overarching
> Recommendations," the four major "Recommendations" by which existing
> technologies could be used to achieve an initial 25% decrease in Nr
> releases in the US (Recommendations 20-24 on pages 153-157), and the
> other specific "Findings" and "Recommendations" that are scattered
> throughout Chapters 2 and 3 and repeated again in Appendix 3 on pages
> 165-180 of the full report. Incidentally, I found Appendix 3 to be a
> very valuable asset to assist us in "reasoning together" about the
> compelling case we all agree is needed.
>   I find the Executive Summary much in need of editorial revision
> -- not so much that it doesn't contain the major scientific facts and
> information that we have gained through the INC process that support
> the scientific findings and recommendations we are offering to EPA,
> but because the present draft falls short of providing a COMPELLING
> case for the kinds of changes in intra-agency and inter-agency
> approaches that we all agree are needed if rNr is to be managed wisely
> in the United States in years ahead.
>
>   As you will see in the attached "Suggested Revisions of the
> Executive Summary," my attention has been focused primarily on trying
> to optimize the WORDING of the various sentences, paragraphs, and
> sections of the Executive Summary, rather than the much more difficult
> challenge of organizing the ideas we have developed into a compelling
> and persuasive case for the kinds of changes that are needed in order
> to deal with all the complexities that are inherent in the roles that
> many different forms of Nr play in food, feed, fiber, and biofuels
> production, and at the same time cause many of the adverse public
> health and ecosystem impacts that occur when excess Nr is lost to the
> environment.
>
>   I continue to believe that an important key to developing the kind
> of compelling case we all believe in, is how we choose to present:
> -- The three "Overarching Recommendations,"
> -- The four major "Recommendations" by which existing technologies
> could be used to active an initial 25% decrease in Nr releases in the
> US (Recommendations 20-24 on pages 153-157 -- which I have suggested
> we rename "Initial Target Goals, and recognize to be distinct from
> both the "Overarching Recommendations" and
> -- The rest of the other issue-specific "Findings" and
> "Recommendations" that are scattered throughout Chapters 2 and 3 in
> the full Report.
> My suggestion is that is that we use a part of our time together
> during the Conference Call on March 5 to consider::
>   --How to make our case more persuasive and compelling, and
>   -- Whether other INC members agree (or disagree) with my suggestion
> that how we present and organize our three different kinds of
> recommendations to EPA will (or will not) help in making our case as
> persuasively as possible.
>
>   Best regards, Ellis

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1 **Reactive Nitrogen in the United States;**

An Analysis of Inputs, Flows, Consequences, Recommendations, and Management Options

Table of Contents

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Executive Summary

Introduction

Reactive nitrogen (Nr) encompasses biologically active, chemically reactive, and radiatively active nitrogen compounds[1]. At the global scale, human activities now create approximately two-fold more Nr than natural terrestrial and aquatic ecosystems produce. Human activities include the production of Nr through the Haber-Bosch process that generates ammonia (NH_3) for synthetic nitrogen fertilizer and industrial feedstocks, the enhancement of biological nitrogen fixation (BNF) by crop cultivation (e.g., legumes), and combustion of fossil fuels. The first two anthropogenic activities form Nr on purpose; the last one forms Nr as an unwanted byproduct -- by accident.

Anthropogenic creation of additional Nr results in large-scale human-benfical and adverse impacts. The first and foremost human-beneficial impact is meeting human food dietary needs. In fact, a large fraction of the human population of the Earth would not be alive today if global food production was not augmented significantly by synthetic nitrogen fertilizers made possible by the haber-Bosch process. At the same time, however, essentially all of the Nr created by human activities is lost to the environment where it circulates between and accumulates in environmental systems that include the atmosphere, and aquatic and terrestrial ecosystems. Once lost to the environment, Nr contributes to a number of adverse public health and environmental effects -- including photochemical smog formation, increased exposure to nitrogen-containing aerosols, decreased atmospheric visibility, acidification of terrestrial and aquatic ecosystems, coastal eutrophication, global warming and other greenhouse effects, and stratospheric ozone depletion. These adverse effects contribute to declines in both human health (e.g., respiratory and cardiac diseases) and ecosystem health (e.g., eutrophication and loss in biodiversity). These human-beneficial and adverse public health and environmental effects are magnified because any one atom of Nr in the environment can contribute to each effect (both beneficial and detrimental) in sequence, as excess Nr moves through various environmental reservoirs;

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This characteristic feature of Nr is the conceptual foundation for the nitrogen cascade (see Figure 3 [or add the nitrogen cascade diagram on page 20 of Chapter 1 to this Executive Summary].

To assist EPA in its management of nitrogen-related air-, water-, and soil-pollution issues, this Integrated Nitrogen Committee (INC) was charged by the Science Advisory Board (SAB) of the US Environmental Protection Agency to addressing the following objectives:

1. Identify and analyze, from a scientific perspective, the problems nitrogen presents in the environment and the links among them;

[1] The term reactive nitrogen (Nr) is used in this paper to include all biologically active, chemically reactive, and radiatively active nitrogen (N) compounds in the atmosphere and biosphere of Earth. Thus, Nr includes inorganic chjemically reduced forms of N (NHx) [e.g., ammonia (NH_3) and ammonium ion (NH_4^+)], inorganic chemically oxidized forms of N [e.g., nitrogen oxides (NO_x), nitric acid (HNO_3), nitrous oxide (N_2O), N2O5, HONO, peroxy acetly compounds such as PAN, [others] and nitrate ion (NO_3^-), as well as organic compounds (e.g., urea, amines, amino acids, and proteins), in contrast to non-reactive gaseous N_2.

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2. Evaluate the contribution an integrated nitrogen management strategy[2] could make to environmental protection;

3. Identify additional risk management options for EPA's consideration; and

4. Make recommendations to EPA concerning improvements in nitrogen research to support risk reduction.

The rest of this Executive Summary gives an overview of the analyses made by the INC committee to fulfill the INC's four charges. It then summarizes the Nr inputs to the United States (US), and the fate of the Nr in the US. The chapter then addresses how both public health and environmental impacts are, and could be, assessed, and then concludes with three "Overarching Recommendations" for both research and management that should be followed to help the EPA develop an integrated nitrogen management strategy, and four "Target Goals" (see "recommendations 20-24 on pages 153-157) by which to achieve an initial 25% decrease in the amount of Nr lost to the US environment using existing technologies.

The Integrated Nitrogen Committee (INC) worked diligently for two

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years gathering scientific data and information on Nr inputs into the US, the flows of Nr through US environmental systems, and the influence that various human activities have had on these flows. The INC also summarized the extensive literature that exists on Nr-related impacts on public health and on both the atmosphere and terrestrial ecosystems and aquatic ecosystems. These very necessary reviews and analyses of existing scientific knowledge provided the intellectual foundation for INC to address the following somewhat more detailed policy-relevant questions:

• How should Nr be managed and how should management priorities be determined?

• To what degree can the US decrease Nr losses to the environment using existing technology?

• What further decreases are needed?

• What more can EPA do to develop a total integrated management strategy for Nr?

In recent years, a few other studies have examined some aspects of the biogeochemical flows of Nr in the US nitrogen cycle, the impacts of alterations in those flows, and suggested policies for addressing some specific consequences of those alterations.

By contrast, this report of the INC committee report seeks to provide an integrated and holistic approach to all aspects of the current Nr-management problems and challenges in our country. Our INC Committee is convinced that the USEPA has a potentially very powerful lead role to play -- together with other federal, state, and local organizations -- in developing integrated strategies by which to maximize beneficial impacts and decrease detrimental impacts of Nr management in this country. In this connection, please note especially:

- The three "Overarching Recommendations" on pages 15-16 of this Executive Summary,
- The four "Specific "Target Goals" for immediate decreases in Nr releases to the environment using existing technologies as outlined in Recommendations 20 through 25 on pages 153-158 in Chapter 3 of the full Report, and the
- The 25 specific "Findings" and associated "Recommendations" given on pages 37-116 in Chapter 2 and on pages 128-158 in Chapter 3 of this Report -- and collated together once again in Appendix 3 on pages 165-180 of this INC report

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2 An integrated nitrogen management strategy takes an holistic approach for managing Nr. In the context of the nitrogen cascade, all Nr anthropogenic creation and destruction mechanisms and all Nr uses are recognized. The strategy should take account of synergies and trade-offs, to ensure that decreasing one problem related to nitrogen does not result in other unintended adverse environmental, economic and societal consequences. By identifying relative priorities, assessing cost effectiveness and risks, the strategy should seek to maximize the benefits of reactive nitrogen, while limiting overall adverse effects.

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Comment [ebc3]: Jim – Tom – Angela – These additional lines of text are suggested to convey in more direct language, the sense of the INC Committee that this Report outlines not only "Overarching, Recommendations" and "Target Goals" for decreases in Nr losses,to the environment, but also "Specific Findings and Recommendations" to guide EPA's interim actions on specific aspects of the Nr problem in this country.

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Overview

The ultimate goal of this INC Report is to aid EPA in the development of an integrated N management strategy. To accomplish this, the committee recommends that EPA and others strengthen the science related to flows and impacts of Nr, that EPA use current knowledge to identify management actions that can be taken now, and that EPA join with other organizations in implementing management actions within a framework that does not exacerbate one problem of N when addressing another problem.

To aid the INC committee in its deliberations, the four initial charges by the Science Advisory Board were elaborated briefly and then followed to completion as described below:

Charge #1: Identify and analyze, from a scientific perspective, the problems N presents in the environment and the links among them.

To address this aspect of the charge, INC first determined the major sources of newly created Nr for the US. Then the committee determined examined the flows of Nr within the food, fiber, feed and biofuel production systems for the US, paying special attention to identifying locations in the food, feed, fiber, and fuel production system where Nr is lost to the environment. The committee did the same thing for energy production, but since all the Nr formed during energy production is lost to the environment, the committee identified the important energy producing sectors that contributed to Nr formation (Section 2.2 on pages 28-56 of the full Report).

The committee then examined the fate of the Nr lost to the environment, determined the amount stored in different systems (e.g., forest soils) and tracked Nr as it was transferred from one environmental system (e.g., the atmosphere) to another (e.g., terrestrial ecosystems) (Section 2.3 on pages 57-82 of the full Report). The end-result of these two activities is summarized in Figures 1 and 2 of the Executive Suymmary.

These two activities set the stage for addressing the various problems Nr presents in the environment and links among them. Using the nitrogen cascade, the committee identified the impacts that Nr has on people and ecosystems as it moves through environmental systems. The committee also addressed the metrics that could be used, i.e., impacts due to environmental changes (e.g., acid deposition), vs. impacts due to losses of ecosystem services (e.g., loss of biodiversity), and trade-offs among Nr Impacts. Section 2.4 on pages 87-125 of the report covers these aspects of the first charge.

Charge #2: Evaluate the contribution an integrated N management strategy could make to environmental protection.

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An integrated management strategy takes into account the contributions of all Nr sources, and all chemical species of Nr to adverse impacts on both human health and environmental systems. Further, the strategy should ensure that solving one problem related to Nr does not exacerbate another problem or decrease the ability to produce food, feed, fiber, or biofuels. In short, the strategy should seek to maximize the benefits of Nr, while limiting overall adverse effects.

To address this aspect of the charge, the committee identified several examples of actions in managing Nr in one environmental system that have caused unintended consequences in another. In addition, it provided examples of types of management actions that could be taken that would be 'integrated' in nature.

Charge #3: Identify additional risk management options for EPA's consideration.

INC has identified four major Target Goals for actions which, collectively, would limit Nr losses to the environment by about 25%, recognizing that decreasing Nr emissions at these points will result in further decreases in Nr-related impacts throughout the nitrogen cascade. In addition, INC has suggested several ways in which each of these Target Goals could be attained including conservation measures, additional regulatory steps, application of modern technologies, and end-of-pipe approaches. These are initial actions; others should be taken once the recommended actions in the report that focus on a better understanding of N dynamics and impacts in the US are completed.

Charge #4: Make recommendations to EPA concerning improvements in Nr research to support risk reduction.

Throughout the report, there are summary statements, labeled "Scientific Findings." Attached to each such "Scientific Finding" is one or more specific "Recommendation" for actions that could be taken by EPA or other organizations." In each case, the intent is to provide the scientific foundation regarding a specific Nr- relevant environmental issue and one or more "Reommendations" by which EPA acting alone or in cooperation with other organizations

could use currently available technology to decrease the amount of Nr lost to the US environment.

In addition, the INC report includes three "Overarching Recommendations" that would enable EPA

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to improve Nr-relevant research in the support of risk reduction strategies.

The remaining sections of this executive summary cover the points made above in greater detail.

Behavior of reactive nitrogen in the environment: transfer and transformations, impacts, and integrated risk reduction strategies

Sources of Nr

At the global scale, human activities introduce approximately two-times more reactive nitrogen than natural processes; in the US, however, this difference in amount of Nr released to the environment by human activities is approximately five-times larger than natural processes. As shown in Figure 1, natural ecosystems in the US introduce about 6.4 teragrams (Tg) of reactive nitrogen per year. In contrast, human activities introduce about 28.5 Tg Nr/per year.

The largest single source of Nr in the US is the Haber-Bosch process, which introduces about 15.2 Tg Nr/yr into the US -- 9.4 Tg Nr/yr from domestic US Nr production and 5.8 Tg Nr/yr from imports of synthetic Nr fertilizers, feed grains and food. This total amount is used in three ways -- 9.9 Tg N/yr is used to produce agricultural crops; 1.1 Tg N/yr is used to produce turf grasses; and 4.2 Tg Nr/yr is used as industrial feedstocks for production of nylon, refrigerants, explosives and other commercial products.

Fossil fuel combustion is the second largest source of Nr. It introduces approximately 5.7 Tg Nr/yr into the environment (almost entirely as NOx) -- 3.8 Tg Nr/yr from transportation sources and 1.9 Tg Nr/yr from stationary sources such as electric utilities and industrial boilers

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Draft Report dated 2/18/09 to Assist Deliberations for the SAB Integrated Nitrogen Committee at its March 4, 2009 Teleconference
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This draft is a work in progress, does not reflect consensus advice or recommendations of the committee, has not been reviewed or approved by the chartered SAB, and does not represent EPA policy

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Comment [ebc4]: This footnote about little NOx frocombustion of wood and other bim omass seems more of a distraction than an essential part of the Executive Summary. Wouldn' it be better to deal with this detailed point in Chapter 2 rather than in the Executive Summary?
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Figure 1: New Nr introduced into the US, 2002, Tg N

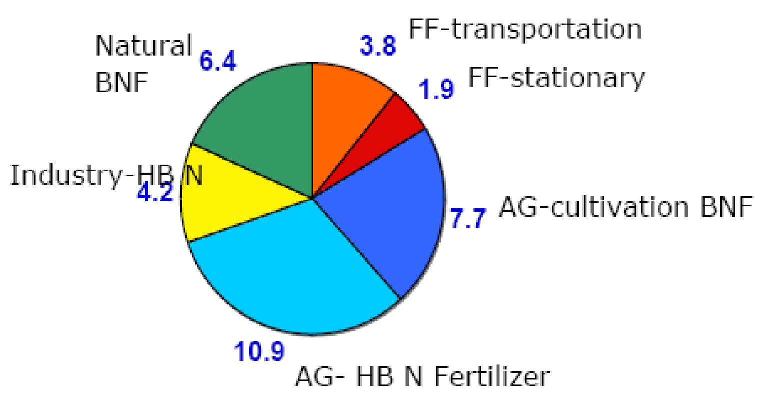

Figure title: Fuigure 1: Sources of reactive nitrogen (Nr) introduced into the US in 2002 (Tg Nr/year)

Explanatory notes:

Numerical units = teragram of reactive nitrogen (Nr) per year (Tg Nr/yr)

Natural BNF = biological nitrogen fixation in natural grasslands, rangelands, and forests,

FF transportation = combustion of fossil fuels in transportation vehicles.

FF stationary = combustion of fossil fuels in power plants and industrial boilers.

AG-cultivation BNF = agricultural augmentation of biological nitrogen fixation -- for example by planting of nitrogen fixing legumes.

AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr.

Industry-HB N = Industrial sources of Nr produced by the Haber-Bosch process.

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The third largest source of Nr introduced into the US is enhancement of biological nitrogen fixation (BNF) by cultivation of crops like soybeans, alfalfa, and rice that have nitrogen fixing symbionts. These Nr fixing crops introduce abouts 7.7 Tg N/yr. A small amount of additional Nr is also imported in grain and meat products; in 2002 this source of added Nr was approximately 0.2 Tg Nr/yr.

In summary, agricultural production of food, feed, fiber, and biofuels and combustion of fossil fuels are the largest sources of of Nr releases into the environment compared to other human sources in the United States. The percentage distribution of Nr releases to the US environment from human activities in 2002 were: about 65% from agricultural sources, about 20% from fossil fuel sources, and about 15% from industrial sources (see Figure 1 once again).

Comment [ebc5]: An important and widely accepted principle for the design of Figures is the notion that the Figure itself and its descriptive caption should "stand alone" and not be dependent on information contained only in the text for understanding by readers. Thus, after a thorough discussion of this guiding prionciple with Jim Galloway, I offer the following recommendations for the revision of this Figure (and also) Figure 2 on page 11 of the Excutive Summary.

The caption this figure should read: Figure 1. Sources of reactive nitrogen (Nr) introduced into the United States in 2002.

The explanatory notes for this figure should read:
Numerical units are teragram of reactive nitrogen per year (Tg Nr/yr). Natural BNF = biological nitrogen foixation in natural grasslands, rangelands, and forests, FF transportation = combustion of fossil fuels.r in transportation vehicles. FF stationary = combustion of fossile fuels in power plants and industrial boilers, AG-cultivation BNF = agricultural augmentation of biological nitrogen fixation, for example planting of nitrogen fixing legumes. AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr. AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr. Industr ... [2]

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Although fossil fuel combustion is widely recognized within EPA and society in general to be a major source of nitrogen, sulfur, and carbon pollutants and resulting environmental quality concerns, in fact, feed and food production and subsequent consumption by animals and humans are much larger (about 3.3 times larger!) sources of reactive nitrogen than fossil fuel combustion.

Reactive nitrogen transfer and transformations in and among environmental systems

There are several possible fates for the approximately 35 Tg Nr/yr introduced into the US environment each year from natural sources and human activities. Emission of N_2O discharge about 0.8 Tg Nr/yr into the global atmosphere. Of the 6.3 Tg Nr/yr of US NO_x emissions, 2.7 Tg N/yr are deposited back onto the land and surface waters of the US. Thus, by difference we estimate that about 3.6 Tg Nr/yr per year are advected out of the US atmosphere. Similarly, of the 3.1 Tg Nr/yr of NH_3 that are emitted into the US atmosphere each year, about 2.1 Tg Nr/yr are deposited onto the land and surface waters of the US, and about 1 Tg N/yr is advected out of the US via the atmosphere. Riverine discharges of Nr to the coastal zone accounts for 4.8 Tg N/yr, while export of N-containing commodities (e.g., grain) removes another 4.3 Tg Nr/yr from the US. Altogether, these these total losses add up to about 14 Tg Nr/yr, leaving about 21 Tg N/yr unaccounted for. Of this amount, we estimate that 5 Tg Nr/yr year are stored in soils vegetation, and groundwater, and, by difference, we estimate that about 16 Tg N/yr are denitrified to N_2 (Figure 2). There are substantial uncertainties (+/- 50%) for some of these rough estimates -- especially those that involve NH_x emission and deposition and terms that are arrived at by difference (e.g., atmospheric advection and denitrification). These significant uncertainties drive the 3 major "Overarching Recommendations" of this INC report.

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Comment [ebc6]: Wouldn't the title for Figure 2 – "**Nr inputs into the US, exchanges with the atmosphere, and losses from the US via exports and riverine and atmospheric transport" – be a better (more accurately descriptive) title for this section of the Executive Summary of our Report?**

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20 estimate of atmospheric advection of Nr can be found in Section 2.3

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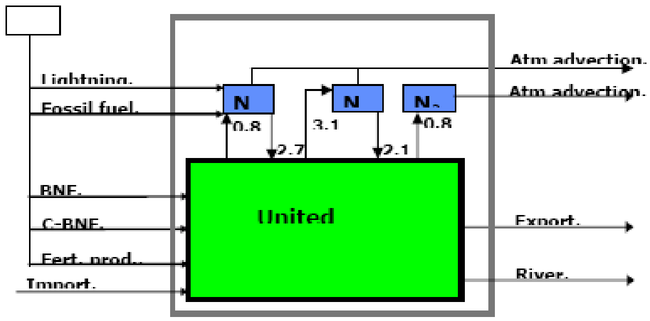
Figure 2: Nr inputs into the US, exchanges with the atmosphere, and losses from the US via exports and riverine and atmospheric transport, 2002US nitrogen budget for 2002

Tg N /yr



Nr Inputs: **35 Tg N**

Nr Outputs: 14 Tg N

Nr Missing: 21 Tg N

Nr Storage: 5 Tg N

~ 2 Tg soils&vegetation

~ 3 Tg groundwater

Nr Denitrified to N_2:

21 Tg N - 5 Tg N = 16 Tg N

Consequences, impacts, and metrics for Nr Use

The most important human-beneficial consequence of Nr use in the United States (and other parts of the world for that matter!) is providing adequate supplies of wholesome food, feed, and fiber crops to meet dietary and other needs of people in this country and abroad – an issue of global food security. In many ecosystems the supply of biologically available Nr is a key factor controlling adequacy of food, feed, and fiber supplies, the profitability of crop and animal agricultural, the nature and diversity of plant life, and vital ecological processes such as the cycling of carbon and soil minerals.

In addition to these very important human-beneficial consequences, however, there are also are numerous and important negative consequences from anthropogenic Nr. These negative consequences include formation of photochemical smog, exposure to toxic aerosolparticules in the air, acidification and eutrophication of terrestrial and aquatic ecosystems, global warming and other greenhouse effects, and stratospheric ozone depletion. Human activities

Comment [ebc8]: Even with both this somewhat incomplete diagram in hand and the text provided at the bottom of page 10, I was unable to understand this figure well enough to suggest the kinds of revisions that would make this figure "stand alone" and be understandable to readers as recommended in the comment for Figure 1 on page 9 of this Executive Summary.

Deleted: 1 **Figure 2: Nr inputs into the US, exchanges with the atmosphere, and losses from the US¶ 2 via exports and riverine and atmospheric transport, 2002US nitrogen budget for 2002¶ 3 Tg N /yr¶ 4¶ 5¶ 6¶ 7 Nr Denitrified to N2:¶ 8¶ 9 21 Tg N - 5 Tg N =¶ 10 16 Tg N¶**

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have not only increased the supply but enhanced the global movement of various forms of Nr through air and water. Mitigating risk from these factors is difficult because one molecule containing Nr can contribute to all of these effects as a consequence of the nitrogen cascade (Figure 3). Nitrogen is a dynamic element easily transformed from one chemical form to

another and is transported rapidly through and between ecosystem reservoirs. These characteristics make nitrogen an especially challenging element to control.

Because nitrogen is both a critically important natural resource and also a contributor to a number of adverse environmental problems, it is imperative to understand how to decrease the risks to society while also providing the food, energy, and materials required by society.

Various approaches can be used to prevent, eliminate, decrease, or otherwise manage Nr risks. Understanding the environmental impacts of Nr can inform decisions on how best to manage nitrogen risks. There are two main approaches to characterizing the adverse public health and environmental impacts of Nr: -- traditional damage estimates and decreases in ecosystem services.

Historically, EPA's environmental protection programs have addressed the adverse public health and public welfare impacts of Nr through use of such common metrics as National Ambient Air Quality Standards (NAAQS) and, in the case of water resources, Total Maximum Daily Loads (TMDLs).

These common metrics have had the considerable advantage of providing frameworks within which air and water quality standards could be derived that are protective of specific human health and environmental risks – the principal missions of the USEPA.

The ecosystem services approach complements these traditionally used common metrics by considering how specific ecosystem services provided by one or more ecosystems are impaired by excess Nr. The attractiveness of this approach is its

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Comment [ebc9]: I believe that Figure 3 on page 20 of Chapter 1, should also be included in the Executive Summary of our INC report!

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recognition that the health of humans and the health of ecosystems are inextricably linked. Less clear, in some cases, however, are ways in which to measure and monitor these adverse impacts. Ecosystem-service-based measurements provide a more rich context for the complex connections among Nr inputs and transformations. Furthermore, impacts on human well-being can help identify those adverse effects of Nr that impose the greatest damage costs to society.

The INC Committee believes that using both common metrics and ecosystem-service based metrics will:

- provide a more clear picture of priorities for action,
- help identify effective control points for decreasing Nr impacts, and
- provide insights into more efficient and cost-effective Nr regulatory strategies.

Tradeoffs Among Nr Risk Management Options

Once the foreseeable impacts are understood and the suite of benefits associated with various risk reduction options are described, then managers can consider trade-offs. Risk reduction integration provides an intellectual framework that allows managers to make informed decisions about which benefits may need to be relinquished for other benefits when not all the desired benefits can be achieved. For example, limiting nitrogen fertilizer application to decrease risks from Nr applied to agro-ecosystems may decrease crop yields and increase food and feed commodity prices, which in turn may result in expansion of crop production area at the expense of natural wetlands, grasslands, and forests.

Measurement of Reactive Nitrogen in the Environment

What air and water quality managers measure determines not only what they think and do but also how they gauge the success or failure of their environmental management strategies and tactics. Most regulations set limits or specify control technologies for specific forms of Nr without regard to the ways in which Nr may be transformed once it is introduced into the environment. Normally, regulations also require some form of monitoring to document compliance. Monitoring of the specific chemical forms of Nr is not enough. There is a need to measure, compute, and report the total amount of Nr present in impacted systems in appropriate units because one chemical form of Nr can be quickly converted to other forms.

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The impacts of reactive nitrogen often can be expressed as the economic costs of damages, the cost of remediation or substitution, or the cost/ton of remediation for each form of reactive nitrogen. Damage costs do not always scale as tons of Nr released into the environment. If damage costs rather than tons of nitrogen were utilized as a metric, the full implications of the cascade, and the setting of priorities for intervention might differ. Similarly, if human mortality and morbidity are the metrics used, priorities for decreases in Nr emissions could be very different.

In order to determine the extent of damage caused by excess nitrogen[4] in environmental reservoirs, one needs to know the both the present Nr concentration or loading within a reservoir and the threshold at which negative impacts are manifested. This threshold then provides a target load that can be used to guide strategies to decrease the amount of Nr in the reservoir. The thresholds for impacts are better known for some adverse impacts than others. For example, the impacts of ozone on human health are known well enough so that EPA has set standards for both ozone and for NO_x, an ozone precursor. The same can be said for the impacts of Nr discharge to coastal waters. Total Maximum Daily Loads (TMDLs) are used to link Nr loading to impact. On the other hand, the impact of Nr deposition on ecosystems is only generally known. There is strong scientific evidence to show that Nr deposition rates of 10 – 20 kg N per hectare per year can cause negative impacts on a variety of ecosystems. Since a large part of the land surface in the northern hemisphere receives Nr deposition in that range, it is necessary to better define the link between Nr deposition and ecosystem response. Further, and related to the previous section, our knowledge of Nr deposition is uncertain, especially for the chemically reduced inorganic and organic forms of Nr. This knowledge needs to be improved to better link deposition to ecosystem response (see Recommendation xx on page xx).

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4 Excess reactive nitrogen (Nr) is defined as the amount of Nr that is present in, or introduced into, an environmental system (e.g., Nr inputs to the atmosphere, Nr inputs to grasslands and forests, N_r inputs to estuaries) from anthropogenic sources that is not incorporated into agricultural and other biological products (e.g., food, feed, fuel and fiber), or stored in long-term storage pools (e.g., cropland soils).

Thresholds are used to determine at what amount excess Nr causes negative effects on ecosystem services and functions, and/or on human health. Thresholds vary by metric (e.g., concentration, loading, etc) and depend on the environmental system (e.g., atmosphere, forest). Examples of specific thresholds are given in Chapter 2 of the full INC Report – Aquatic Thresholds on pages 99 – 102, Atmospheric thresholds on pages 107 and 108, and Terrestrial thresholds on pages 110 113.13

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Integrated Risk Reduction Strategies for Nr

Typically, quantitative risk assessment; technical feasibility; economic, social and legal factors; and additional benefits of various air and water management strategies contribute to the development of a suite of risk reduction strategies from which managers select an optimal approach.

Management Strategies for Nr

There are several ways in which the release and control of Nr in the environment can be approached. In general these can be classified as follows:

_1. Improved practices and conservation—in which the flux of Nr that creates an impact is decreased through better management practices (e.g. on-field agricultural practices, control of urban runoff, controlled combustion conditions)

_2. Product substitution—in which a product is developed or promoted which has a smaller dependency on Nr (e.g. use of switchgrass instead of corn grain as a feedstock for biofuel ethanol production).

_3. Transformation—in which one form of nitrogen is converted to another less damaging form of nitrogen (e.g. nitrification of municipal wastewaters, denitrification of Nr by converting it back to non-reactive gaseous N_2).

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4. Source limitation—in which the amount of Nr introduced into the environment is decreased (e.g. lower fertilizer application rates, use of low-NOx burners in power plants).

5. Removal—in which particulate forms of Nr are captured in a more readily managed physical form such the bacterial sludge which can be disposed of by land application or incineration.

6. Improved use or reuse efficiency—in which the efficiency of production that is dependent on Nr is improved (e.g. increased grain yields per unit of Nr fertilizer applied, decreased NO_x emissions from more efficient diesel engines in trucks and off-road construction equipment).

Efficient and cost-effective management of Nr often requires combinations of these six Nr management strategies hes; no one approach is a perfect alternative for decreasing excess Nr in the environment.

Policy Mechanisms for Management of Nr in the Environment

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Generally speaking, US environmental policies employ one or more of the following four mechanisms for management of pollutants in the environment:

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1. Command-and-Control—in which permitted limitations on pollutant or chemical-precursor emissions are issued under various regulatory statues. Violations may result in the assessment of penalties.

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2. Government-based programs affecting the desirability of an environmental management mechanism, such as directed taxes, price supports for a given commodity, subsidies to bring about a particular end-result, and grants for capital expansion or improvement of pollution-abatement technologies.

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3. Market-based instruments for pollution control in which cap and trade markets are used to bring about a desired policy end-result -- often at decreased overall cost to society.

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4. Voluntary programs in which desired environmental outcomes are achieved using private or government-initiated agreements or through targeted outreach and education programs.

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An integrated approach to the management of Nr must use a combination of implementation mechanisms. Each mechanism must be appropriate to the nature of the problem at hand, supported by critical research on decreasing the risks of Nr, and reflect an integrated policy that recognizes the complexities and tradeoffs associated with the nitrogen cascade. Management efforts at one point in the cascade may be more efficient and cost effective than control or intervention at another point. This is why understanding the nature and dynamics of the N cascade is critically important.

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Findings and Recommendations

The committee's recommendations can be loosely organized into several tiers. These include recommendations that:

1. address deficiencies in knowledge about Nr flows and fates.

2. concern ecological and human impacts of Nr.

3. address specific actions that can be taken to decrease Nr in the environment.

4. address how EPA could develop an integrated N management strategy, in cooperation

with other agencies. There is significant over-lap among these tiers, since some recommendations call for both research and immediate action. But collectively they represent our INC committee convictions about what will be needed to develop an optimally integrated Nr management strategy based on sound science. This integrated strategy keeps in mind the food, feed, fiber, and biofuel production demands of the US population and its trading partners. Specific "Scientific Findings" and "Recommendations" for implementing an integrated Nr strategy appear in the subsequent chapters of this report. In addition to providing these specific "Findings" and Recommendations," the report also makes three "Overarching Recommendations:"

Recommendation A

EPA should pursue an integrated multi-medium approach to develop the scientific understanding necessary for science-based policies, regulations, and incentives. To be successful, this integrated approach must to avoid and/or remediate the impacts of excess Nr on terrestrial and aquatic ecosystems, human health, and climate. Such integration must cut across media (air, land, and water), chemical forms of Nr including chemically oxidized, chemically reduced, and organic forms of Nr, federal, state, and local government agencies, and private-sector organizations, and legislative statutes including the Clean Air Act (CAA), Clean Water Act (CWA), and the Energy Independence and Security Act (EISA).

Recommendation B

EPA should form an Intra-Agency Nr Management Task Force that builds upon existing Nr research and management efforts within the Agency. This Intra-Agency Task Force should identify the most efficient and cost-effective means by which to avoid the various adverse impacts of Nr loads cascading through the environment. These loads pose a significant threat to human health and environmental quality and directly affect climate change.

Recommendation C

EPA should also join with other agencies within the federal government in establishing an Inter-agency Nr Management Task Force that includes at least the following agencies: U.S. Department of Agriculture (USDA), U.S. Department of Energy (DOE), U.S. Department of Transportation (DOT), National Oceanic and Atmospheric Administration (NOAA), and U.S. Geological Survey

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(USGS). This Task Force would coordinate federal programs that address Nr concerns and help ensure clear responsibilities for monitoring, modeling, researching, and regulating Nr in the environment. EPA should nserve as the lead agency for this Interagency Task Force.

This Interagency task forces should take a systems approach to both scientific research and public policy by:

- evaluating critical loads,
- adopting Nr budgets and life cycle accounting,
- establishing an Nr monitoring system as the basis for informed policies, regulations, and incentive frameworks for addressing excess Nr loads,
- developing systemic models for use in recommending best management practices (BMPs) for application of fertilizers on farms and both residential and commercial landscaping purposes;
- developing Nr indicators for excess Nr effects on human health and environment;
- assessing combined carbon (C) and Nr effects on terrestrial and aquatic ecosystems,
- addressing indicators/endpoints, costs, benefits and risks associated with impairment of human health and decline and restoration of ecosystem services
- investigating the need for new regulations
- implementing new education, outreach, and communication initiatives
- implementing economic incentives, particularly those that integrate air, aquatic, and land sources of excess Nr;
- developing new infrastructures for managing Nr releases to the environment; and
- reviewing existing and proposed legislation for purposes of extending regulatory authority or streamlining procedures for enacting Nr risk reduction strategies.

In addition to these three overarching recommendations, the INC committee has developed and presented within the main body of this INC Report, a series of xx "Findings" and "Recommendations" that deal with specific Nr-related cases and issues. All of these specific "Findings" and "Recommendations" are collated in Appendix 3 on pages 165 through 180 of this Report.

Also included in this collated list are four "Target Goals" [see Recommendations 20 through 24 on pages 153-157 in Chapter 3] that EPA could take together with other agencies using existing technologies to achieve an initial 25% decrease in the amount of Nr lost to the US environment.

Given the issues of Nr accumulation in the US and global environment, these initial steps will not be enough to reverse the collective Nr damages to terrestrial and aquatic ecosystems and human health. Other

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steps will need to be taken after consideration is given to the three "Overarching Recommendations," four "Target Goals" and various other specific "Findings" and "Recommendations" contained in this report.

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Comments on Recommendations and Findings

Jim -- Tom -- Angela --
Once again, on Jim's advice I have given primary attention to the careful wording of the all of the statements of findings and recommendations in our INC Report. As indicated yesterday, I have used as a guide for all the suggestions in the attached revision of Appendix 3 (and of course also in Chapters 2 and 3, where they are presented in their original form), the published "Guidelines for Development of Statements of Scientific Findings to be used for Policy Purposes" developed by the Oversight Review Board of the National Acid Precipitation Assessment Program. In a few cases, there is some confusion about what is designated as a "Finding" and as a Recommendation" in both Appendix 3 and in chapters 2 and 3.

As also indicated yesterday, I continue to believe that an important key to developing the kind believe in from our INC experience, is how we choose to present:
-- The three "Overarching Recommendations,"
-- The four major "Recommendations" by which existing technologies could be used to active an initial 25% decrease in Nr releases in the US (Recommendations 20-24 on pages 153-157 -- which I have suggested we rename "Initial Target Goals, and recognize to be distinct from both the "Overarching Recommendations" and
-- The rest of the other issue-specific "Findings" and "Recommendations" that are scattered throughout Chapters 2 and 3 in the full Report.

Looking forward to our teleconference call from 1:00 to 3:00 on March 4.

Best regards, Ellis

Draft Report dated 2/18/09 to Assist Deliberations for the SAB Integrated Nitrogen Committee at its March 4, 2009 Teleconference
Do not Cite or Quote
This draft is a work in progress, does not reflect consensus advice or recommendations of the committee, has not been reviewed or approved by the chartered SAB, and does not represent EPA policy

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Appendix 3: Findings and Recommendations of the Integrated Nitrogen Committee

I. Introduction

This appendix contains a compilation of all the Findings and Recommendations of the Integrated Nitrogen Committee. Following a listing of the four overarching recommendations, the more specific recommendations are listed with appropriate section headings.

II. Overarching Recommendations

Recommendation A

EPA should pursue an integrated multi medium approach to develop the scientific understanding necessary for science-based policies, regulations, and incentives by which to decrease some of the serious adverse

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impacts of excess Nr on terrestrial and aquatic ecosystems, human health, and climate change. Such integration must cut across media (air, land, and water), multiple chemical forms of Nr including chemically oxidized, chemically reduced, and organic forms of Nr, many different federal, state and local government agencies, and private sector organization,, and legislative statutes including the Clean air Act (CAA), Clean Water Act (CWA), and the Energy Independence and Security Act (EISA).

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Recommendation B

EPA should form an Intra-agency Nr Mangement Task Force that will build on existing Nr research and management capabilities within the Agency. This Intra-Agency Task Force should be aimed at increasing scientific understanding of: 1) Nr impacts on terrestrial and aquatic ecosystems, human health, and climate, 2) Nr-relevant monitorioring requirements, and 3) identify the most efficient and cost-effective means by which to decrease various adverse impacts of Nr loads as they cascade through the environment.

Recommendation C

EPA should join with other agencies within the US government in establishing an Inter-agency Nr Management Task Force . The members of this Inter-Agency Task Force should include at least the following five federal agencies U.S. Department of Agriculture (USDA), U.S. Department of Energy (DOE), U.S. Department of Transportation (DOT), National Oceanic and Atmospheric Administration (NOAA), and U.S. Geological Survey (USGS). This Task Force would coordinate federal programs that address Nr concerns and help ensure clear responsibilities for monitoring, modeling, researching, and managing Nr in the environment.

These two Nr-Management Task Forces should take a systems approach to both scientific research and public policy by emphasizing the following research and management goals:

- evaluating the critical loads approach to air and water quality management;
- exploring Nr budgets and life cycle accounting methods;
- monitoring as the basis for informed policies, regulations, and incentive frameworks for addressing excess Nr loads;

- developing systemic models for use in recommending best management practices (BMPs) for application of fertilizers on farms and for both residential and commercial landscaping purposes;
- developing Nr indicators for excessNr effects on human health and environment;
- assessing combined carbon (C) and Nr effects on terrestrial and aquatic ecosystems;
- addressing indicators/endpoints, costs, benefits and risks associated with impairment of human health and decline and restoration of ecosystem services;

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- investigating the need for new Nr management approaches;
- implementing new education, outreach, and communication initiatives;
- implementing economic incentives, particularly those that integrate air, aquatic, and land sources of excess Nr;
- developing new infrastructures for managing Nr releases to the environment; and
- reviewing existing and proposed legislation for purposes of extending Nr regulatory authority or streamlining procedures for enacting Nr risk reduction strategies.

III. Findings and Recommendations Related to the Sources of Nr to the US

Finding 1

Crop agriculture receives 63% of US annual Nr inputs from anthropogenic sources (9.8 Tg from N fertilizer, 7,7 from crop BNF versus 29 Tg total) and accounts for 58% (7.6 Tg) of total US Nr losses from terrestrial systems to air and aquatic ecosystems, yet current monitoring of fertilizer use statistics by federal agencies is inadequate to accurately track trends in quantities of N applied to major crops and the geospatial pattern by major watersheds.

Recommendation 1: *I ncrease the specificity and regularity of data acquisition for fertilizer application to major agricultural cropsuse by major crop (and for urban residential and recreational turf) and by county (or watershed) to better inform decision-making about policies and mitigation options for Nr in these systems, and tofacilitatte monitoring and evaluation of impact from implemented policies and mitigation efforts.*

Finding 2

Nr inputs to crop systems are critical to sustain crop productivity and soil quality. Moreover, given limited land and water resources, global population growth and rapid economic development in the world's most populous countries, the challenge is to accelerate increases in crop yields on existing farm land while also achieving a substantial increase in N fertilizer uptake efficiency. This process is called "ecological intensification" because it recognizes the need to meet future food, feed, fiber, and biofuel demand of a growing human population while also protecting environmental quality and ecosystem services for future generations (Cassman, 1999). More diverse cropping systems with decreased Nr fertilizer input may also provide an option if a decrease

in Nr losses per unit of crop production can be achieved without indirect land use change from expansion of crop production area to replace the loss in production.

Recommendation 2:

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technologies; fertilizer and nutrient best management practices (BMPs)
• development of Nr indicators necessary for the assessment of effects related to
excess Nr on human health and the environment
• assessing combined carbon (C) and N effects
• addressing indicators/endpoints, costs, benefits and risks associated with the
impairment of human health and decline and restoration of ecosystem services
• investigating the need for new regulations
• new education, outreach, and communication initiatives
• implementing economic incentives, particularly those that integrate air,
aquatic, and land sources of Nr
• new infrastructures for managing Nr releases to the environment
• review of enabling legislation for purposes of extending regulatory authority
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a) Develop data on nitrogen fertilizer use efficiency and Nr mass balance, based on direct measurements from production-scale fields for major agricultural crops to identify which cropping systems and regions are of greatest concern with regard to mitigation of Nr load to better focus research investments, policy development, and prioritization of risk mitigation strategies.

B) Investigate means by which to increase the rate of gain in crop yields on existing farm land while increasing N fertilizer uptake efficiency and adoption of lower-yielding more diverse cropping systems with lower N fertilizer input requirements when the impact of indirect land use change is considered.

C) EPA should work closely with the U.S. Department of Agriculture (USDA), Department of Energy (DOE), and the National Science Foundation (NSF) to help identify research and education priorities for prevention and mitigation of Nr applied to agricultural systems.

Finding 3

Nitrous oxide emissions from the Nr inputs to cropland from fertilizer, manure, and legume fixation represent a large proportion of agriculture's contribution to greenhouse gas emissions, and the importance of this source of anthropogenic Greenhouse gas will likely increase unless nutrient use efficiency is markedly improved in crop production systems. Despite its importance, there is considerable uncertainty in the estimates of nitrous oxide emissions from fertilizer and research must focus on decreasing this uncertainty.

Recommendation 3:

The committee recommends that EPA join with USDA, DOE, and NSF in research to decrease uncertainty in estimates of nitrous oxide emissions from crop agriculture.

Finding 4

Rapid expansion of biofuel production is changing the cost-benefit ratio of N fertilizer use in crop production and also changing the nutrient profile of livestock diets with consequences for effective management of Nr.

Recommendation 4:

EPA should develop means by which to understand and predict these changes in terms of maximizing the N efficiency of both crop and livestock production systems and develop strategies for avoiding increased Nr load in the environment as a

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Deleted: 14 Greater diversity in a cropping system is achieved by increasing the number of different crop species used in the rotation (temporal diversity) or as a polycrop or intercrop (spatial diversity).
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result of current and future expansion of biofuel production from corn and other "second generation" biofuel feedstock crops.

Finding 5

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There are no nationwide monitoring networks in the US to quantify agricultural emissions of greenhouse gases, NO, N_2O, chemically reduced sulfur compounds, VOCs, and NH_3. In contrast there is a large network in place to assess the changes in the chemical climate of the US associated with fossil fuel energy production, ie the National Atmospheric Deposition Program/National Trends Network (NADP/NTN), which has been monitoring the wet deposition of sulfate (SO_4^{2-}), NO_3^-, and NH_4^+ since 1978.

Recommendation 5:

The status and both spatial and temporal changes gases and particulate matter emitted from agricultural emissions, e.g., NO_3^- and NH_4^+ should be monitored nationwide by a network of monitoring stations.

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Finding 6

Farm-level improvements in manure management can substantially decrease Nr loads and losses. There are currently no incentives or regulations to decrease these losses and loads despite the existence of management options to mitigate.

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Recommendation 6:

EPA should develop policy, regulatory, and incentive framework to improve manure management methods and thus decrease Nr loads and ammonia losses, taking into account phosphorus load issue as well.

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IV. Findings and Recommendations Related to Nr Transfers and Transformations in and between environmental systems

Finding 7

Scientific uncertainty about the origins, transport, chemistry, sinks, and export of Nr remains high, but evidence is strong that atmospheric deposition of Nr to the Earth's surface as well as emissions from the surface to the atmosphere contribute substantially to environmental and health problems. Atmospheric emissions and concentrations of Nr from agricultural practices (primarily in the form of NH_3) have not been well monitored, but NH_4^+ ion concentration and wet deposition (as determined by the National Atmospheric Deposition Program's National Trends Network are increasing. Both wet and dry deposition contribute substantially to NH_x removal from the atmosphere, but only wet deposition is known

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with much scientific certainty. Air concentrations of ammonia, ammonium ion, and organic forms of Nr increase Nr exposures to both people and terrestrial and aquatic ecosystems. Thus consideration should be given to adding these chemically reduced ad organic forms of Nr to the list of Criteria Pollutants.

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Recommendation 7a. *Increase the scope and spatial coverage of the Nr concentration and flux monitoring networks (such as the National Atmospheric Deposition Program and the Clean Air Status and Trends Network) and appoint an oversight review panel for these two networks.*

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Mecommendation 7b. *Monitor NH_3, NH_x, NO_y, NO_2, NO, and PAN concentrations, measure or infer deposition, and support the development of new measurement and monitoring methods.*

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Recommendation 7c. *The current NO_2 standard is inadequate to protect health and welfare, and compliance monitoring for NO_2 is inadequate for scientific understanding.*

Comment [ebc10]: This is a statement of finding, not a recommendation.

Recommendation 7d. *Measure deposition directly both at the CASTNET sites and nearby locations with non-uniform surfaces such as forest edges.*

Recommendation 7e. *EPA should continue and support research into convective venting of the Planetary Boundary Layer and long range transport.*

Recommendation 7f. **EPA should d***evelop techniques and support observations of atmospheric organic N compounds in vapor, particulate, and aqueous phases.*

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Recommendation 7g. *Increase the quality and regional distribution of measurements of the NH_3 flux to the atmosphere from major sources especially agricultural practices.*

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Recommendation 7h. *Improve numerical models of NO_y and NH_x especially with regard to r chemical transformation, surface deposition, and off-shore export features. Also, develop linked ocean-land-atmosphere models for Nr.*

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Finding 8

Although total N budgets within all terrestrial systems are highly uncertain, Nr losses from grasslands and forests (vegetated) and urban (populated) portions of the N Cascade appear to be more uncertain, on a per cent of input basis, than from agricultural lands. The relative amount of these losses ascribed to leaching, runoff and denitrification, are as uncertain as the N budgets themselves.

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Recommendation 8:

EPA, should join with USDA, DOE, and universities in efforts to ensure that the N budgets of terrestrial systems are properly quantified and that the magnitude of at least the major loss vectors are known.

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Finging 9

Over the past 25 years, there has been a growing recognition of anthropogenic eutrophication as a serious problem in coastal estuaries (NRC, 2000). The last comprehensive national National Coast Condition Report was published in 2004 (EPA, 2004) included an overall rating of "fair" for estuaries, including the Great Lakes, based on evaluation of over 2000 sites. The water quality index, which incorporates nutrient effects primarily as chlorophyll-a and dissolved oxygen impacts, was also rated "fair" nationally. Forty percent of the sites were rated "good" for overall water quality, while 11% were "poor" and 49% "fair."

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Recommendation 9: In the next National Cost Condition Report, *EPA should consider a more comprehensive range of spatial scales reflecting ecosystem, watershed, and regional levels that include all inputs, e.g. atmospheric and riverine, of marine eutrophication dynamics and management.*

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Finding 26

Denitrification of Nr in terrestrial and aquatic systems is one of the most uncertain parts of the nitrogen cycle. Denitrification is generally considered to be a dominant N loss pathway in both terrestrial and aquatic systems, but it is poorly quantified

Recommendation 10:

EPA, USDA, DOE, and universities should work together to ensure that denitrification in soils and aquatic systems is properly quantified, by funding *appropriate research.*

V. Findings and Recommendations Related to the Impacts and Metrics for Nr

Finding 11

The committee finds that there is a need to measure, compute, and report the total amount of Nr present in impacted systems in appropriate units. Since what is measured influences what we are able to perceive and respond to; in the case of Nr, it is especially critical to measure total amounts and different chemical forms, at regular intervals over time.

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Recommendation 11.

The committee recommends that EPA routinely and consistently account for the presence of Nr in the environment in forms appropriate to the medium in which they occur (air, land, and water) and that accounting documents be produced and published periodically (for example a fashion similar to National Atmospheri Deposition Program summary reports). The committee understands that such an undertaking will require substantial resources, and encourages the Agency to develop and strengthen partnerships with appropriate federal and state agencies and private sector organizations with parallel interests in advancing the necessary underlying science of Nr creation, transport and transformation, impacts, and management.

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Finding 12

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Finding 12

The committee finds that reliance on only one approach for categorizing the measurement of Nr is unlikely to result in the desired outcome of translating Nr-induced degradation into the level of understanding needed to develop support for implementing effective N management strategies.

Recommendation 12.

It is, therefore, recommended that the EPA examine the full range of traditional and ecosystem response categories, including economic and ecosystem services, as a basis for expressing Nr impacts in the environment, and for building better understanding and support for integrated management efforts.

Finding 13

Intervention to control Nr under most water management programs generally occurs in three ways:

- Prevention or source controls

• Physical, chemical or biological "dead ending" or storage within landscape compartments where it is rendered less harmful (e.g., long-term storage in soils or vegetation; denitrification, primarily in wetlands; reuse)
• Treatment using engineered systems such as sewage treatment plants or best mangagement plants s for stormwater and nonpoint source runoff.
While most management programs focus on the third (treatment) approach, there are opportunities for combining the three that can be more effective and cost less.

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Recommendation 13.

To better address Nr runoff and discharges from the peopled landscape the committee recommends that EPA:

13a. *Evaluate the suite of regulatory and non regulatory tools used to manage Nr in populated areas from nonpoint sources, stormwater and domestic sewage and industrial wastewater treatment facilities, including goal-setting through water quality standards and criteria. Determine the most effective regulatory and voluntary mechanisms to apply to each type of source with special attention to the need to regulate nonpoint sources and related land use practices.*

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13b. *Review current regulatory practices for point sources, including both wastewater treatment plants and stormwater, to determine adequacy and capacity to meet national Nr management goals. Consider technology limitations, multiple pollutant benefits, and funding mechanisms as well as potential impacts on climate change from energy use and greenhouse gas emission including nitrous oxide.*

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13c. *Set Nr management goals on a regional/local basis, as appropriate, to ensure most effective use of limited management dollars. Fully consider "green"*

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management practices such as low impact development and conservation measures that preserve or re-establish Nr removing features to the landscape as part of an integrated management strategy along with traditional engineered best management practices.

13d. *Research best management practices that are effective in controlling Nr, especially for nonpoint and stormwater sources, including land and landscape feature preservation and set Nr management targets that realistically reflect these management and preservation capacities. Construct a decision framework to assess and determine implementation actions consistent with management goals.*

13e. *Use ecosystem-based management approaches that balance* natural and anthropogenic needs and presence in the landscape.

Finding 14

Meeting Nr management goals for estuaries, when a balance must be struck between economic, societial and environmental needs, under current federal law seems unlikely. Enforceable authorities over nonpoint source, stormwater, air (in terms of critical loads), and land use are not adequate to support necessary Nr controls. Funding programs are presently inadequate to meet existing pollution control needs. Furthermore, new technologies and management approaches are required to meet ambitious Nr control needs aimed at restoring national water quality.

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Recommendation 14. *The committee recommends that EPA reevaluate water quality management approaches to ensure Nr management goals are attainable, enforceable, and affordable and that monitoring and research are adequate to problem definition and resolution, particularly in the development of nitrogen removal technologies. This may require changes in the way EPA sets water criteria and some compromises in ecosystem goals to accommodate human uses of the air, land and water.*

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Finding 15

The committee has determined that an integrated approach to monitoring that includes multimedia (air, land and water) components and considers a suite of environmental and human concerns (e.g., Nr effects, climate change, human health) would be most useful and efficient. Some of the phenomena that we present in this report simply need more definition and verification but, more importantly, as control is brought to bear on Nr, improvements need to be measured (i.e. monitored) to validate the success of one control or another. If the desired improvements are not realized as shown by the collected data, corrective measures will be required. The pool of data would be used to formulate new management procedures. The process of monitoring and control revisions is termed adaptive management—a process that the committee believes is highly desirable since it does

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not delay actions that can be taken immediately and acknowledges the likelihood that management programs will be altered (adapted) as scientific and management understanding improve**.**

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Recommendation 15.

The committee recommends that EPA initiate discussions and take action to develop a national, multimedia monitoring program that monitors sources, transport and transition, effects of Nr using indicators where possible, and sinks of Nr in keeping with the nitrogen cascade concept. This comprehensive program should build upon existing EPA and state initiatives as well as monitoring networks already underway in other federal agencies such as the US Geological Survey and National Atmospheric Desposition program efforts.

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Finding 16

The committee finds that the net benefit of decreasing NH_3 emissions from agricultural and other sources greatly outweighs any potential harm.

Comment [ebc11]: Please clarify the wiording of Finding 16 – it is not clear what "harm" woiuld results from decreasing NH3 emissions.

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Recommendation 16. *The committee recommends that the EPA presumption that NH_3 is not a $PM_{2.5}$ precursor should be reversed and states should be encouraged to address NH_3 as a harmful $PM_{2.5}$ precursor.*

Finding 17

The committee notes that the effective management of Nr in the environment must recognize the existence of tradeoffs across impact categories involving the cycling of other elements, particularly C.

Recommendation 17.

The committee recommends that the integrated strategies for Nr management outlined in this report be developed in cognizance of these interrelations and tradeoffs

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VI. Findings and Recommendations Related to Integrated Risk Reduction Strategies for Nr

Finding 18

The committee finds that there have been persistent increases in the amounts of Nr that have been emitted into and retained within various ecosystems and are affecting their normal functions. Unless this trend is reversed, it will become increasingly difficult for many of these ecosystems to provide the services upon which human well-being are dependent. The committee believes that there is a need to regulate certain forms of Nr to address specific problems related to excess Nr, and we believe that the best approach for an overall management strategy is the concept of defining acceptable total Nr critical loads for many of these environmental systems.

Recommendation 18. *The committee recommends that the Agency work toward adopting the critical loads approach in the future. In carrying out this recommendation the committee recognizes that it will in many cases be necessary for the Agency to enter into new types of research, policy, and regulatory agreements with other Federal, State, and Tribal units based on cooperative, adaptive, and systemic approaches that derive from a common understanding of the nitrogen cascade.*

Finding 27

Human activities have significantly increased Nr loads into the US environment, and while there have been significant benefits resulting from food production, there have also been, and continue to be, major risks to the health of both ecosystems. To optimize the benefits of Nr, and to minimize its impacts, will require an integrated nitrogen management strategy that not only involves EPA, but also coordination with other federal agencies, the States, the private sector, and a strong public outreach program. The committee understands that there are real economic costs to the recommendations contained in this report. For each recommendation there will of necessity be tradeoffs derived from the varying cost-effectiveness of different strategies.

Finding 28

Emissions of Nr from fuel combustion (in the form of NO_x) have been decreased substantially for some classes of emitters such as power plants and light duty vehicles. Other Nr sources, including most off road vehicles, some industrial equipment, and some older electricity generating units, operate with little or no NO_x controls. Most sources can be controlled (with well established engineering practices and at a reasonable cost) to the point of achieving 90% decreases of NO_x emissions relative to uncontrolled combustion. NO_y concentrations in the atmosphere remain too high to protect public health and welfare; thus continued decreases in NO_x emissions are necessary. Most NO_x sources can be controlled at the 90% level (relative to uncontrolled combustion) with existing technology and at a reasonable cost, and this should be an across the board goal.

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Comment [ebc12]: This excellent paragraph would be a superior substitute or addition to the Introduction of this entire list of INC Findings and Recommendations in Appopendix 3and that the suggested revisions of wording of Recommendatioons a through c provided at the beginning of this Appendiax is preferable to the wording that is shown immediately after this very fine paragraph.
Deleted: The committee makes three over-arching recommendations:¶
Recommendation A. *EPA should pursue an integrated approach to develop the¶ understanding necessary for science-based policies, regulations, and incentives to avoid¶ and remediate the impacts of excess Nr on the environmental, human health, and climate.¶ Such integration must cut across media (air, land, and water), Nr form (oxidized and¶ reduced), federal agencies, and existing legislative statutes [e.g., EISA – Energy¶ Independence and Security Act (EISA), the Clean Air Act, and the Water Quality Act¶ (CWA)].¶*
Recommendation B. *EPA should form an Intra-agency Task Force on Managing Nr¶ that builds upon existing Nr efforts within the Agency. The task force would identify the¶ most cost-effective approaches to avoid the negative impacts of Nr loads cascading¶ through the environment. These loads pose a significant threat to human health and¶* ... [18]
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Accordingly, the Agency should continue to decrease NO_x emissions from major point sources, such as electricity generating units, using a market mechanism such as cap and trade. Under this scenario, it is likely that high efficiency, low emission power plants will be built to help meet future US energy needs.

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Recommendation 20a. *Decrease NOx emissions from off road vehicles, some industrial equipment, and some older electricity generating units that currently operate with little or no NO_x controls.*

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Recommendation 20b. *Improve monitoring and modeling of NO_x from all mobile sources.*

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Recommendation 20d. *For total NO_x from all mobile sources the Agency should consider a cap that decreases with time.*

Recommendation 20e. *The Agency should implement and maintain programs such as inspection and maintenance or road-side monitoring to ensure that most light-duty vehicles meet emissions standards.*

Recommendation 20c. *The committee recommends that in implementing this approach, the Agency consider the mass of NO_x emitted per unit of power provided, rather than the magnitude of past emissions, as the basis for determining recommended emissions targets for power plants.*

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Recommendation 20g. *The Agency should promulgate more strict NO_x emissions standards for heavy duty diesel vehicles and off road vehicles including locomotives, construction, farm, and landscaping equipment, and marine vehicles.*

Deleted: **Recommendation 20d.** *For total NOx from all mobile sources the Agency should¶ consider a cap that decreases with time.*

Deleted: **Recommendation 20e.** *The Agency should implement and maintain programs such as¶ inspection and maintenance or road-side monitoring to ensure that most light-duty¶ vehicles meet emissions standards.¶*

Recommendation 20f. *The Agency should require major sources of NO_x from industrial fuel combustion to implement control technologies and/or include in cap and trade programs.*

Deleted: **Recommendation 20g.** *The Agency should promulgate stricter NOx emissions standards¶ for heavy duty diesel vehicles and off road vehicles including locomotives, construction,¶ farm, and landscaping equipment, and marine vehicles.¶*

Recommendation 20h. *The Agency should encourage, through its sustainability initiatives, replacement of electricity generating units powered by fossil fuels with cleaner energy sources such as wind and solar.*

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Recommendation 20i. *The Agency should promote changes in lifestyle, urban planning, and public transit conducive to energy conservation and decreased emissions.*

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Finding 29

The committee believes that excess flows of Nr into streams, rivers, and coastal systems can and should be decreased by approximately 20% **(~1 Tg)** through improved landscape management and without undue disruption to agricultural production. This would include activities such as using wetland management (e.g., USDA Wetlands Protection Program), improved tile drainage systems and riparian buffers on crop land, and implementing storm water and nonpoint source management practices (e.g., EPA permitting and funding programs). In addition, the committee believes that crop N-uptake efficiencies can and should be increased by up to 25% over current practices through a combination of knowledge-based practices and advances in fertilizer technology (such as controlled release and inhibition of nitrification). Crop output can be increased while decreasing total Nr emissions by up to 20% of applied artificial Nr. The committee believes that these recoimmendations will decrease Nr releases by about **2.4 Tg** current amounts of loss to

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the environment. These are appropriate targets with today's available technologies and further progress is possible.

The acreage of farm land devoted to corn production in the US has increased substantially for corn based ethanol production during the past several years (with nearly one-third of the crop currently devoted to bioethanol production), with fertilizer nitrogen increasing by at least 10% **(0.5 Tg N/yr)**, largely to meet biofuel feedstock demand. In the absence of Nr controls and a failure to implement best practices, current biofuels policies will make it extremely difficult to decrease Nr losses to soils, water and air (Simpson et al. 2008). Integrated management strategies will be required. In this regard, the committee endorses Section 204 of the 2007 Energy Independence and Security Act (EISA) which calls on EPA y to adopt a life cycle approach to the assessment of future renewable fuel standards as a positive step toward a comprehensive analysis.

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Recommendation 21. *The committee recommends that improved specificity and regularity of data acquisition for fertilizer use by major crop (and for urban residential and recreational turf) and county (or watershed) be undertaken in order to better inform decision-making about policies and mitigation options for nitrogen in these systems.*

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Recommendation 21b. *The committee recommends that improved estimates of N fertilizer uptake efficiency for the major N-using crops and cropping systems based on direct measurements from a representative range of production-scale farmer's fields should be undertaken to help guide prioritization of risk mitigation strategies.*

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Recommendation 21c. *The committee recommends that EPA work with other agencies to develop better estimates of NH_3, NO_x, and NO_3^- leaching, N_2O emissions, amounts of Nr storage reservoirs (or loss in soils coupled with organic carbon); the amounts that can be attributed to denitrification in soils and water.*

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Recommendation 21d. *The Agency should work closely with USDA and other agencies to identify research and education priorities for prevention and mitigation of Nr applied to agricultural systems.*

Recommendation 21e. *The committee recommends that research on the accelerating the rate of gain in crop yields on existing farmland be increased while substantially increasing N fertilizer uptake efficiency.*

Recommendation 21f. *The committee recommends that EPA develop and promote incentives for the use of advanced fertilizers and enhanced efficiency products in both crop and anmimal agriculture.*

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Draft Report dated 2/18/09 to Assist Deliberations for the SAB Integrated Nitrogen Committee at its March 4, 2009 Teleconference
Do not Cite or Quote
This draft is a work in progress, does not reflect consensus advice or recommendations of the committee, has not been reviewed or approved by the chartered SAB, and does not represent EPA policy

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Recommendation 21g. *The committee recommends that the Agency undertake an expanded research program for wetlands design and management focused, in part, on Nr dynamics and removal.*

Finding 30

N_2O concentrations in the atmosphere have increased substantially in recent years. For additional production of liquid biofuels beyond the grandfathered amount in Energy Independence and Security Act, EPA has the power to exercise some controls on N_2O emissions through the life cycle greenhouse gas accounting requirements. In addition, greenhouse gas emissions trading will provide both opportunities and challenges with regard to mitigation of Nr environmental and health impacts.

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Recommendation 22. *The committee recommends that policies and regulations that support implementation of emissions trading consider Nr impacts on greenhouse gas (GHG) emissions and reward decreases of N-related GHGs. Biofuel subsidies should accurately account for Nr contributions to GHG emissions, and individual biofuel plants should be certified for GHG impact and serve as aggregators in the biofuel production life-cycle to reward reductions in N_2O emissions through BMPs by farmers producing feedstock and use of co-products in livestock diets.*

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Finding 31

There are two funding sources of significance authorized in the CWA that are used to fund projects relevant to the control of Nr. Section 319 establishes state nonpoint source management programs to plan for and implement management measures that abate sources of nonpoint pollution from eight source categories, including both urban and agricultural sources. Over the years section 319 has made available, through 60% matching funds, over $1.6 billion in assistance. The much larger source of funding comes under Title VI of the CWA, which has provided over $24 billion (federal) for the construction of treatment facilities for point sources of wastewater over the past twenty years, although only a fraction of this amount has been dedicated to denitrification processes. These programs have been, and continue to be, important ways of managing Nr in the urban environment. As shown in section 3.2, national loadings of Nr to the environment from public and private wastewater point sources are relatively modest in comparison with global Nr releases, however they can be important local sources with associated impacts. In most cases Nr ultimately finds its way into municipal and private sewers and treatment systems where, irrespective of its initial chemical form, it is partially or completely nitrified. Subsequent engineered complete denitrification processes (including tertiary wastewater treatment, engineered or restored wetlands, and algae production for biofuels) can convert the nitrate to N_2. Federal and State assistance programs directed at construction of treatment plants are an important element Nr control

policy in the US. The committee believes that **0.5 to 0.8 Tg N/yr** can be cut from Nr inputs to the environment.

Recommendation 23. *The committee recommends that a high priority be assigned to nutrient management through a targeted construction grants program under the Clean Water Act.*

The committee recommends that a high priority be assigned to nutrient management through targeted construction grants program under this Act.

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Finding 32

In spite of gains made over the last several decades in decreasing the amount of NO_x emitted from stationary and mobile combustion sources, the total amount of Nr released into the atmosphere has remained relatively constant. This is related to the essentially unregulated release of ammonia from livestock operations. At the present time, fewer livestock are required to produce more animal products than in the past. For example, since 1975 milk production has increased linearly at the rate of ~ 180 kg milk per cow /yr while milk cow herd population decreased at the rate of ~69,000 head per yr, i.e. the 60% greater amount of milk produced in 2006 compared to 1970 required 25% fewer cows. Animal inventories declined by 10% for beef brood cows from 36 million head in 1970 to 33 million head in 2006, and the inventory of breeder pigs and market hogs declined 8% from 673 million head to 625 million head in the same period, even with similar or greater annual meat production. These trends resulted from greater growth rates of animals

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producing more meat in a shorter amount of time. In 1970, broilers were slaughtered after 80 days on feed at 1.7 kg live weight, but by 2006 the average weight was 2.5 kg after only 44 days on feed. These trends are in requiring fewer animals to produce more animal food products through improved diet and increased production efficiency will continue.

Implementation of improved methods of livestock management and manure handling and treatment to decrease NH_3 emissions that have been developed since 1990 and will further decrease ammonia and other gases and odor emissions. For example, sawdust litter helps decrease NH_3 emissions from pig manure with 44-74% of manure N converted to N_2. Storage covers for slurry storage tanks, anaerobic lagoons, and earthen slurry pits decrease emissions from those containments. Anaerobic digestion in closed containment has been studied for many types of applications. Recent research demonstrates reduction in NH_3 emissions after a permeable cover was installed, e.g a polyethylene cover decreased NH_3 emissions by ~80%. A well managed swine lagoon can denitrify approximately 50% of the excreted N to N_2. Recently engineered developments utilizing closed loop systems (Aneja et al. 2008) substantially reduce atmospheric emissions of ammonia (> 95%) at hog facilities.

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Recommendation 24. *The committee recommends a goal of decreasing livestock-derived NH_3 emissions to approximately 80% of 1990 emissions, a decrease of* ***0.5 Tg***

N/yr *(by a combination of best management practices and engineering solutions). This is expected to decrease air concentrations of $PM_{2.5}$ by ~0.3 µg/m3 (2.5%); and improve health of ecosystems by achieving progress towards critical load recommendations. Additionally we recommend decreasing NH_3 emissions derived from fertilizer applications by 20% (decrease by ~**0.2 Tg N/yr**), through the use of NH_3 treatment systems and best management practices.*

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Finding 33

The CAA (1970) and its Amendment (1990), have resulted in NO_x emissions that are <50% of what they would have been without the controls. While this is an admirable accomplishment, there is still a need to seek improvements, as NO_x emissions are still an order of magnitude greater than at the beginning of the 20th century, and as a consequence there are still negative impacts on both humans and ecosystems.

In 2002,
coal-fired utilities generated approximately 1.2 Tg Nr annually. If all coal-fired plants used state-of-the-art NO_x controls, this number could be decreased by 0.6 Tg or about 50% ; in fact the NO_x SIP call implemented in 2003 and 2004 decreased 2002 emissions by 0.3 Tg N/yr, so in essence, half the recommended decrease has already been accomplished. Looking at mobile sources, highway source emissions are around 2.2 Tg and off-highway around 1.2 Tg for a total of 3.4, again 2002 numbers. Assuming a 40% decrease for these sources (most off-highway mobile sources currently have no controls,

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but could achieve 80-90% NO_x removal), there is a potential decrease in emissions of about 1.4 Tg. The
total decrease is then approximately 2 Tg.
The decreases in NO_x emissions by 2 Tg N /yr may be inadequate for many areas to achieve the new 65 ppb ozone standard recommended by the Clean Air Act Scientific Advisory Committee or even the 75 ppb currently promulgated. Additional measures such as increasing the role of solar- and wind-generated electricity and wider use of hybrid or electric cars should be considered.

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Recommendation 25. *The committee recommends that the EPA expand its NO_x control efforts from the current decreases of emissions of passenger cars and power plants to include other important unregulated mobile and stationary sources sufficient to achieve a 2.0 Tg decrease in the generation of reactive nitrogen.*

The committee's recommendations, if implemented, would reduce total Nr loadings to the environment in the US by approximately 25% below current amounts. Figure 40 compares current and proposed Nr flows in the US. The committee believes that these represent realistic intermediate targets based on current technology, however further decreases are needed for many N-sensitive ecosystems (e.g., estuarine and coastal waters). Developing these opportunities, and going beyond these recommended Nr emission targets, are critical given the growing demand from population and economic growth for food- and fiber-production and energy use.

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Comments from Dr. Otto Doering

Not something we can do right now, but I believe that we are going to have to provide much more detail on the estimates of potential reduction in NR by sector that we give in the report. As an example, Tom made a presentation to an EPA agriculture advisory group the beginning of the week, and they really wanted to know how we got to the 80% reduction in ammonia (atmospheric N) from livestock production and what part of the sector did this involve.

My guess is that we are going to have to provide much more detail in these areas, and that this is certainly something that external reviewers will pick up on.

Comments from Dr. William Herz

Overall I also feel that the report comes across as scholarly and balanced. I struggled a bit with the review as I wanted to see everything in track changes mode so I could understand the edits that Cowling and Stacy made. In almost all cases I think they make the text clearer and the intent more understandable.

The issue I am struggling with most is one that is mostly left unsaid; in that there is a inherent public health tradeoff in imposing additional costs on agriculture in that it inevitably will raise prices of food; which may impact those least able to afford it. We saw as recently as 2008 a spike in food prices that had this exact impact; food security was impacted and food riots occurred in various countries. This is not 'theoretical.'

We also don't speak to the fact that certain types of food production result in far higher losses of Nr than others, but perhaps this is too specific to get into in this section.

Comments from Dr. Joanne Lighty

Lighty comments:

p. 8: Footnote – Combustion of wood and other forms of biomass, which have low nitrogen content, generally occurs at temperatures too low to convert to N2 and Nr
NOTE: I think I have a hard time conveying this thought. Some biomass has higher N content and that would convert to Nr. Also, when the outside reviewers read this they thought it didn't fit.

p. 10: line 19 – I think "through" should be thorough.

p. 16: line 2 – the "be formed" at the end needs to be removed.

p. 30: line 10 – add to read, "show decreases between 15-30% from 1990 to 2002 (Figure 5).

p. 32: line 12-13 – change to read, "Louisiana and Texas have high emissions due to various industries located in these states."

Since the section 2.2.2 is one I wrote, at one point I added findings and recommendations to maintain consistency within the chapter. I think in the various moves, they are either relocated or gone.

p. 153: the recommendations are a bit repetitive (within the recommendation 20 and 25) and difficult to read – here is a cut… As a note, I might move 25 to 21 because it is closely aligned with 20.

20a. In the case of heavy-duty diesel and off-road vehicles including locomotives, contruction, farm, and landscaping equipment, and marine vehicles, EPA should promulage stricter NOx emission standards.

20b. The Agency should consider the mass of NOx emitted per unit of power provided, rather than past emissions, as the figure of merit for EGUs.

20c. For total NOx from all mobile sources, the Agency should consider a cap that decreases with time.

20d. The Agency should implement and maintain programs such as inspection and maintenance or road-side monitoring to ensure that most light-duty vehicles meet emissions standards (I DON'T UNDERSTAND HOW THIS IS DIFFERENT FROM TESTING YOUR CAR AND NOT SURE I AGREE WITH THIS.)

20e. The Agency should encourage, through its sustainability initiatives, cleaner energy sources such as wind and solar and promote changes in lifestyle, urban planning, and public transit conducive to energy conservation and reduced emissions.

p. 157: line 17 – change 1.2 to 1.3 for a total of 3.5 (consistent with Table 1)
p. 157-158: line 33-37 and 1-3 – should be removed as they are repeated on p. 158 lines 5-11.

Comments from Dr. Arvin Mosier

Comments on INC Report version 2/18/09----A. Mosier (2/23/09)

The following are comments are editorial :

Page 5, footnote, last line N2 should be N_2

Page 8, line 12: Findings and recommendation numbers need to be checked—I counted to 24 on page 180.

Page 13, line 30: Need recommendation #

Page 16, line 30: # of recommendations?

Page 25, line 10: remove underline from NO3

Page 30, Fig. 4: y axis caption NO2 needs to be NO_2

Page 40, line 11: last word of sentence—US required

Page 41, line 25-34: Look at consistency of listing recommendations numbers/after this recommendation where there are multiple recommendations they are listed as 2a, 2b, 2c

Page 43, line 5: The Aulakh, 1992 citation should be Aulakh et al. 1992

Page 43, line 30: The Crutzen et al., 2007 citation should be Crutzen et al. 2008
This reference is missing from the Reference section on page 189. The reference is:

Crutzen, P.J., A.R. Mosier, K.A. Smith, and W. Winiwarter. 2008. N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. Atmospheric Chemistry and Physics, Atmos. Chem. Phys., 8: 389–395.

Page 55, line 17: remove the underline from the word range

Page 57-70: This section used [] to note references while () are used in rest of document

Page 83, line 16: remove underline from 3,420

Page 87: Figure 18 belongs in the Appendix on page 183

Figure numbering from here on needs to be redone in text and captions

Page 101: Table 23 should be #18; line 8 table #

Page 106, line 9: Table 3-23 should be # 19

Page 107, lines 1 & 5: Table 18 should be 19
Page 111, lines 26-29: Should this part be noted as a recommendation?

Page 111, line 25: should be section 2.4.5.4

Page 112, lines 16-33: Is this a repeat from page 111 lines 8-24 that should be deleted?

Pages 114, 115, 116: Table numbering (should be # 20-22?)-----also: where are these tables discussed?

Page 118, line 17 & 21: Figure #?

Page 119, lines 1, 6, 8: Figure #s?

Page 120, lines 1 & 10: Figure #s

Page 121, line 1: Fig. #

Page 122, lines 6 & 9: Fig #

Page 123, lines 27, 32, 37 & 32: Fig #s

Page 124, Fig #s

Page 126, line 37: Table #

Page 127, line 1: Table #

Page 130, line 33: Table #

Page 131, line 32: Fig #

Page 132, Table#, Fig #

Page 135: Table #

Page 136, line 1: Table #-- lines 1-10 is this Fig part of the previous table? Or should this have a Fig #?

Page 136, line 31: Fig. #

Page 137, line 5: Fig. #

Pages 137-142: Inside text box need to match figure and table #s with text

Page 143, line 17: Change the word “choke” to “control”

Page 146, line 35: match Fig # with Fig on page 147

Page 151, line 27: It looks like Finding 19 (just the words Finding 19) needs to be omitted

Page 153: Here on the numbering of the Findings/ Recommendations needs be changed

Page 158, lines 12 & 26: Fig #

Page 167: Numbering of recommendation 2 needs to be reformatted to match the rest of the multiple recommendations listings; i.e. 2a, 2b etc.

Page 170, Finding-26 should be Finding 10

Page 174: What is listed as Finding 27 and recommendations A,B,C are repeated and should be omitted here

Page 175, Finding 28 should be finding 19 and Recommendation 20a-i should be number 19a-i

Page 176-178, Finding 29 should be Finding 20 and Recommendations 21-21g should be Recommendation 20a-20g

Page 178, Finding/Recommendation 30/21 should be 21 & 21

Page 178: Finding 31 should be Finding 22

Page 179: Recommendation 23 should be R-22

Finding 32 should be # 23

Recommendation 24 should be # 23

Page 180: Finding 33 should be 24 & Recommendation 25 should be # 24

Page 183: Insert Fig. from page 87

Page 189: Insert the Crutzen et al. 2008 reference

Comments from Dr. Hans Paerl

(Please see separate pdf with marked up changes)
Aside from the textual changes I have made, I have no additional major comments at this time. Some of the changes I suggested before, like the text omissions on P. 75, but maybe they fell through the cracks. I think the report is fairly well balanced. There are issues regarding handling and management of N wastes in agriculture that probably need to be discussed a bit more (i.e. which to emphasize), but I feel this is out of my area of expertise.

Comments from Dr. Paul Stacey

I took Ellis' revision and worked on that. No way I could get into the main chapters with the amount of time I had available.

Ellis - great revision, but I reworked it some more. I hope you concur that it's moving in the right direction. Thanks for your support. It still needs a lot of work, in my opinion, as there needs to be more substance and the bottom line recommendations.

Executive Summary

Introduction

Reactive nitrogen (Nr) encompasses biologically active, chemically reactive, and radiatively-active nitrogen compounds[1]. At the global scale, human activities now create approximately two-fold more Nr than natural terrestrial and aquatic ecosystems once produced; in the U.S., that increase of Nr caused by human activity is about 5-fold. Primary causes for this increase are the production of Nr through the Haber-Bosch process that generates ammonia (NH_3) for synthetic nitrogen fertilizer and industrial feedstocks, the enhancement of biological nitrogen fixation (BNF) by crop cultivation (e.g., legumes), and the combustion of fossil fuels. The first two anthropogenic activities form Nr on purpose; the last one forms Nr as an unwanted byproduct -- by accident.

Anthropogenic creation of Nr results in large-scale, and essential, benefits for humans, first and foremost meeting human food dietary needs. In fact, a large fraction of the human population of the Earth could not be sustained if food production was not augmented significantly by synthetic nitrogen fertilizers. There are, however, some costs for this human largesse. Essentially all of the Nr created by human activities is lost to the environment, often with negative, unintended consequences. There it circulates between, and accumulates within, environmental systems that include the atmosphere, and aquatic and terrestrial ecosystems and contributes to a number of adverse public health and environmental effects. These effects are of great concern to environmental and human well-being and include photochemical smog formation, increased exposure to nitrogen-containing aerosols, decreased atmospheric visibility, acidification of terrestrial and aquatic ecosystems, coastal and freshwater nitrogen imbalances and saturation, global warming and other greenhouse effects, and stratospheric ozone depletion.

Nr effects are manifest as declines in both human health (e.g., respiratory and cardiac diseases) and ecosystem health (e.g., eutrophication and loss in biodiversity). The effects are often magnified because any one atom of nitrogen in the environment can contribute to both beneficial and detrimental effects in sequence, as excess Nr moves through various environmental reservoirs. This characteristic of Nr is the conceptual foundation for the ***nitrogen cascade*** (Figure 1) [add the nitrogen cascade diagram].

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[1] The term reactive nitrogen (Nr) is used in this paper to include all biologically active, chemically reactive, and radiatively active nitrogen (N) compounds in the atmosphere and biosphere of Earth. Thus, Nr includes inorganic chjemically reduced forms of N (NHx) [e.g., ammonia (NH3) and ammonium ion (NH4 +)], inorganic chemically oxidized forms of N [e.g., nitrogen oxides (NOx), nitric acid (HNO3), nitrous oxide (N2O), N2O5, HONO, peroxy acetly compounds such as PAN, [others] and nitrate ion (NO3¯), as well as organic compounds (e.g., urea, amines, amino acids, and proteins), in contrast to non-reactive gaseous N_2.

The nitrogen cascade concept provides an ideal structure to assess and quantify the effects of Nr as it originates, flows and transitions through key, medium-based compartments, i.e., the atmosphere, the land and the water. The framework provides for relevant organization of Nr sources within each compartment, its transfer among the compartments, and the benefits and impacts along the way. It further highlights potential sites of source reduction or management intervention within each compartment in a manner that integrates those actions among sources and media to provide an efficient mechanism for both understanding and management.

To assist EPA in its understanding and management of nitrogen-related air-, water-, and soil-pollution issues, this Integrated Nitrogen Committee (INC) was formed and charged by the Science Advisory Board (SAB) of the US Environmental Protection Agency to address the following objectives:

1. Identify and analyze, from a scientific perspective, the problems nitrogen presents in the environment and the links among them;
2. Evaluate the contribution an integrated nitrogen management strategy[2] could make to environmental protection;
3. Identify additional risk management options for EPA's consideration; and
4. Make recommendations to EPA concerning improvements in nitrogen [monitoring, assessment and] research to support risk reduction.

Procedure

The INC followed a very structured procedure to meet the four objectives established by the SAB, with the nitrogen cascade serving as the framework for analysis. The INC found the nitrogen cascade model to be the most suitable approach for incorporating air, land and water aspects of integrated Nr research and management that included both human and ecosystem effects in a comprehensive fashion. This was essential given the varied and diverse make up of the INC that needed to cross the boundaries of individual expertise to create an integrated outcome. This was accomplished through regular interactions among the members, both in person and via conference call and e-mail exchange with coordination by the co-chairs of the INC and the SAB Designated Federal Officer (DFO). The nitrogen cascade structure allowed for sharing of information and concepts without fear of redundancy or omission.

Several steps in the early phase of the INC work were necessary to ensure a complete and functional nitrogen cascade structure. These included compartmentalization of the cascade into media-based compartments (air, land and water) and establishing the transfer routes and interactions among them. The relationships among the compartments allowed identification of Nr sources, kinetics, and the related stressors and receptors within them and the ready application of risk analysis principles. Once the nitrogen cascade was fully populated, and risks identified,

[2] An integrated nitrogen management strategy takes an holistic approach for managing Nr. In the context of the nitrogen cascade, all Nr anthropogenic creation and destruction mechanisms and all Nr uses are recognized. The strategy should take account of synergies and trade-offs, to ensure that decreasing one problem related to nitrogen does not result in other unintended adverse environmental, economic and societal consequences. By identifying relative priorities, assessing cost effectiveness and risks, the strategy should seek to maximize the benefits of reactive nitrogen, while limiting overall adverse effects.

points of intervention for Nr control and other actions to reduce risk were determined. The INC used that understanding to estimate national load reduction potential from management of major sources and points of intervention, and also assessed the feasibility of attaining those targets and assessing the level of risk reduction from those actions. To assist EPA with management approaches, the INC also reviewed federal management programs and authorities as currently implemented to identify areas where enhancement or revision might be recommended. Finally, as anticipated in the INC charge, the INC developed recommendations for monitoring, assessment and research that would build the understanding necessary to improve Nr management and better attain the goals and objectives for both environmental and human health protection in the future.

This Executive Summary is structured to parallel those activities, and overview the analyses made by the INC to fulfill the four charges. The detailed analyses that support the conclusions and recommendations made herein follow in the main body of the report. It summarizes the Nr inputs to the United States (US), and the fate of the Nr in the US and addresses how both public health and environmental impacts are, and could be, assessed. The recommendations are organized within three "overarching" recommendations for both research and management that the INC believes would help the EPA develop an integrated nitrogen management strategy. More specific recommendations are related to provide a comprehensive overview of the study, as well as to support and clarify the intent of the overarching recommendations. Finally, "Target Goals" are suggested for management actions that could achieve an initial 25% decrease in the amount of Nr lost to the US environment using existing technologies.

The Integrated Nitrogen Committee (INC) worked diligently for two years gathering scientific data and information on Nr inputs into the US, the flows of Nr through US environmental systems, and the influence that various human activities have had on these flows within the nitrogen cascade. Extensive literature that exists on Nr-related impacts on public health and on both the atmosphere and terrestrial ecosystems and aquatic ecosystems was drawn upon and summarized. These very necessary reviews and analyses provided the intellectual foundation for INC to address the following somewhat more detailed policy-relevant questions:

- How should Nr be managed and how should management priorities be determined?
- To what degree can the US decrease Nr losses to the environment using existing technology?
- What further decreases are needed?
- What more can EPA do to develop a total integrated management strategy for Nr?

In recent years, a few other studies have examined some aspects of the biogeochemical flows of Nr in the US nitrogen cycle, the impacts of alterations in those flows, and suggested policies for addressing some specific consequences of those alterations.
By contrast, this report of the INC committee report seeks to provide an integrated and holistic approach to all aspects of the current Nr-management problems and challenges in our country. Our INC Committee is convinced that the EPA has a potentially very powerful lead role to play -- together with other federal, state, and local organizations -- in developing integrated strategies by which to maximize beneficial impacts and decrease detrimental impacts of Nr management in this country.

Comment [ebc14]: [Jim – Tom – Angela -- Should literature citations be included for one or more of these earlier reports?]

Comment [ebc15]: Jim – Tom – Angela –
These additional lines of text are suggested to convey in more direct language, the sense of the INC Committee that this Report outlines not only "Overarching, Recommendations" and "Target Goals" for decreases in Nr losses,to the environment, but also "Specific Findings and Recommendations" to guide EPA's interim actions on specific aspects of the Nr problem in this country.

Overview

To aid the INC in its deliberations, the four initial objectives established by the SAB were elaborated briefly and then followed to completion as described below:

Objective 1: Identify and analyze, from a scientific perspective, the problems N presents in the environment and the links among them.

To address this objective, the INC used the nitrogen cascade framework to first determine the major sources of newly created Nr in the US. The flows of Nr within the food, fiber, feed and biofuel production systems for the US were examined, paying special attention to the locations in the food, feed, fiber, and fuel production system where Nr is lost to the environment. The same process was employed for energy production but, since all the Nr formed during energy production is lost to the environment, the committee identified the important energy producing sectors that contribute to Nr formation (Section 2.2 on pages 28-56 of the full Report).

The committee next examined the fate of the Nr lost to the environment, determined the amount stored in different systems (e.g., forest soils) and tracked Nr as it was transferred from one environmental system (e.g., the atmosphere) to another (e.g., terrestrial and aquatic ecosystems) (Section 2.3 on pages 57-82 of the full Report). The end results of these two activities are summarized in Figures 2 and 3.

These two activities set the stage for addressing the environmental and human health problems Nr presents, and links among them. Using the nitrogen cascade, the committee identified the impacts that Nr has on people and ecosystems as it moves through environmental systems. The committee also addressed the metrics that could be used, i.e., impacts due to environmental changes (e.g., acid deposition), vs. impacts due to losses of ecosystem services (e.g., loss of biodiversity), and trade-offs among Nr Impacts. (Section 2.4 on pages 87-125 of the report covers these aspects of the first objective.)

Objective #2: Evaluate the contribution an integrated N management strategy could make to environmental protection.

An integrated management strategy must take into account the contributions of all Nr sources, and all chemical species of Nr that adversely impact both human health and environmental systems. Further, the strategy should ensure that solving one problem related to Nr does not exacerbate another problem or diminish necessary human services to produce food, feed, fiber, or biofuels. In short, the strategy should seek to maximize the benefits of Nr, while limiting overall adverse effects.

To address this challenge, the committee identified several actions that could be taken to better manage Nr in one environmental system that have caused unintended consequences in another. In addition, examples of management actions that could be taken that would be ‘integrative’ in nature are highlighted.

Objective #3: Identify additional risk management options for EPA's consideration.

The INC has identified four major Target Goals for actions which, collectively, would limit Nr losses to the environment by about 25%, recognizing that decreasing Nr emissions at these points will result in further decreases in Nr-related impacts throughout the nitrogen cascade. In addition, INC has suggested several ways in which each of these Target Goals could be attained including conservation measures, additional regulatory steps, application of modern technologies, and end-of-pipe approaches. These are initial actions; others should be taken once the recommended actions in the report that focus on a better understanding of N dynamics and impacts in the US are completed.

Objective #4: Make recommendations to EPA concerning improvements in Nr [monitoring, assessment and] research to support risk reduction.

Throughout the report, there are summary statements, labeled "Scientific Findings." Attached to the scientific findings are one or more specific "Recommendations" for actions that could be taken by EPA or other management authorities. In each case, the intent is to provide the scientific foundation regarding a specific Nr-relevant environmental issue and one or more recommendations by which EPA acting alone or in cooperation with other organizations could use currently available technology to decrease the amount of Nr lost to the US environment.

In addition, the INC report includes three "Overarching" recommendations, supported by more specific, action-oriented recommendations that would enable EPA to improve Nr-relevant research in the support of risk reduction strategies.

The remaining sections of this executive summary cover the points made above in greater detail.

Results of the Integrated Nitrogen Analysis

Objective 1: Identify and analyze, from a scientific perspective, the problems N presents in the environment and the links among them.

1. Consequences and Impacts Associated with Nr

The most important human-beneficial consequence of Nr use in the United States (and other parts of the world for that matter!) is providing adequate supplies of wholesome food, feed, and fiber crops to meet dietary and other needs of people in this country and abroad – an issue of global food security. In many ecosystems the supply of biologically available Nr is a key factor controlling adequacy of food, feed, and fiber supplies, the profitability of crop and animal agricultural, the nature and diversity of plant life, and vital ecological processes such as the cycling of carbon and soil minerals.

In addition to these very important human-beneficial consequences, however, there are also are numerous and important negative consequences from anthropogenic Nr. These negative consequences include formation of photochemical smog, exposure to toxic aerosol particles in the air, acidification and eutrophication of terrestrial and aquatic ecosystems, global warming and other greenhouse effects, and stratospheric ozone depletion. Human activities have not only increased the supply but enhanced the global movement of various forms of Nr through air and water. Mitigating risk from these factors is difficult because one molecule containing Nr can contribute to all of these effects as a consequence of the nitrogen cascade (Figure 3). Nitrogen is a dynamic element easily transformed from one chemical form to another, and can have cascading effects in the air, land and water compartments identified in this report. These characteristics make nitrogen an especially challenging element to control. [I think we need more here – the problem is not well defined – PES]

Comment [ebc16]: I believe that Figure 3 on page 20 of Chapter 1, should also be included in the Executive Summary of our INC report!

2. Sources of Nr

At the global scale, human activities introduce approximately two-times more reactive nitrogen than natural processes; in the US, however, this difference in amount of Nr released to the environment by human activities is approximately five-times larger than natural processes. As shown in Figure 1, natural ecosystems in the US introduce about 6.4 teragrams (Tg) of reactive nitrogen per year. In contrast, human activities introduce about 28.5 Tg Nr/per year.

The largest single source of Nr in the US is the Haber-Bosch process, which introduces about 15.2 Tg Nr/yr into the US – 9.4 Tg Nr/yr from domestic US Nr production and 5.8 Tg Nr/yr from imports of synthetic Nr fertilizers, feed grains and food. This total amount is used in three ways: 9.9 Tg N/yr are used to produce agricultural crops; 1.1 Tg N/yr are used to produce turf grasses; and 4.2 Tg Nr/yr are used as industrial feedstocks for production of nylon, refrigerants, explosives and other commercial products.

Fossil fuel combustion is the second largest source of Nr. It introduces approximately 5.7 Tg Nr/yr into the environment (almost entirely as NOx) – 3.8 Tg Nr/yr from transportation sources and 1.9 Tg Nr/yr from stationary sources such as electric utilities and industrial boilers.

Figure 1: New Nr introduced into the US, 2002, Tg N

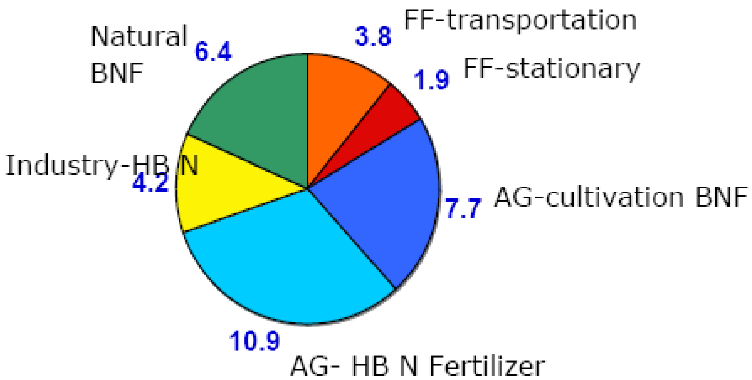


Figure title: Figure 2: Sources of reactive nitrogen (Nr) introduced into the US in 2002 (Tg Nr/year)
Explanatory notes:
Numerical units = teragram of reactive nitrogen (Nr) per year (Tg Nr/yr)
Natural BNF = biological nitrogen fixation in natural grasslands, rangelands, and forests,
FF transportation = combustion of fossil fuels in transportation vehicles.
FF stationary = combustion of fossil fuels in power plants and industrial boilers.
AG-cultivation BNF = agricultural augmentation of biological nitrogen fixation **--** for example by planting of nitrogen fixing legumes.
AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr.
Industry-HB N = Industrial sources of Nr produced by the Haber-Bosch process.

Comment [ebc17]: An important and widely accepted principle for the design of Figures is the notion that the Figure itself and its descriptive caption should "stand alone" and not be dependent on information contained only in the text for understanding by readers. Thus, after a thorough discussion of this guiding prionciple with Jim Galloway, I offer the following recommendations for the revision of this Figure (and also) Figure 2 on page 11 of the Excutive Summary.

The caption this figure should read: Figure 1. Sources of reactive nitrogen (Nr) introduced into the United States in 2002.

The explanatory notes for this figure should read:
Numerical units are teragram of reactive nitrogen per year (Tg Nr/yr). Natural BNF = biological nitrogen foixation in natural grasslands, rangelands, and forests, FF transportation = combustion of fossil fuels.r in transportation vehicles. FF stationary = combustion of fossile fuels in power plants and industrial boilers, AG-cultivation BNF = agricultural augmentation of biological nitrogen fixation, for example planting of nitrogen fixing legumes. AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr. AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr. Industry-HB N = industrial sourdces of Nr produced by the Haber-Bosch process.r

The third largest source of Nr introduced into the US is enhancement of biological nitrogen fixation (BNF) by cultivation of crops like soybeans, alfalfa, and rice that have nitrogen fixing symbionts. These Nr fixing crops introduce about 7.7 Tg N/yr. A small amount of additional Nr is also imported in grain and meat products; in 2002 this source of added Nr was approximately 0.2 Tg Nr/yr.

In summary, agricultural production of food, feed, fiber, and biofuels and combustion of fossil fuels are the largest sources of Nr released into the environment compared to other human sources in the United States. The distribution of Nr released to the US environment from human activities in 2002 was: about 65% from agricultural sources; about 20% from fossil fuel sources; and about 15% from industrial sources (Figure 1).

Although fossil fuel combustion is widely recognized within EPA and society in general to be a major source of nitrogen, sulfur, and carbon pollutants and resulting environmental quality concerns, in fact, feed and food production and subsequent consumption by animals and humans is a much larger (about 3.3 times larger!) source of reactive nitrogen than fossil fuel combustion.

3. Transfer and Transformation of Nr among Compartments

There are several possible fates for the approximately 35 Tg Nr/yr introduced into the US environment each year from natural sources and human activities. Emissions of N_2O discharge about 0.8 Tg Nr/yr into the global atmosphere. Of the 6.3 Tg Nr/yr of US NO_x emissions, 2.7 Tg N/yr are deposited back onto the land and surface waters of the US. Thus, by difference we estimate that about 3.6 TgNr/yr per year are advected out of the US atmosphere. Similarly, of the 3.1 Tg Nr/yr of NH_3 that are emitted into the US atmosphere each year, about 2.1 Tg Nr/yr are deposited onto the land and surface waters of the US, and about 1 Tg N/yr is advected out of the US via the atmosphere.

Riverine discharges of Nr to the coastal zone account for 4.8 Tg N/yr, while export of N-containing commodities (e.g., grain) removes another 4.3 Tg Nr/yr from the US. Altogether, these total losses add up to about 14 Tg Nr/yr, leaving about 21 Tg N/yr unaccounted for. Of this amount, we estimate that 5 Tg Nr/yr year are stored in soils, vegetation, and groundwater, and, by difference, we estimate that about 16 Tg N/yr are denitrified to N_2 (Figure 3). There are substantial uncertainties (+/- 50%) for some of these rough estimates, especially those that involve NH_x emission and deposition and terms that are arrived at by difference (e.g., atmospheric advection and denitrification). These significant uncertainties drive the three overarching recommendations of this INC report.

Objective #2: Evaluate the contribution an integrated N management strategy could make to environmental protection.

[Need something on this objective]

Objective #3: Identify additional risk management options for EPA's consideration.

1. Integrated Risk Reduction Strategies

Nitrogen is both a critically important natural resource and also a contributor to a number of adverse environmental problems; therefore, it is imperative to understand how to decrease the risks to society while also providing the food, energy, and materials required by society. Various approaches can be used to prevent, eliminate, decrease, or otherwise manage Nr risks. Understanding the environmental impacts of Nr can inform decisions on how best to manage nitrogen risks. There are two main approaches to characterizing the adverse public health and environmental impacts of Nr: traditional damage estimates and decreases in ecosystem services.

Historically, EPA's environmental protection programs have addressed the adverse public health and public welfare impacts of Nr through use of such common metrics as National Ambient air Quality Standards (NAAQS) and, in the case of water resources, Total Maximum Daily Loads (TMDLs) built upon attainment of water quality standards and criteria. These common metrics have had the considerable advantage of providing frameworks within which air and water quality standards could be derived that are protective of specific human health and environmental risks – the principal missions of the USEPA.

The ecosystem services approach complements these traditionally used common metrics by considering how specific ecosystem services provided by one or more ecosystems are impaired by excess Nr. The attractiveness of this approach is its recognition that the health of humans and the health of ecosystems are inextricably linked. Less clear, in some cases, however, are the ways these adverse impacts are measured and monitored. Ecosystem-service-based measurements provide a richer context for the complex connections among Nr inputs and transformations. Furthermore, impacts on human well-being can help identify those adverse effects of Nr that impose the greatest damage costs to society.

The INC Committee believes that using both common metrics and ecosystem-service based metrics will:

- provide a more clear picture of priorities for action,
- help identify effective control points for decreasing Nr impacts, and
- provide insights into more efficient and cost-effective Nr regulatory strategies.

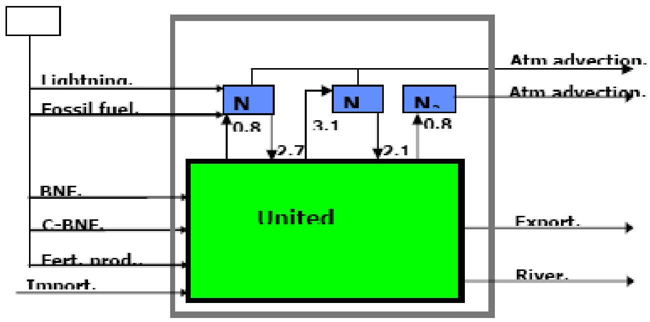
[I think this needs to be more of a summary of findings – PES]

2. Tradeoffs Among Nr Risk Management Options

Once the foreseeable impacts are understood and the suite of benefits associated with various risk reduction options are described, then managers can consider trade-offs. Risk reduction integration provides an intellectual framework that allows managers to make informed decisions about which benefits may need to be relinquished for other benefits when not all the desired benefits can be achieved. For example, limiting nitrogen fertilizer application to decrease risks from Nr applied to agro-ecosystems may decrease crop yields and increase food and feed commodity prices, which in turn may result in expansion of crop production area at the expense of natural wetlands, grasslands, and forests.

Figure 2: Nr inputs into the US, exchanges with the atmosphere, and losses from the US via exports and riverine and atmospheric transport, 2002US nitrogen budget for 2002

Tg N /yr



Nr Inputs: **35 Tg N**

Nr Outputs: **14 Tg N**

Nr Missing: 21 Tg N

Nr Storage: 5 Tg N

~ 2 Tg soils&vegetation

~ 3 Tg groundwater

Nr Denitrified to N_2:

21 Tg N - 5 Tg N = 16 Tg N

Figure 3.

3. Management Options to Reduce Risk

Typically, quantitative risk assessment; technical feasibility; economic, social and legal factors; and additional benefits of various air and water management strategies contribute to the development of a suite of risk reduction strategies from which managers select an optimal approach. There are several ways in which the release and control of Nr in the environment can be approached to reduce environmental risk. In general these can be classified as follows:

1. Improved practices and conservation—in which the flux of Nr that creates an impact is decreased through better management practices (e.g. on-field agricultural practices, control of urban runoff, controlled combustion conditions)
2. Product substitution—in which a product is developed or promoted which has a smaller dependency on Nr (e.g. use of switchgrass instead of corn grain as a feedstock for biofuel ethanol production).
3. Transformation—in which one form of nitrogen is converted to another less damaging form of nitrogen (e.g. nitrification of municipal wastewaters, denitrification of Nr by converting it back to non-reactive gaseous N_2).

4. Source limitation—in which the amount of Nr introduced into the environment is decreased (e.g. lower fertilizer application rates, use of low-NOx burners in power plants).
5. Removal—in which particulate forms of Nr are captured in a more readily managed physical form such the bacterial sludge which can be disposed of by land application or incineration.
6. Improved use or reuse efficiency—in which the efficiency of production that is dependent upon Nr is improved (e.g. increased grain yields per unit of Nr fertilizer applied, decreased NO_x emissions from more efficient diesel engines in trucks and off-road construction equipment).

Efficient and cost-effective management of Nr often requires combinations of these six Nr management strategies hes; no one approach is a perfect alternative for decreasing excess Nr in the environment.

3. Policy Mechanisms for Management of Nr in the Environment

Generally speaking, US environmental policies employ one or more of the following four mechanisms for management of pollutants in the environment:

1. Command-and-Control—in which permitted limitations on pollutant or chemical-precursor emissions are issued under various regulatory statues. Violations may result in the assessment of penalties.
2. Government-based programs affecting the desirability of an environmental management mechanism, such as directed taxes, price supports for a given commodity, subsidies to bring about a particular end-result, and grants for capital expansion or improvement of pollution-abatement technologies.
3. Market-based instruments for pollution control in which cap and trade markets are used to bring about a desired policy end-result, often at decreased overall cost to society.
4. Voluntary programs in which desired environmental outcomes are achieved using private or government-initiated agreements or through targeted outreach and education programs.

An integrated approach to the management of Nr must use a combination of implementation mechanisms. Each mechanism must be appropriate to the nature of the problem at hand, supported by critical research on decreasing the risks of Nr, and reflect an integrated policy that recognizes the complexities and tradeoffs associated with the nitrogen cascade. Management efforts at one point in the cascade may be more efficient and cost effective than control or intervention at another point. This is why understanding the nature and dynamics of the N cascade is critically important.

Objective #4: Make recommendations to EPA concerning improvements in Nr [monitoring, assessment and] research to support risk reduction.

1. Measurement of Reactive Nitrogen in the Environment

What, where and how air and water quality managers measure Nr from sources and in the environment guides not only how they assess and react to impacts, but also how they gauge the success or failure of their environmental management strategies and tactics. Most regulations set limits or specify control technologies for specific forms of Nr without regard to the ways in which Nr may be transformed once it is introduced into the environment. Normally, regulations also require some form of monitoring to document compliance. Monitoring of the specific chemical forms of Nr is not enough. There is a need to measure, compute, and report the total amount of Nr present in impacted systems in appropriate units because one chemical form of Nr can be quickly converted to other forms.

2. Risk Assessment and Metrics Research Needs

The impacts of reactive nitrogen often can be expressed as the economic costs of damages, the cost of remediation or substitution, or the cost/ton of remediation for each form of reactive nitrogen. Damage costs do not always scale as tons of Nr released into the environment. If damage costs rather than tons of nitrogen were utilized as a metric, the full implications of the cascade, and the setting of priorities for intervention might differ. Similarly, if human mortality and morbidity are the metrics used, priorities for decreases in Nr emissions could be very different.

To determine the extent of damage caused by excess nitrogen[3] in environmental reservoirs, both the current Nr concentration, or loading, within a reservoir and the threshold at which negative impacts are manifested must be known. This threshold then provides a target load that can be used to guide strategies to decrease the amount of Nr in the reservoir. Some thresholds for adverse impacts are better known than others. For example, the impacts of ozone on human health are known well enough for EPA to set standards for both ozone and for NO_x, an ozone precursor. The same can be said for the impacts of Nr discharge to coastal waters. Total Maximum Daily Loads (TMDLs) are used to link Nr loading to impact.

On the other hand, the impact of Nr deposition on ecosystems is only generally known as a critical load, or effects threshold. There is strong scientific evidence to show that Nr deposition rates of 10 – 20 kg N per hectare per year can cause negative impacts on a variety of ecosystems. Since a large part of the land surface in the northern hemisphere receives Nr deposition in that range, it is necessary to better define the link between Nr deposition and ecosystem response. Further, our knowledge of Nr deposition is uncertain, especially for the chemically reduced

[3] Excess reactive nitrogen (Nr) is defined as the amount of Nr that is present in, or introduced into, an environmental system (e.g., Nr inputs to the atmosphere, Nr inputs to grasslands and forests, Nr inputs to estuaries) from anthropogenic sources that is not incorporated into agricultural and other biological products (e.g., food, feed, fuel and fiber), or stored in long-term storage pools (e.g., cropland soils).

Thresholds are used to determine at what amount excess Nr causes negative effects on ecosystem services and functions, and/or on human health. Thresholds vary by metric (e.g., concentration, loading, etc) and depend on the environmental system (e.g., atmosphere, forest). Examples of specific thresholds are given in Chapter 2 of the full INC Report – Aquatic Thresholds on pages 99 – 102, Atmospheric thresholds on pages 107 and 108, and Terrestrial thresholds on pages 110 113.13.

inorganic and organic forms of Nr. This knowledge needs to be improved to better link deposition to ecosystem response (see Recommendation xx on page xx).

Findings and Recommendations

The ultimate goal of this INC Report is to aid EPA in the development of an integrated N management strategy. To accomplish this, the committee recommends that EPA and others strengthen the science related to flows and impacts of Nr, that EPA use current knowledge to identify management actions that can be taken now, and that EPA join with other organizations to implement management actions within a framework that does not exacerbate one Nr problem when addressing another.

The committee's recommendations can be loosely organized into several tiers. These include recommendations that:

1. address deficiencies in knowledge about Nr flows and fates.

2. concern ecological and human impacts of Nr.

3. address specific actions that can be taken to decrease Nr in the environment.

4. address how EPA could develop an integrated N management strategy, in cooperationwith other agencies.

There is significant over-lap among these tiers, since some recommendations call for both research and immediate action. But collectively they represent our INC committee convictions about what will be needed to develop an optimally integrated Nr management strategy based on sound science. This integrated strategy keeps in mind the food, feed, fiber, and biofuel production demands of the US population and its trading partners.

As indicated earlier, this report organizes its specific recommendations around three overarching recommendations:

Recommendation A

EPA should pursue an integrated multi-medium approach to develop the scientific understanding necessary for science-based policies, regulations, and incentives. To be successful, this integrated approach must to avoid and/or remediate the impacts of excess Nr on terrestrial and aquatic ecosystems, human health, and climate. Such integration must cut across media (air, land, and water), chemical forms of Nr including chemically oxidized, chemically reduced, and organic forms of Nr, federal, state, and local government agencies, and private-sector organizations, and legislative statutes including the Clean Air Act (CAA), Clean Water Act (CWA), and the Energy Independence and Security Act (EISA).

Recommendation B

EPA should form an Intra-Agency Nr Management Task Force that builds upon existing Nr research and management efforts within the Agency. This Intra-Agency Task Force should identify the most efficient and cost-effective means by which to avoid the various adverse impacts of Nr loads cascading through the environment. These loads pose a significant threat to human health and environmental quality and directly affect climate change.

Recommendation C

EPA should also join with other agencies within the federal government in establishing an Inter-agency Nr Managaement Task Force , that includes at least the following agencies: U.S. Department of Agriculture (USDA), U.S. Department of Energy (DOE), U.S. Department of Transportation (DOT), National Oceanic and Atmospheric Administration (NOAA), and U.S. Geological Survey (USGS). This Task Force would coordinate federal programs that address Nr concerns and help ensure clear responsibilities for monitoring, modeling, researching, and regulating Nr in the environment. EPA should nserve as the lead agency for this Interagency Task Force.

[I agree with Ellis that the findings and recommendations from Appendix 3 ought to be brought forward here, and reorganized according to the preceding categories/along the lines of the nitrogen cascade. We did that at one of our earlier meetings, that I think put actions and recommendations in an organized framework. Somehow, that was lost along the way. Probably all of them ought to be brought forward but, I think, when they're reorganized, we'll find a few redundancies, and holes to fill with other recommendations. But, right now, I'm out of time – PES.]

10 This Interagency task forces should take a systems approach to both scientific research and public policy by:

11 • evaluating critical loads,
12 • adopting Nr budgets and life cycle accounting,
13 • establishing an Nr monitoring system as the basis for informed policies, regulations, and incentive frameworks
14 for addressing excess Nr loads,
15 • developing systemic models for use in recommending best management practices (BMPs) for application of fertilizers on farms and both residential and commercial landscaping purposes,;
16
17 • developing Nr indicators for excess
18 Nr effects on human health and environment;
19 • assessing combined carbon (C) and Nr effects on terrestrial and aquatic ecosystems,
20 • addressing indicators/endpoints, costs, benefits and risks associated with
21 impairment of human health and decline and restoration of ecosystem services
22 • investigating the need for new regulations
23 implementing• new education, outreach, and communication initiatives

- implementing economic incentives, particularly those that integrate air, aquatic, and land sources of excess Nr;
- developing new infrastructures for managing Nr releases to the environment; and
- reviewing existing and proposed legislation for purposes of extending regulatory authority or streamlining procedures for enacting Nr risk reduction strategies.

In addition to these three overarching recommendations, the INC committee has developed and presented within the main body of this INC Report, a series of xx “Findings” and “Recommendations” that deal with specific Nr-related cases and issues. All of these specific “Findings” and “Recommendations” are collated in Appendix 3 on pages 165 through 180 of this Report.

Also included in this collated list are four “Target Goals” [see Recommendations 20 through 24 on pages 153-157 in Chapter 3] that EPA could take together with other agencies using existing technologies to achieve an initial 25% decrease in the amount of Nr lost to the US environment.

Given the issues of Nr accumulation in the US and global environment, these initial steps will not be enough to reverse the collective Nr damages to terrestrial and aquatic ecosystems and human health. Other steps will need to be taken after consideration is given to the three “Overarching Recommendations,” four “Target Goals” and various other specific “Findings” and “Recommendations” contained in this report.

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[3] Combustion of wood and other forms of biomass generally occurs at temperatures too low to convert N_2 to Nr

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An important and widely accepted principle for the design of Figures is the notion that the Figure itself and its descriptive caption should "stand alone" and not be dependent on information contained only in the text for understanding by readers. Thus, after a thorough discussion of this guiding prionciple with Jim Galloway, I offer the following recommendations for the revision of this Figure (and also) Figure 2 on page 11 of the Excutive Summary.

The caption this figure should read: Figure 1. Sources of reactive nitrogen (Nr) introduced into the United States in 2002.

The explanatory notes for this figure should read:

Numerical units are teragram of reactive nitrogen per year (Tg Nr/yr). Natural BNF = biological nitrogen foixation in natural grasslands, rangelands, and forests, FF transportation = combustion of fossil fuels.r in transportation vehicles. FF stationary = combustion of fossile fuels in power plants and industrial boilers, AG-cultivation BNF = agricultural augmentation of biological nitrogen fixation, for example planting of nitrogen fixing legumes. AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr. AG HB N fertilizer = agricultural use of synthetic nitrogen fertilizers produced byb the Haber Bosch process for converting gaseous to Nr. Industry-HB N = industrial sourdces of Nr produced by the Haber-Bosch process.r

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Tg N

3.8

1.9

7.7

10.9

4.2

6.4

FF-transportation

FF-stationary

AG-cultivation BNF

AG- HB N Fertilizer

Industry-HB N

Natural

BNF

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N N

C-BNF,
Fert. prod.,
United
3.1
2.7
0.8
Import,
Export,
Atm advection,
Lightning,
Fossil fuel,
BNF,
2.1
N_2
0.8
Atm advection,
River,
Nr Inputs: 35 Tg N
Nr Outputs: 14 Tg N
Nr Missing: 21 Tg N
Nr Storage: 5 Tg N
~ 2 Tg soils&vegetation
~ 3 Tg groundwater

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global warming, eutrophication, ecotoxicity, human health (cancer and non-cancer),

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acidification, smog formation, and ozone depletion, among others. Sometimes these impacts can

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be expressed in common metrics

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defining
14 a straightforward

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protective of human health and the environment, the principal mission of EPA. Such metrics also

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encourage evaluation of damage from collective sources, as long as the characterization metric

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used is genuinely representative of the impact of a given contaminant. Thus, for example, the

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total impact of acidic gases such as sulfur dioxide (SO_2) and NO_x on the acidification of

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watersheds can be expressed as a common metric.

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causative contaminant emissions. It

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or the corresponding causative functions (e.g. categories such as climate change,

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nutrient cycling, and food production)

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The committee makes three over-arching recommendations:

Recommendation A. *EPA should pursue an integrated approach to develop the understanding necessary for science-based policies, regulations, and incentives to avoid and remediate the impacts of excess Nr on the environmental, human health, and climate. Such integration must cut across media (air, land, and water), Nr form (oxidized and reduced), federal agencies, and existing legislative statutes [e.g., EISA – Energy Independence and Security Act (EISA), the Clean Air Act, and the Water Quality Act (CWA)].*

Recommendation B. *EPA should form an Intra-agency Task Force on Managing Nr that builds upon existing Nr efforts within the Agency. The task force would identify the most cost-effective approaches to avoid the negative impacts of Nr loads cascading through the environment. These loads pose a significant threat to human health and environmental quality and directly affects climate change*

Recommendation C. *The federal government should form an Inter-agency Task Force on Managing Nr be formed, with EPA as the lead agency that includes at a minimum U.S. Department of Agriculture (USDA), U.S. Department of Energy (DOE), U.S. Department of Transportation (DOT), National Oceanic and Atmospheric Administration (NOAA), and U.S. Geological Survey (USGS). This Task Force would coordinate federal*

programs that address Nr concerns and help ensure clear responsibilities for monitoring, modeling, researching, and regulating Nr in the environment.

The task forces should take a systems approach to science and research by:

• evaluating critical loads
• Nr budgets and life cycle accounting
• monitoring as the basis for informed policies, regulations, and incentive frameworks for addressing excess Nr loads
• development and use of systemic models for Nr management; new technologies; fertilizer and nutrient best management practices (BMPs)
• development of Nr indicators necessary for the assessment of effects related to excess Nr on human health and the environment
• assessing combined carbon (C) and N effects
• addressing indicators/endpoints, costs, benefits and risks associated with the impairment of human health and decline and restoration of ecosystem services
• investigating the need for new regulations
• new education, outreach, and communication initiatives
• implementing economic incentives, particularly those that integrate air,

aquatic, and land sources of Nr

- new infrastructures for managing Nr releases to the environment
- review of enabling legislation for purposes of extending regulatory authority or streamlining procedures for enacting Nr risk reduction strategies.