CROSS-EPA EFFORTS ON REACTIVE NITROGEN AND CO-POLLUTANTS: SCIENCE TO INFORM ACTION

August 31 – September 2, 2016
Research Triangle Park, North Carolina

MEETING SUMMARY

October 7, 2016

Submitted to:
U.S. Environmental Protection Agency
Office of Research and Development

Prepared by:
ICF
Durham, North Carolina

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EXECUTIVE SUMMARY

The 2016 *Cross-EPA Effort on Reactive Nitrogen and Co-Pollutants: Science to Inform Action* Workshop was held on August 31 – September 2, 2016 in Research Triangle Park, North Carolina. The purpose of the workshop was to build upon the Science Advisory Board (SAB) Integrated Nitrogen Committee (INC) recommendations and the Cross-EPA Nitrogen and Co-Pollutant Research Roadmap for greater intra-agency interaction to break down media-based or disciplinary barriers.

The workshop brought together more than 70 United States (US) Environmental Protection Agency (EPA) scientists in the Safe and Sustainable Water Resources (SSWR), Air Climate and Energy (ACE), Sustainable and Healthy Communities (SHC), and Human Health Risk Assessment (HHRA) research programs.

The first day of the workshop began with a plenary session outlining the Cross-EPA Nitrogen and Co-Pollutant Research Roadmap, followed by program office perspectives on the need for intra-agency coordination of nutrient science and management. Scientists from the Office of Research and Development (ORD) and other program offices presented their work through a series of "lightning talks".

On Day 2, the discussion focused on the intra-agency challenges and how to better connect program offices to regional needs. Key scientists from other agencies and universities were invited to provide lessons learned to illustrate how EPA nitrogen research could better link with other nitrogen research efforts. The second day concluded with parallel breakout groups to discuss a series of proposed questions to identify and address science gaps and ways to foster collaboration across the EPA and other agencies. Workshop participants were divided into three discussion groups for each topic: Sources and Fate/Transport, Effects, and Integration. The breakout groups reconvened to share their findings.

On Day 3, panel members from various program offices discussed ways to connect the research to the program offices. A question and answer session between the conference participants and the speaker panel followed the presentations. To conclude, participants discussed next steps and revisions to the Roadmap to incorporate new ideas and implement relevant issues in advance of the Fiscal Year (FY) 2016/2017 Board of Scientific Counselors (BOSC) review.

Each breakout group provided specific gaps in the Nitrogen Cascade framework, gaps in scientific knowledge, and roadblocks to integration. As a group, the workshop participants identified the following emerging areas of research to prioritize:

- Linkages between nutrients and HABs (especially cyanobacteria)
- Interactions between nutrients and climate
- Understanding of biodiversity and biogeochemical cycle feedbacks between nutrients and climate
- Integrated approaches that allow decision-makers to make trade-offs (regulatory, voluntary, incentives, markets, etc.)
- Dose-response functions for ecological endpoints and ecosystem services

- Measurement Model Fusion—using an integrated approach for data fusion
- Integration of monitoring across media—air/water/soil
- Attention to issues of scale—national, regional, local; right model for the right scale

While the Nitrogen & Co-Pollutant Research Roadmap is a tool to foster integration, participants identified the need to improve internal communication. Recommendations included:

- Face-to-Face meetings, at a minimum annually are needed
- Meetings/Research Seminars—quarterly around a topic/issue
- Monthly update "newsletter"

Additional details are provided in the remainder of the report. The workshop agenda (Appendix A) and a list of workshop participants (Appendix B) are also included.

ABBREVIATIONS

ACE – Air, Climate and Energy Research Program

BMPs – best management practices

BOSC – Board of Scientific Counselors

CAA – Clean Air Act

CAFOs – Concentrated Animal Feeding Operations

CAMD – Clean Air Markets Division

CGEM – Coastal Generalized Ecosystem Model

CWA – Clean Water Act

EPIC – Environmental Policy Integrated Climate

FY – Fiscal Year

HAB – harmful algal bloom

HHRA – Human Health Risk Assessment

IOAA – Immediate Office of the Assistant Administrator

ISA – Integrated Science Assessment

LCA – life cycle assessment

MARGA - Monitor for AeRosols and GAses in ambient air

N – nitrogen

Nr – reactive nitrogen

NAAQS – National Ambient Air Quality Standards

NASA – National Aeronautics and Space Administration

NCEA – National Center for Environmental Assessment

NCER – National Center for Environmental Research

NERL – National Exposure Research Laboratory

NHEERL – National Health and Environmental Effects Research Laboratory

NOAA – National Oceanic and Atmospheric Administration

NOx – nitrogen oxide

NPS – National Park Service

NRMRL – National Risk Management Research Laboratory

NRSA – National Rivers and Streams Assessment

OAQPS – Office of Air Quality Planning and Standards

OAR – Office of Air and Radiation

OGWDW – Office of Ground Water and Drinking Water

OP – Office of Policy

ORD – Office of Research and Development

OST – Office of Science and Technology

OW – Office of Water

P – phosphorus

PACT – Partner Alliance and Coordination Team

PI – principal investigator

RARE – Regional Applied Research Effort

RfP – Request for Proposal

RMS – Research Management System

S – sulfur

SAB – Science Advisory Board

SDWA – Safe Drinking Water Act

SETAC – Society of Environmental Toxicology and Chemistry

SHC – Sustainable and Health Communities

SOT – Society of Toxicology

SOx – sulfur oxide

SSWR – Safe and Sustainable Water Resources

STAR – Science To Achieve Results

StRAP – Strategic Research Action Plan

SWAT – Soil and Water Assessment Tool

SWAT-CUP – SWAT-Calibration and Uncertainty Program

SWMM – Stormwater Management Model

TDEP – total deposition

US EPA – United States Environmental Protection Agency

USDA – United States Department of Agriculture

USFS – United States Forest Service

USGS – United States Geological Survey

VELMA – Visualizing Ecosystem Land Management Assessments

WERF – Water Environment and Reuse Foundation

WQT – water quality trading

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INTRODUCTION

Nitrogen is an essential nutrient that is used in agriculture and energy production, but excess nitrogen leads to air and water quality degradation. In August 2011, the United States (US) Environmental Protection Agency (EPA) Science Advisory Board's (SAB) Integrated Nitrogen Committee (INC) released the report *Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, Consequences, and Management Options*. The SAB made several research and management recommendations, including taking an integrated approach to the management of reactive nitrogen (Nr), forming an intra-Agency task force to build on the existing research and management capabilities within EPA, and working with other Agencies and departments outside of EPA to manage Nr more effectively and efficiently.

In response, the EPA developed the cross-EPA Nitrogen & Co-Pollutant Research Roadmap (henceforth "Roadmap"). As part of this process, the *Cross-EPA Efforts on Reactive Nitrogen and Co-Pollutants* workshop was held on August 31 – September 2, 2016 in Research Triangle Park, North Carolina. The main purpose of this workshop was to provide an opportunity for EPA scientists working on similar issues in different labs and offices to meet, share their research, and build Office of Research and Development (ORD) and program collaborations. EPA scientists working on nutrient research from across the Agency were in attendance. The Safe and Sustainable Water Resources (SSWR), Air Climate and Energy (ACE), Sustainable and Healthy Communities (SHC), and Human Health Risk Assessment (HHRA) research programs were represented, as well as program office staff in Office of Water (OW) and Office of Air and Radiation (OAR).

The workshop was purposefully scheduled early in the research planning cycle (2016-2019) to provide EPA scientists in the initial stages of their research the opportunity to learn about related work and identify areas of coordination and collaboration across EPA. The workshop enabled EPA project investigators and program scientists to present the work they are planning or conducting in their tasks (Day 1) and also fostered discussion in particular focal areas (Day 2), such as systems modeling, water quality trading, ecosystem services, research integration, and communication. Day 3 included a panel discussion to connect program office and regional needs and provide recommendations for the implementation of the Cross-EPA Nitrogen and Co-Pollutant Research Roadmap.

This report summarizes presentations and panel discussions from the workshop. The technical content of this report is based entirely on information and discussions from the workshop. This report is organized according to the workshop agenda, which is included in Appendix A. A list of registered participants can be found in Appendix B.

DAY 1: Wednesday August 31, 2016

THE NEED FOR INTRA-AGENCY COORDINATION ON NUTRIENT SCIENCE AND MANAGEMENT

Reactive Nitrogen in the United States: An Analysis of the Inputs, Flows, Consequences, and Management Options – A Report of the EPA Science Advisory Board

Jana Compton (ORD/NHEERL)

Dr. Jana Compton provided an overview of the US EPA SAB report on Nr in the United States, describing it as a good management and scientific framework to identify research gaps and policy areas that has been used by multiple organizations. Nr is considered a "wicked" problem because of its complexity, and necessitates a detailed framework for successful management. Nr provides essential benefits to the human population as a fertilizer for food production, but excess Nr in the environment can cause numerous issues, including many large-scale environmental concerns (e.g., hypoxia, acid rain, smog, global warming) as well as human health impacts (e.g., respiratory and cardiovascular issues and skin cancer). Thus it is necessary to balance the need for Nr with the environmental and social costs of excess Nr. The SAB report was created to provide advice to EPA from a scientific perspective on managing the numerous problems caused by Nr. Specifically, the SAB report recommended using the movement of nitrogen among environmental reservoirs in multiple ecosystems and media, also referred to as the Nitrogen Cascade (see Figure 1 below), as a framework for understanding and more effectively managing Nr.

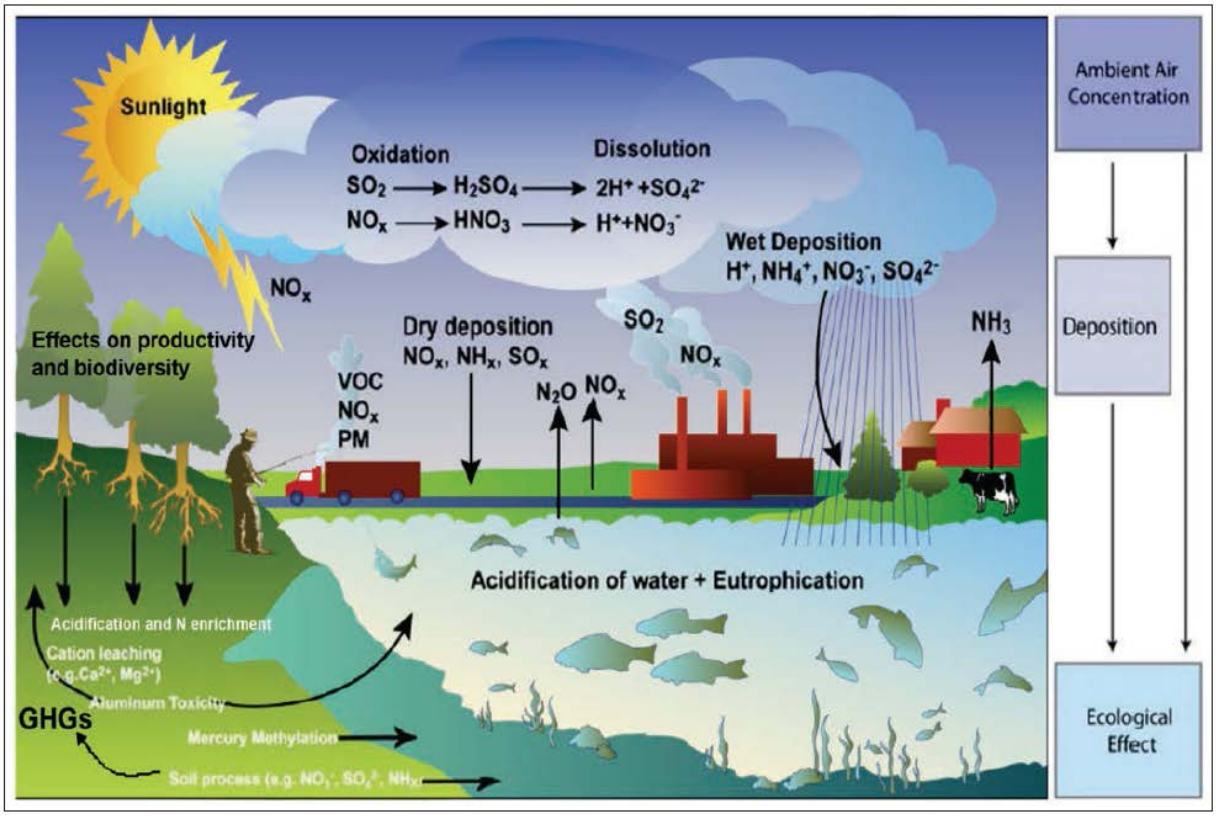

Figure 1. Simplified diagram of the ecological effects caused by nitrogen and sulfur air pollution (Greaver et al., 2013).

The SAB proposed integrated cross-media management approaches and regulatory structures to recognize tradeoffs and focus management efforts at points of the Nitrogen Cascade where they are most efficient and cost-effective. They also proposed that inter- and intra-EPA task forces should be assembled to accomplish this. To better inform decision-making, several research and data needs were identified, including research on management strategies; agricultural data; the nitrogen (N) budget; and measurement, monitoring, and modeling approaches. Finally, the SAB emphasized the importance of educating the public on the problem of excess Nr in order to build support for Nr management. If action is taken by EPA and other management authorities, the SAB estimated that a 25% reduction in Nr introduced into the environment could be achieved with existing technologies in the next 10-20 years. Dr. Compton stated this workshop was a result of these recommendations, and urged continued collaborative effort.

Discussion and Q&A

- **Jim Hagy** stated that the report looks at sources of Nr introduced into the United States in 2002 and asked what has changed since then (e.g., new emissions standards for vehicles, increase in fracking, shift from coal to natural gas, etc.). **Jana Compton** said that she believed air levels have gone down, but fertilizer inputs have stayed level; overall there have been little shifts. **Randy Waite** commented that nitrogen oxide (NO_x) emissions have gone down while ammonia has leveled off, as best as they know. Thus ammonia as a component of total N has increased in importance.
- **Jana Compton** mentioned that they attempted an estimate of total N input (by redoing the SAB report's pie chart) at the US Department of Agriculture (USDA) meeting, but were unable to do it quickly or accurately. One of the roadblocks was the availability of current data on agricultural inputs, primarily the fertilizer and biological N fixation.

The Need for Intra-Agency Coordination on Nutrient Science and Management: An OW Perspective
Mary Reiley (OW/OST)

Ms. Mary Reiley explained that nutrients—where they come from, where they go, how much is too much, how to get rid of them—are a top-tier priority for OW. She stated the need for cross-office research and collaboration in the following areas:

- Exacerbated impacts on aquatic life and human health,
- Land-based and air-based non-point source loading,
- Fate and transport,
- Contributions of that to impaired water designations, and
- Proper management of source water.

Additional issues include the numeric nutrient criteria for protection of aquatic life; indicator species and biomeasures for early warnings of pollution problems; the connection between nutrients and harmful algal blooms (HABs); the contribution of nutrient loading to HABs that cause impacts to recreational use, livestock, and wildlife; and modeling to inform nutrient loading reduction alternatives. One big question going into the Roadmap was whether or not best management practices (BMPs) technologically capable of removing a certain amount of nutrients are actually observing that return when they are put into place in the field. How can they be placed to maximize

that return, and how can infield uses be managed? Ms. Reiley discussed the need for public communication and stakeholder involvement in the area of the economics of nutrients, and the costs and benefits of different options (removal, treatment, reuse, no action, etc.).

Discussion and Q&A

- **Walt Nelson** asked **Mary Reiley** to comment on OW's biggest priority. **Mary Reiley** stated the need to put their programs out there in a way that will ensure states implement nutrient reductions (dealing with technology issues and affordability); recreational criteria for toxins from HABs; and optimization techniques or innovative technology that can be promoted to utilities to encourage them to take on the reductions needed to return water to their designated uses.

OAR Perspective

Randy Waite (OAR/OAQPS)

Mr. Randy Waite reviewed OAR's program needs for N and sulfur (S) research: support for reviews of secondary National Ambient Air Quality Standards (NAAQS), support for tracking progress from implementation of rules and standards, and inputs and methods for calculating benefits of improvements in ecosystems for use in regulatory impact analyses. He also discussed some of the ecosystem impacts from air pollution like NO_x, sulfur oxide (SO_x), and mercury deposition, including acidification of streams, lakes, and forests; eutrophication of wetlands, streams, lakes, forests, fields, and deserts; methylation of mercury in streams and lakes; and phytotoxic effects on trees and plants. Mr. Waite identified four categories of OAR's research needs:

1. Exposure characterization – improving modeling, measuring, and monitoring methods
2. Dose-response relationships – collecting data to improve existing models
3. Ecosystem services –communicating the value of these needs to the public
4. National assessments – ensuring local tools are scalable to national level

Mr. Waite also provided examples of specific OAR research priorities to improve modeling of ecosystem exposures and service changes and to develop cost-effective strategies to monitor long-term changes to ecosystems. He reviewed some current research efforts, and emphasized the importance of collaborating with other organizations (such as United States Geological Survey (USGS), United States Forest Service (USFS), and National Park Service (NPS)) to achieve research goals. For example, OAR is collaborating with USGS to assess the impact of S deposition on mercury methylation in air-dominated waterbodies. He stated that OAR supports continued work on N and S deposition, and hopes for continued collaboration throughout these research efforts.

Discussion and Q&A

- **Jason Lynch** recommended adding forests to the research priorities due to the number of cooperative projects that exist. He emphasized the need for climate-change research in interaction with Nr. This is based on a discussion about forest indicators from an internal meeting where the Climate Change Division presented their indicators. He emphasized that one of the large contributions of OAR/Clean Air Markets Division (CAMD) is to air monitoring

and the work needed to understand total N. Projects examining total deposition (TDEP) in concert with other organizations are ongoing.

- **Rick Greene** asked if the effort to nationally assess the impact of Nr deposition on estuaries, lakes, rivers, and isolated wetlands was collaborative with OW and ORD. **Randy Waite** said at this point it is just funding a conceptual approach, and he could talk more about it later to anyone interested.
- **A participant** asked about air-dominated waterbodies. **Randy Waite** answered that USGS said that the S-load to the waterbody was mostly from air (vs. land), which is important in determining where to focus a management approach.

Regional Perspective

Carole Braverman (Region 5)

Dr. Carole Braverman emphasized the importance of working together and shared two examples of projects that highlight collaborative efforts:

1. Region 8 Regional Applied Research Effort (RARE) project is a collaboration between Region 5, ORD, NPS, Colorado, universities, etc. The ORD lead is John Walker. This project is focused on air and regional ammonia sources and transport in Rocky Mountain National Park. The focus is on N deposition and the identification of BMPs to reduce ammonia emissions in the area.
2. In a collaboration funded by OW, last April, a Region 5 HAB-Clean Water Act (CWA)-Safe Drinking Water Act (SDWA) Workshop was held that brought together groups (ORD, multi-state agencies, etc.) to discuss water issues. Dr. Braverman emphasized that nutrients are a high priority to the regions; for example, the nutrient, phosphorus (P) is driving many issues in the Great Lakes.

Due to the volume of work that is being conducted in this area, Dr. Braverman stressed the importance of sharing information with other offices.

Discussion and Q&A

- **Amy Shields** asked **Carole Braverman** the best method to share ideas for projects with OAR and ORD and inform them of the important issues to her region. **Carole Braverman** explained two ways: the RARE program for high-priority issues, which is competitive but Region 5 has funded several projects that way, and SSWR and other ORD research programs that involve the regions in the research as it is undertaken. There are a number of partner and alliance coordination teams. For example at SSWR there is research related to HABs and green infrastructure. Regions often go through science councils to address the regional needs before developing research programs.

Cross-ORD N Perspective and Roadmap Context

Anne Rea (ORD/IOAA)

Dr. Anne Rea explained that the Roadmap is a cross-cutting research initiative to bring together research programs to address "wicked" problems – those problems difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often challenging to

recognize. Roadmaps describe intra-agency (across EPA programs) and inter-agency (across federal institutions and other partners) collaboration and integration efforts. For the Nitrogen Roadmap, ORD realized they could not do it alone, so they made other program offices co-leads and brought in other agencies (USDA, USGS, etc.). She explained that nutrients are mission-critical and pose a problem that EPA is uniquely positioned to help solve. Through collaboration, EPA can start to reduce nutrient loading across air, land, and water. N management involves multiple media, research and work by multiple agencies, and management interventions at multiple points in the Nitrogen Cascade. In the Roadmap, the overarching outcome (ultimate goal) and outputs (specific research products) are linked to six science challenges, each of which is structured with specific defined sub-outcomes and sub-outputs. ORD conducted a gap analysis to make recommendations for a strategic research action plan (StRAP). The six science challenges are:

1. Where should we target reductions in nitrogen and co-pollutant loads?
2. How do we set nitrogen and co-pollutant reduction goals for priority areas?
3. What's in our toolbox to manage and reduce nitrogen and co-pollutant loads and does it work?
4. What are some new, innovative approaches we haven't tried before?
5. Are we getting the reductions and ecosystem and human health benefits we expect?
6. How do we best maintain intra-office accountability, assess progress, and communicate results to the public?

To develop the Roadmap, ORD analyzed the policy, science, and regulatory basis for management actions, as well as the scientific basis for N and co-pollutant management. Over 100 recommendations came out of the discussion; ORD tried to place them in the research program or program office best suited to address it. The main research areas were models, technologies and tools, BMPs, and cross-ORD/OW/OAR research (for recommendations that did not apply to one research program, e.g. impact of climate change on N and co-pollutants). Dr. Rea provided some examples of N and co-pollutant related research that informs EPA decision-making, as well as an example of how ORD took an issue (nutrient enhanced coastal acidification) and fully integrated it into a research project. In terms of moving beyond the Roadmap, she said they were able to get some research recommendations into FY16-19 StRAPs, and have been responsive to SAB, program office, regional, and state needs. Sound research integration needs to inform management decisions. She concluded by posing the following considerations: How can the Roadmap be used to their benefit? What does and doesn't work? How can it be better? What are some approaches to inform science-based management, strengthen collaborations, improve communications, and identify alternative approaches to integrative management?

Overview of ORD Nr and Co-pollutant Portfolio: Draft Analysis

Chris Clark (ORD/NCEA)

Dr. Chris Clark provided an overview of a draft approach to understand the portfolio of research that already exists for aspects of the Nr problem and how that research may or may not intersect with other agency activities. This project was initiated after a June 2014, three-agency (EPA, USDA, USGS) workshop on coordinating Nr research and management activities. Due to differences in reporting requirements, accessibility, and retrospective and prospective datasets, the data across agencies was difficult to compile and compare. At the end of the process they decided to take a step back and

develop a common prospective database for EPA and USDA on Nr activities from the ground up. They assessed the potential datasets from each of the three agencies and settled on full Research Management System (RMS) project plans for EPA and the Research, Education, and Economics Information System database for USDA. USGS input is still pending. They examined various ways to analyze converted files (from Word to csv) and ultimately selected Pushgraph. Later they will use QDA Miner Lite for advanced qualitative analytics.

In the future they would like to pull together all the project plans to answer questions about a number of different studies, but for now they are looking only at the N subset. Currently, there are 3 national programs, 34 RMS projects, 76 RMS tasks, and 33 different project leads in the EPA/ORD/Nr database. Information can be divided by concept, national program, and other clustering options. Dr. Clark explained that there is a lot of proximity between different projects in different national programs. He provided an example related to drinking water and showed how the task description, principal investigator (PI), and other information is available for each project. The database also shows related projects and their respective PIs, to facilitate identification of and connection with potential colleagues. Dr. Clark highlighted the ability to use the database to identify topical areas with more emphasis, which can help inform discussions of whether that allocation is appropriate. Next steps include: cleaning up the database to make queries more user-friendly, refining the concepts to make them more meaningful, reviewing the Pushgraph documentation to better understand how it works, incorporating activities from other parts of ORD and other groups, and expanding the database to include all project plans.

Discussion and Q&A

- **A participant** asked how the topical areas are identified. **Chris Clark** said the user defines the clusters and that it is a critical step to determine the number of clusters that gives meaning to the portfolio. It is something they are currently figuring out, and they are using 20 for now.
- **Tara Greaver** pointed out that within HHRA, the Integrated Science Assessments (ISAs) are the project, which is mixing N and non-N research, so she agreed it was challenging. **Chris Clark** said the benefit of pulling in all the project plans allowed them to score tasks based on how frequently a word shows up, which presumably is somehow related to the emphasis.
- **A participant** asked if they had thought about using a Request for Proposal (RfP) instead of mining RMS. **Chris Clark** agreed, but said the challenge with an RfP is that they are susceptible to participation; if there is a group that is more participatory than another, there will be disproportionate representation. Thus it is safer to go with RMS.
- **A participant** asked if there was a way to identify if the Roadmap actually does what was intended. **Chris Clark** said that the Roadmap identifies projects and tasks, but that is not in the database yet. Once it is, they can see what areas of the ORD portfolio are integrated or not.
- **Jim Hagy** said that when he and others developed project plans, **Anne Rea** provided a list of research needs from the Roadmap, so many of them cited specific needs of the Roadmap in their plans. He asked if they had opened up project plans and searched for "N Roadmap." **Chris Clark** said that all of the research questions are included, so if a project addresses a research question, the project description should be referenced. **Anne Rea** explained that

was why she asked for cross-references to the Roadmap in as many places as possible, because they will need to capture that at some point.

- **Blake Schaeffer** recommended Mindmapper as a good tool. One can put in the Roadmap and do some descriptive mindmaps. **Chris Clark** said he would like to talk with **Blake Schaeffer** about it.

NITROGEN AND CO-POLLUTANT RESEARCH IN THE ORD RESEARCH PROGRAMS AND PROGRAM OFFICES

Presenters gave 3-5 minute "lightning talks" to introduce current research initiatives and projects in the ORD Research Programs and Programs Offices.

SOURCES/INPUTS

USA Nr Inventory: Sources and Fates of Nr Throughout the USA

Robert Sabo (ORD/NCEA)

Mr. Robert Sabo described the ongoing initiative to create a standardized quantitative description of Nr sources and fluxes throughout the United States by compiling high resolution current datasets to inform trends analyses in N sources, identify drivers of water and air-quality improvement, and facilitate policy planning and research prioritization. This is an ongoing compilation; the ultimate goal is to have an applied database that can be used to identify primary sources.

Nitrogen Cascade Research: Air Inputs

Donna Schwede (ORD/NERL)

Ms. Donna Schwede explained that one research challenge for ORD is to understand the different sources of N and how they are deposited, known as the Nitrogen Deposition budget. She reviewed some recent trends in the budget: overall N deposition has decreased due to air quality standards, and the ratio of oxidized to reduced N deposition is changing. ORD research is focusing on uncertainties in deposition estimates including deposition processes, atmospheric chemistry, and meteorology. She explained that the ammonia/NO_x bi-directional exchange model is used for modeling N exchange between the atmosphere and biosphere. She also said that organic N has been a focus area for ORD, as it accounts for about 25% of the N budget. Finally she discussed lightning data assimilation, which has important implications for N deposition estimates.

Discussion and Q&A

- **Scot Hagerthey** asked if one of the goals of the Roadmap is to report effectiveness of actions and expectations, because if methods are different from year to year, one can't compare across years. As a result, the ability to assess effectiveness drops dramatically. He said it may be something **Robert Sabo** would want to address.
- **Blake Schaeffer** asked if the inventory contains data from an annual basis. **Robert Sabo** said the inventory was for every 5 years.
- **Donna Schwede** clarified that the TDEP map was from the TDEP science committee.
- **Mario Sengco** asked if **Robert Sabo** included any state information. **Robert Sabo** said one of the fluxes will be wastewater discharge, and that the team has contacts in USGS who will provide surface water data across the US, which will be included in Phase II.

- **Heather Golden** asked how the updated inventory is more process based. **Robert Sabo** said the TDEP map is based on harvested N.

FATE/TRANSPORT

Addressing Uncertainties in the Watershed System for Viable Water Quality Trading Approaches

Chris Nietch (ORD/NRMRL)

Dr. Chris Nietch explained that his focus is on the biophysical and scientific uncertainty currently limiting the viability of water quality trading (WQT). A variety of tools are used, including the Soil and Water Assessment Tool (SWAT), which is a common watershed model capable of simulating a diversity of crop types and management options, as well as the SWAT-Calibration and Uncertainty Program (CUP) and the Stormwater Management Model (SWMM). They use hydrologic response units, which are unique combinations of land use, soils, and slope with the models. While nutrient modeling in SWAT is complex, it is still a crude representation of what is actually happening in the environment. WQT feasibility analyses make cost-effectiveness comparisons among supply and demand for nutrient credits.

Management Practices Research, Analysis of NARS Data, Communication and Outreach Work

Jana Compton (ORD/NHEERL)

Dr. Jana Compton discussed the SSWR 4.03 Task C: "Monitoring and multimedia modeling approaches for verifying reduction," led by Yongping Yuan. She reviewed a paper by Bellmore et al. (currently in EPA review) that examined N inputs to National Rivers and Streams Assessment (NRSA) watersheds, and showed a graph displaying how N sources vary in intensity and spatially across the United States. She explained that regardless of the form of N (total, dissolved inorganic, etc.), N inputs drive concentrations. She then described the Partnership to Improve Nutrient Efficiency, a project to set the social and management stage for water quality improvements in the Southern Willamette Valley involving multiple stakeholders (farmers, state government, etc.). It involves collecting soil and water data, sharing it with farmers, and helping them adjust their management practices based on that data. So far it has been very successful.

Cyanobacteria Assessment Network

Blake Schaeffer (ORD/NERL)

Dr. Blake Schaeffer reviewed the following aspects of the Cyanobacteria Assessment Network:

- **Problem:** How to support the environmental management and public use of US waters by monitoring HABs and related water quality using satellites?
- **Opportunity:** Cyanobacteria, chlorophyll-a, turbidity, and temperature indicators can be monitored with satellites.
- **Approach:** Strengthen EPA, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and USGS cross-agency research to mainstream satellite capabilities for water quality management decisions.
- **Results:** New methods to quantify frequency of occurrence and spatial extent of cyanobacteria HABs.

- **Impact:** Scalable information across any geo-political boundary. Potential to prioritize locations for management actions.

Discussion and Q&A

- **Amy Shields** stated that the issue of manure management (the inability to understand manure inputs and inter-state transfers) is a huge priority, especially in Region 7. She asked if those are included in NRSA data. **Jana Compton** replied that manure was included in the NRSA analysis, inputs were generated from Concentrated Animal Feeding Operations (CAFOs); however, it is unclear how it is applied to the landscape. States probably have a better understanding of it, and a suitable approach would be to work directly with Departments of Agriculture for each state. **Amy Shields** replied that states are uncertain too.
- **Jim Hagy** inquired about WQT.

EFFECTS AND BENEFITS

OST/HECD Efforts to Address Nutrient Pollution and Harmful Algal Blooms

Dana Thomas (OW/OST)

Dr. Dana Thomas reviewed the national scope of the nutrient problem and some of the recent algal bloom incidents that have made the news. Media coverage has made the public more interested and aware, helping to steer the conversation toward public health effects of nutrient pollution. EPA is currently developing new recreational water quality criteria, and a model to link total N and total P concentrations to adverse effects. They are linking numeric nutrient criteria recommendations to adverse effects for three designated uses (i.e., source drinking water, recreation, and aquatic life), defining classes of lakes using statistical methods, and using National Lakes Assessment data to derive criteria for each lake class. Next steps include outreach to states and other stakeholders on these approaches, and continuing to develop criteria and advisories.

Integrated Science Assessment for Nitrogen and Sulfur Oxides (NOx and SOx ISA)

Tara Greaver (ORD/NCEA)

Dr. Tara Greaver provided some background information on NAAQS and ISAs. She explained that EPA is currently reviewing the secondary NAAQS for NO_x and sulfur oxides SO_x together, including the atmospheric science and ecological effects of gas-phase NO_x and SO_x and N and S deposition. Approximately 3,500 publications are included. The first draft of the ISA is targeted for public release in January 2017.

Quantifying Effects of Nitrogen and Co-Pollutants on Human and Aquatic Life Uses of Aquatic Ecosystems

Jim Hagy (ORD/NHEERL)

Dr. Jim Hagy emphasized that sensitive, specific, and meaningful ways to monitor and communicate nutrient effects are needed in order to better motivate, inform, and update nutrient management. He reviewed a strategy using a Sediment Profile Imager to assess benthic community status. He also explained “metabarcoding” for bio-indicators, which can be used to characterize algal, microbial, and faunal community composition and evaluate nutrient sensitivity and tolerance. He discussed the ongoing nutrient reduction tracking in Narragansett Bay. He emphasized that better data is needed

to understand how systems change, as fully documented ecosystem responses to nutrient-driven degradation and recovery are uncommon.

Human Health Effects Associated with Exposure to Toxic Cyanobacteria

Elizabeth Hilborn (ORD/NHEERL)

Dr. Elizabeth Hilborn explained that there are multiple sources of human exposure to toxic cyanobacteria (e.g., drinking water, recreational water, hemodialysis treatment); however only two of them, surface water and hemodialysis treatment, have been documented to result in adverse human health effects. The other categories are theoretical risks. There are a range of illnesses associated with cyanotoxins, and there are documented incidents of death resulting from exposure. Illnesses are being reported more frequently as awareness is increasing. Currently no diagnostic test for cyanobacteria-associated illness exists, so cases cannot be accurately confirmed.

N Deposition Effects on Terrestrial Systems

Chris Clark (ORD/NCEA)

Dr. Chris Clark reviewed the current portfolio of projects, which have been divided into "hard" and "soft" research. Hard research projects include determining new species-level critical loads, dynamic modeling, estimating of soil-base cation weathering, estimating "future forests", and integrating carbon-nitrogen. Soft research includes the development of an online "CL Mapper Tool" and a three-volume "Guide of Species Sensitive to N deposition." Next steps include integrating multiple critical loads in the National Critical Loads Database, combining apportionment with the database to assess full effects of an example point source or class of sources, and reviewing strategies for remediation.

National Water Quality Benefits: A Three-Office Effort

Matt Heberling (ORD/NRMRL)

Dr. Matt Heberling explained that EPA is seeking to improve its ability to value the full range of benefits of rules under the Clean Water Act. ORD, Office of Policy (OP), and OW formed a team of economists, ecologists, and water quality modelers to develop a national water quality benefits framework beyond just nutrients. There is ongoing intramural and extramural research made available through Science To Achieve Results (STAR) grants.

SYSTEMS MODELING

Nitrogen Cascade Research and Systems Modeling: N and P Landscape Inputs

Ellen Cooter (ORD/NERL)

Dr. Ellen Cooter explained they are estimating regional-to-national scale N and P terrestrial inputs using a systems modeling approach. A variety of tools, including Visualizing Ecosystem Land Management Assessments (VELMA), Environmental Policy Integrated Climate (EPIC), and SWAT are being used. Ongoing model development activities include expanding to unmanaged forest ecosystems, improving vegetation data layer, including a more complete climate and carbon dioxide change response, and expanding spatially to northern Mexico and southern Canada.

Multimedia Modeling of Nutrient Response and Recovery in Coastal Ecosystems

Jim Hagy (ORD/NHEERL)

Dr. Jim Hagy reviewed the ecological endpoints, drivers, ecosystems, and models of interest and explained the objective was to evaluate nutrient load vs. response for strategic planning and communication or regulatory actions. The Coastal Generalized Ecosystem Model (CGEM) is used to simulate nutrient load reductions and climate change scenarios. He discussed the model's performance and sensitivity, and explained that they are hoping to apply it around the country.

DAY 2: Thursday September 1, 2016

INTRA-AGENCY CHALLENGES PANEL DISCUSSION: CONNECTING PROGRAM OFFICE AND REGIONAL NEEDS TO ORD RESEARCH ON N AND CO-POLLUTANTS

Moderator: Richard Lowrance (ORD/NRMRL)
Each group provided an overview of their office, a description of projects they are currently engaged in, and addressed the questions: what science is missing, and how can we better connect to OAR/OW/ Regional needs?

OAR Connections
Bryan Hubbell (OAR/OAQPS), Jason Lynch (OAR/CAMD)

Dr. Jason Lynch discussed the purpose of CAMD, which runs the NO_x and SO_x program, and explained the many levels of monitoring:

- Air emissions and the ecological aspects (both ecological and depositional effects),
- Monitoring of stack level NO_x and SO_x (a rich data set exists),
- Air concentrations and connection to National Atmospheric Program, and
- Monitoring streams and lakes via the long term monitoring program.

He proposed four ways to better connect the research to OAR needs:

1. Direct measurements of dry deposition
2. Ecosystem services
3. Understanding ecological change and loading and at what level of loading
4. Climate change indicators

He stated the best method to connect research needs is to establish the individual connection to researchers and work together to come up with solutions. He provided some examples of teams coming up with TDEP maps, use of the Monitor for AeRosols and GAses in ambient air (MARGA) to measure deposition, and work with critical loads. The main issue is to learn how to connect across agencies. His recommendation is to think broadly but act locally around an issue; complex issues become less complex when a group is formed. ORD can help to bridge those gaps.

Dr. Bryan Hubbell serves as the science advisor for the Health and Environmental Impacts Division. He briefly described the current focus of programs within in his office including: climate policies, air quality analysis, and implementation.

He focused on integrated science, risk and policy assessment for secondary standards for NO_x and SO_x. The release date for the ISA is in January 2017 and Dr. Hubbell encouraged authors of research articles to get published in time for use in the report.

He addressed the following research needs during the development of the risk assessment:

- Addressing the amount of data and modeling information has expanded, so there is more to address.

- Accessing the strength of the science examining ecosystem services.
- Addressing the importance of scaling information to make broader statements on a regional and national level.
- Understanding critical loads and load response functions to reduce emissions for ecological effects.
- Recognizing the asymmetry in responses and effects of seasonal patterns.
- Addressing the impact of air loadings and how to attribute baseline effects, especially when dealing with coastal waters.
- Compiling current research efforts, quantitatively and qualitatively, to get a nationwide perspective.

He agreed that bringing together groups and holding meetings is important to help them understand that there are synergies. He also pointed out the need to start broadly to establish the contacts and then work down to the individual level.

OW Connections

Mary Reiley (OW/OST), Mario Sengco (OW/OST)

Ms. Mary Reiley focused on the need to fill the gaps and utilize more the ORD expertise to complete the skill mix and to respond to Nr jointly, within EPA and across the offices within ORD. She told the group that she will serve as the primary contact within OW, along with Ed Ohanian to help establish those connections.

Ms. Reiley introduced several individuals who can serve as contacts within OW for their respective subject expertise:

- Dana Thomas: biological criteria program,
- Meghann Niesen: HABs program at the role of nutrients,
- Mario Sengco: OST (Office of Science and Technology), Standards and Health Protection Division, nutrients and economics, and
- Nicole Tucker: drinking water program, human health and drinking water and infrastructure.

While not represented at this workshop, OW is actively working in other areas including wastewater, BMPs, climate and nutrients, and air deposition. Ms. Reiley emphasized the main idea is to supplement the skill sets across ORD, working together on areas, rather than have duplicate efforts. She stated the OW has begun the update of the “infamous color-coded spreadsheet” used to indicate which offices have requested the work. The update should be completed over the next 6 months.

Dr. Mario Sengco represented the Division of OST, Water Quality Standards Program. This program uses the developed criteria and works with the states to implement those standards, address questions towards implementation and expense, and assist with variances due economic impact. In addition to social and economic impacts, a controversial topic is that stricter guidelines might not be as beneficial as leaving it in place. He provided an example of a wealthy community in Colorado. A case was made that the upgrades to reverse osmosis would increase impacts to the environment, by causes higher energy cost and increase of sediments.

His office is collaborating on a project with Risk Management Research Lab, Sustainable Technology Division, to examine the benefits of lifecycle assessment (LCA). Working with a consulting company, they have also built an LCA model to look systematically and compare economic benefits of technologies. He stated that the focus is on the environmental impacts, as well as the fiscal effects. The next phase will be more involved than an LCA process, and will address the removal of additional pollutants (organics and heavy metals). He posed another issue: how do you consider all these potential issues (smog, eutrophication, greenhouse gas emissions, etc.) while integrating and weighing them appropriately for policy decision-making?

Ms. Katie Foreman provided some background on the drinking water connection and specific research needs, specifically the Office of Ground Water and Drinking Water (OGWDW) and their work centered on algal blooms and cyanotoxins in drinking water. A strategic plan has been created which focuses on the science behind cyanotoxins, particularly linking N and P loading to toxin production.

Discussion and Q&A

The following emerging issues and priorities were discussed:

- The need to consider agricultural-dominated systems, where non-point nutrient sources are 80-90% of the discharge.
- The scope of the LCA report is only within the boundaries of the treatment facility; currently the environment around the facility where it is being released is not being examined.
- In the realm of LCA, it is important to consider the Nr fixation as this would have a big implication of the results.
- ORD is starting an LCA Center for all of ORD in Cincinnati, OH. There will a team leader for the center and it will be a resource for this type of work.
- Trigger levels for nutrient levels for toxin production.
- Disinfection by-products and linking to algal and nutrient issues and learning about precursors, and regulations for disinfection by-products as they come into a water treatment plans.
- Source water protection actions and the effectiveness of small-scale models to help decision makers.

There was follow-up discussion regarding maps of source waters. Drinking Water (DW) maps is the newest viewer tool to delineate a source water protection area, which can be linked to a geographic information system. Vulnerability assessments are needed to discuss risk and prioritize areas that need more protections.

- **Jana Compton** said her office has the landscape and loading information and would like to combine efforts with OGWDW. **Blake Schaeffer** stated that they have the risk ranking for surface water intakes.
- **Carole Braverman** asked whether the Colorado the proposal a disincentive for using more environmental energy sources. **Mario Sengco** said that they are looking a different ratios of

energy sources and if local communities can show whether they are getting various energy sources from a renewable source they will be considered.

Regional Connections

Carole Braverman (Region 5)

Dr. Carole Braverman started the discussion by reiterating the need to reach out to help establish connections. **Ms. Wendy Drake** (OW/OGWDW) explained the need to better understand relative N pathways to waters of concern with more focus on studying N transportation via groundwater to nearby surface waters. She indicated an important gap in the science: "How much does it cost to make nutrient management changes rather than treat for nitrate?"

Other gaps include:

- How to reduce the amount of manure and fertilizer that is applied to soil to just the amount that is needed to grow crops.
- Tools to better assess which sources are contributing nitrate to contaminated wells.
- Development of standard lab methods (for co-contaminants) for microbial source tracking indicators.
- Information on the role of Nr in the development of algal toxins in the Great Lakes as well as in inland lakes and rivers.

National Center for Environmental Research (NCER) Nutrient Centers

Moderator: Ben Packard (ORD/NCER)

In 2013, the EPA Centers for Water Research on National Priorities Related to a Systems View of Nutrient Management were established to conduct water research and demonstration projects that are innovative and sustainable using a systems approach for nutrient management in the Nation's waters. Representatives from each of the four Centers provided an overview of the Center's activities.

Center for Comprehensive, OptimaL, and Effective Abatement of Nutrients (CLEAN): A System-Approach to Management of Nitrogen Pollution in Water Systems

Mazdak Arabi (Colorado State University)

Dr. Mazdak Arabi explained that the mission of the CLEAN center is to create knowledge, build capacity, forge collaboration, and develop and demonstrate sustainable solutions for the reduction of nutrient pollution. The Center has a wide range of partners including universities, cities, utilities, federal agencies, and EPA regions and offices. The themes of the Center are:

1. Understanding the physical system,
2. Understanding people and policy, and
3. Assessment and decision making.

Dr. Arabi also reviewed the details of a case study in Big Dry Creek.

National Center for Resource Recovery and Nutrient Management

Christine Radke and Lola Olabode (Water Environment and Reuse Foundation (WERF))

Ms. Christine Radke and Ms. Lola Olabode explained that the WERF Center's mission is to provide data, demonstrations, and tools to shift the water quality community to find solutions for resource recovery and reuse including nutrients, energy, and water. They reviewed several Center projects including Nutrient Recovery Through Urine Separation; Development and Implementation of a Process Technology Toolbox for Sustainable Biological Nitrogen Removal Using Mainstream Deammonification; Manure Resource Recovery: Co-Digestion with Low-Cost Ammonia Stripping; and Enhanced Removal of Nutrients from Urban Runoff with Novel Unit Process Capture, Treatment, and Recharge Systems.

Overview of the National Research Center for Reinventing Aging Infrastructure for Nutrient Management (RAINmgt)

James Mihelcic (University of South Florida)

Dr. James Milhelcic explained that the Center's mission is to achieve sustainable and cost-effective health and environmental outcomes by re-imagining aging coastal urban infrastructure systems for nutrient recovery and management. He reviewed the Center's three research areas:

1. Point Sources of Nutrients,
2. Diffuse Sources of Nutrients, and
3. Life Cycle Thinking and Systems Integration.

He also discussed several of the projects within those research areas including Decentralized (Building-Scale) Nutrient Recovery from Urine Using Sorption-Precipitation, Innovative Onsite Wastewater Treatment Systems, and Scaling Up Integrated Hydroeconomic Modeling to Address Coastal Nutrient Management Challenges.

Center for Nutrient Pollution Solutions: An Innovative Approach to Exploring Nutrient Pollution Solution Scenarios

James Shortle (Pennsylvania State University)

Dr. James Shortle explained that the Center's expected outcomes are improved tools for nutrient management at multiple scales for multiple objectives, a set of messages and rules for nutrient management, lessons for Susquehanna River-Chesapeake Bay nutrient management, and stakeholder engagement processes for community-based solutions. The Center objectives are:

- Develop strategic planning and management tools for watershed-based solutions,
- Develop solutions that integrate site level management tactics with systems level strategies, and
- Infuse public engagement into all it does.

BREAKOUT SESSIONS: SCIENCE COORDINATION AND GAPS

Workshop participants divided into three discussion groups for each topic: Sources and Fate/Transport, Effects, and Integration. After several hours of brainstorming and dialogue, a representative from each group gave a summary presentation. The following questions were provided:

1. What are the most important science gaps in this topic area?
2. What scales are missing or under-represented? What system types are missing?
3. What is EPA doing that addresses these gaps?
4. What can be done to foster collaboration across EPA on this topic?
5. What is covered by other agencies?
6. What can be done to foster collaboration with other agencies?
7. What are some policy or regulatory roadblocks/gaps that keep us from being successful?
8. What happens when an integrated analysis comes up with a different answer than a single source or single media analysis, how do we move forward?

SOURCES AND FATE/TRANSPORT

Facilitators: *Heather Golden (ORD/NRMRL), Brenda Rashleigh (ORD/NHEERL), Robert Sabo (ORD/NCEA), Tanya Spero (ORD/NERL), Ginger Tennant (OAR/OAQPS), John Walker (ORD/NRMRL)*

Participants: *Richard Lowrance (ORD/NRMRL), Chris Nietch (ORD/NRMRL), James Paeur (ORD/NHEERL), Mary Reiley (OW/OST), Donna Schwede (ORD/NERL), Nicole Tucker (OW/OGWDW), Yongping Yuan (ORD/NERL)*

Discussion Question 1: What are the most important science gaps in this topic area?

- Reducing uncertainty in ammonia emissions from animal production and fertilized soils. BMPs for reducing ammonia emissions.
- Characterizing N emissions. How much denitrification is going on in the landscape?
- Organic N emissions in atmosphere, and their role in the deposition budget. All are difficult to measure. Fire emissions (not well understood). Any from pesticides?
- Addressing urea: how to characterize slow release from fertilizers?
- Mineralization from soils: enhanced by reducing fertilizer?
- How have N sources changed through time and in space (potentially through statistical analysis of past data)?
- Deposition flux measurements over different surfaces (can vary, would be interesting to test in a watershed model). Deposition to ground vs. to cell in a model.
- How to characterize mixed land use for modeling? Important to understand that particularly for BMP effects in watersheds.
- SWAT doesn't simulate ammonia from soils (EPIC is a possible solution).
- Groundwater: characterizing sources and legacy contamination (which is not addressed by BMPs). Gap in modeling integration between surface water and groundwater models.
- Uncertainty in rate constants, and the need to characterize those values more regionally.
- Models do not characterize reactive carbon well.
- N availability: how much of the input (particularly in a modeling system) is available? Currently make assumptions but overall not well characterized.

- N from urban surfaces, and the effects of green infrastructure on nutrient loading to waters.
- Influence of different forms of N deposition on ecosystems.

Discussion Question 2: What scales are missing or under-represented? What system types are missing?

- Smaller scales/more spatially explicit models needed for watershed BMPs, in order to see how parcel-scale decisions (e.g. green infrastructure) actually figure into N.
- Scale of climate models is not accurate enough for watershed models (e.g., wind). Down-scaling doesn't necessarily increase accuracy.
- Extreme precipitation events in water quality models typically don't do well.
- Ammonia monitoring: short distances and timescales, particularly very dramatic changes downwind of sources.
- Calculating mass balance at watershed scales.

Discussion Question 3: What is EPA doing that addresses these gaps?

- Community Multi-Scale Air Quality (CMAQ) modeling system working together with monitoring and modeling informing each other (Donna Schwede).
- Models as a service (National Exposure Research Laboratory (NERL) Athens).
- USDA and EPA working collectively on ammonia (John Walker).
- SSWR 5.01 green infrastructure projects bringing together nutrients and air.
- Environmental Research Institute of the States/Environmental Council of the States could be used to get interactions with the states.

Discussion Question 4: What can be done to foster collaboration across EPA on this topic?

- Modeling needs to be done in concert with monitoring: more support or collaboration or both. Agencies that do this look at less impacted area, but need to also characterize areas that are more impacted.
- Software development collaboration and interoperability of models.
- RARE, Regional Research Partnership Program (R2P2): regional exchange programs to foster collaboration.

Discussion Question 5: What is covered by other agencies?

- USGS – simpler models, flow analysis. Laurie Sprague: National Water-Quality Assessment Program trend analyses report coming out.
- USDA – characterizing ammonia emissions for animal production. How efficient are fertilizers? Long Term Agroecosystem Research program: 18 sites (also a place to foster collaboration).
- NOAA – EPA uses their datasets. Large field campaigns. Good relationship on Great Lakes.

Discussion Question 6: What can be done to foster collaboration with other agencies?

- Inventory of datasets with other agencies.
- Participation in the 2018 Federal Interagency Meeting on Watersheds in West Virginia (Heather Golden is contact).
- Liaisons in EPA Office of Wetlands, Oceans, and Watersheds.

- Harmful Algal Bloom and Hypoxia Research and Control Amendments Act – nice avenue for collaboration on HABs.
- Necessary to recognize and appreciate collaboration at the individual level.

Discussion Question 7: What are some policy or regulatory roadblocks/gaps that keep us from being successful?

- EPA has limited authority in groundwater and nonpoint source pollution. Total Maximum Daily Loads (TMDLs) are through states.
- Censored fertilizer/manure data, so don't know where it is being applied.
- Funds transfer across agencies and interagency agreements are a lot of work: create administrative barriers to collaborating.

EFFECTS

Facilitators: *Chris Clark (ORD/NCEA), Jana Compton (ORD/NHEERL), Bryan Hubbell (OAR/OAQPS), Jason Lynch (OAR/CAMD)*

Participants: *Jesse Bash (ORD/NERL), Emmi Felker-Quinn (OAR/OAQPS), Katie Foreman (OW/OGWDW), Tara Greaver (ORD/NCEA), Jim Hagy (ORD/NHEERL), Scot Hagerthey (ORD/NCEA), Matt Heberling (ORD/NRMRL), Jeff Herrick (ORD/NCEA), Ann Keely (ORD/NRMRL), Meredith Lassiter (ORD/NCEA), Walt Nelson (ORD/NHEERL), Meghann Niesen (OW/OST), Ben Packard (OAR/CAMD), Anne Rea (ORD/IOAA), Kristin Riha (OAR/OAQPS), Amy Shields (Region 7),Travis Smith (OAR/OAQPS), Dana Thomas (OW/OST), Alan Talhelm (ORD/NCEA)*

The Effects group focused on systems: freshwater, terrestrial, human health, and coastal systems. Within each of these systems, they identified the science gaps, barriers to solving the problem, and collaboration opportunities. They also addressed how to foster collaboration across EPA.

Freshwater System

There is a need to better understand the big picture with regards to nutrient criteria. There is an OW map that provides state-level criteria, but only a fixed number of states have specific criteria.

- Progress has been made, largely in terms of lake P – more setting of nutrient criteria.
- Need a better understanding of when N vs. P is causing problems. When, where, what are the drivers?
- Lack of political will to set nutrient criteria.
  - Role of science in convincing and communication of effects and HABs; focusing the energy on a better understanding. Looking at endangered species?
- Dynamics of recovery/response to reductions – in some cases there are time lags.
  - Acidification recovery has been studied/modeled.
  - What constitutes recovery? Evolving baselines and knowing what the baseline is to know what to the return point needs to be.
- Low-head dams and increase in algal blooms – effects?
- Drinking water intakes – lake/stream gaps.

Collaborative opportunities for freshwater systems include:

- Nutrient criteria – to include using the same approach as the air deposition response work and use of this work to help model methods. And vice versa, can the nutrient criteria work help air deposition response work?
- Ecosystem services – the concept in connecting to designated use and public welfare and public interest and make the nutrient issue clear.
- Designated uses – and need for public welfare.
- Connecting to public interest.

The group mentioned that a barrier is the problem of how to capitalize on places like Chesapeake Bay or Iowa to increase political will and community-based decision making and the ability to transfer that model to other places where there is less understanding of the problem.

Terrestrial System

- Tying changes to ecosystem services:
  - Dose response for N dep- carbon storage.
  - Time trends in these relationships.
  - Connecting to economic benefits (i.e., recreation and non-use benefits).
- Integration of acidification and eutrophication responses – both happening at the same time.
- Dry deposition estimates and incorporation into dose-response relationships.
- Better understanding of ammonia emissions from CAFOs (also a source issue).
  - NASA products could help.
- Understanding baseline of N inputs.
- Differing types of N and impacts.
- N and invasive species.
- Conditional sensitivities.
- Synthesis studies are needed.
  - N impacts on endangered species.

The group identified a collaborative opportunity to connect air-land response to regional efforts. They suggested Partner Alliance and Coordination Teams (PACTs) could assist in this area, as there is interest in working with the regions.

Human Health and Economics

- Uncertainties about cyanotoxins (measurement and monitoring), especially saxotoxins and multiple toxins.
- Lag times in analytical process – need for quicker screening tools.
- Toxin sensors – monitoring for HABs; should each lake that has an identified problem being monitored.
- Predictive models for HAB occurrences.
- Economic setting and understanding the costs of N removal (i.e., keeping it out of water vs. treating) and remediation vs. avoidance; need a better understanding of the cost issues).
- Human health impacts of nutrients.

- What are treatment costs? – can do for small areas?
  - Shovel-ready environmental projects.
  - Disaster recovery and lawsuit settlements.

Collaborative opportunities were also mentioned. With regard to HABs, the group asked "What is the niche of EPA/ORD?" and discussed the three office water quality benefits work to connect critical loads and ecosystem services (a key research need across the Agency) and to connecting social science and natural science. Because of the need to be able to translate these changes to aquatic life, this area is also a barrier.

Coastal System

A barrier to coastal systems is that recovery is often hampered by changes by other factors besides nutrients. For instance, the physical structure has been changed and may hamper the ability to recover. Scientific gaps that were identified include:

- Short-term vs. long term change trajectories (monitoring).
- Complexity of trophic interactions that get in between dose-response relationship.
- What can we learn from terrestrial approaches? Are there ideas that can be used across the board?
- Use externally derived standards/criteria? There is a 10% rule.
- Historical background for dissolved oxygen settings.
- Scaling of experiments.
- Communication about recovery.

Discussion and Q&A

- **Ben Packard** stated that the Nutrient Centers provide another area of collaboration. A progress review meeting will possibly take place at the WERF symposium or contact them directly.
- **Mario Sengco** wanted to highlight HABs the opportunity to learn from NOAA. He stated that in order to avoid the danger of intra-agency repetition it would be beneficial to maintain contact and communication from these groups.
- **Chris Clark** emphasized there are good relationships with the USFS and NPS and the need to share new information to them.
- **Jana Compton** emphasized the need to foster collaboration, some methods include:
  - Peer-to-peer interaction.
  - PACTs could be a starting point and point you to the right person.
  - Drivers are needed to initiate work; sometimes that driver is a community need.
  - Need for a color-coded spreadsheet to show the inter-agency collaboration. The group questioned whether there was one for OAR.
  - Use of regional liaisons and proposed opportunities to increase the collaboration.

INTEGRATION

Facilitators: *Ellen Cooter (ORD/NERL), Val Garcia (ORD/NERL), Randy Waite (OAR/OAQPS)*

Participants: *Mario Sengco (OW/OST), Vicki Sandiford (OAR/OAQPS), Megan Mehaffey (ORD/NERL), Denice Shaw (ORD/IO), Rick Greene (ORD/IOAA)*

The Integration group discussed three broad areas: gaps in the Nitrogen Cascade framework, gaps in scientific knowledge, and roadblocks to integration.

Overall the group felt the Nitrogen Cascade was a valid framework for integration, however the following gaps were identified:

- Cascade is not unidirectional; need to include feedbacks (e.g., re-use, stakeholder responses, biodiversity responses).
- Address scale and whether it is an open or closed system (nutrient center presentations: nutrient transfers).
- Better linkage between social factors and biogeochemical interactions.
- Systems approach needs to be brought to urban environments/green infrastructure.
- In ORD, groundwater components are poorly defined and poorly integrated into the system.

Multiple scientific gaps were identified and discussed by group members:

- Attention to relationship of co-pollutants to nitrogen cascade (P, iron, other trace minerals).
- Data to support systems model development (better temporal/spatial resolution), which could come from collaboration with other agencies, citizen science, and low cost monitors.
- Need more information on variability and extremes (goes back to need for temporally/ spatially resolved data).
- Comparable valuation methods across media to support trade-off analyses.
- Biodiversity and nitrogen cycle feedbacks (food web interactions).
- Water quantity often not included in systems description, even though it affects TMDLs of contaminants, like nitrogen. Possible interaction with USGS and NOAA.
- Understanding relationship between different forms of N and biologic response (HABs).
- Systems understanding/characterization of emerging issues e.g., renewable energy systems, HABs, climate change.

The group identified multiple institutional road blocks to integration across different programs:

- Decision-makers need to have faith in integrated model results.
- Separate policies (CWA, SDWA, and Clean Air Act (CAA)) promote stovepiping and add to the separation between offices.
- Different programs have varying jurisdiction to address issues spanning across land, air, and water as well as varying spatial jurisdiction (regional versus national).
- Better integration could allow division implementation responsibilities and also would allow for incentive programs (trade-offs).

DAY 3: Friday September 2, 2016

PANEL DISCUSSIONS: CONNECTING TO PROGRAM OFFICE AND REGIONAL NEEDS

POLICY SOLUTIONS

***Panelists:** Randy Waite (OAR/OAQPS), Scot Hagerthey (ORD/NCEA, Nitrate ISA), Dana Thomas (OW/OST)*

Mr. Randy Waite discussed the limited ability of OAR to apply national standards to a local problem. He used the Chesapeake Bay as an example of how OA and OW were able to work together to reduce nitrogen air deposition in the Bay area.

Dr. Scot Hagerthey represented the National Center for Environmental Assessment (NCEA) Integrated Risk Information System program and described their work developing reference doses for specific chemicals. The reference dose information is then used by program offices to perform risk assessments associated with various chemicals. The ammonia assessment with an inhalation exposure value should be published in September. The nitrite/nitrate is on the list for a chemical assessment, a process that is one of the top five priorities, and is in the initial scoping stage.

Dr. Dana Thomas represented the criteria and standards program whose goals are to establish standards, educate people about the importance of nitrogen in freshwater, and provide translator values for states to use to translate their narrative statements. Many point sources do not have permits for nitrogen or phosphorus and they are trying to address this through two initiatives. One is the development of NSmart which is a recognition program for wastewater treatment plants who implement a higher level of technology, similar to the energy star program. The second initiative is a survey of wastewater treatment plants to measure the influent and effluent concentrations of nitrogen and phosphorus.

After the panel the following issues were discussed:

- The costs and benefits of standards and how they influence adoption and implementation.
- The difference between developing a translator value and developing exact criteria.
- The view of states and EPA on implementing continuous monitoring.
- The process for submitting an information collection request to the Office of Management and Budget.

TECHNICAL SOLUTIONS

***Panelists:** Rick Greene (ORD/IOAA, Hypoxia Task Force perspective), Yongping Yuan (ORD/NERL), Allison Costa (OAR/OAQPS)*

Dr. Rick Greene discussed nutrient reduction strategies for states. He shared an example from Illinois and the process they developed. The first step was to determine baseline nutrient loads, then they established targets, and finally they evaluated agricultural practices and developed scenarios. The scenarios incorporate a combination of practices and estimate the percent reduction of N and P that would occur. He also mentioned that the Center for Watershed Protection and the Walton Family

Foundation held a workshop to develop a white paper summarizing the estimated BMP efficiencies and cost per acre for the different BMPs listed in the three states' plans.

Dr. Yongping Yuan presented work on multi-media modeling to integrate air, landscape, watershed, and coastal processes. Five models (Weather Research and Forecasting/CMAQ/EPIC/SWAT/CGEM) have been integrated to assess the potential impact of CAA regulations, climate change, land use and land management on nutrient fate and transport in large river basins.

Ms. Allison Costa spoke about her work on management practices in agriculture. Collaborating with ORD and USDA, they examine differences in ammonia modeling. They work on conservation measures regarding what agriculture entities can do to reduce emissions from their sources and they are developing a reference guide on demonstrated mitigation strategies for the agricultural industry.

After the panel the following issues were discussed:

- The extent of reduction that can be accomplished by mitigation strategies and modeling efforts to estimate the efficiency of reduction strategies.
- The need for additional data and the right data to scale up modeling efforts from the farm scale to regional or national scale.
- The status of the development for an emission estimation methodology.
- The limitations of integrated models to address larger scale (large lakes and reservoirs) and the need to go beyond linking models to coupling models.

ECONOMIC BENEFITS, ECOSYSTEM SERVICES, AND HUMAN HEALTH

***Panelists:** Mario Sengco (OW/OST), Jana Compton (ORD/NHEERL), Matt Heberling (ORD/NRMRL)*

Dr. Mario Sengco presented the results of an economic report on the cost to implement a range of different treatments at waste water treatment plants and decentralized systems to address nutrient pollution. The report provided context for mitigation costs by presenting the cost associated with harmful algal blooms and the cost of direct water treatments to remove nutrients. The report has been a valuable tool for state partners.

Dr. Jana Compton shared three areas that ORD/National Health and Environmental Effects Research Laboratory (NHEERL) are working in related to ecosystems services and economics. The first area is the ecosystem research being conducted in SHC to define ecosystems and services and connect them to beneficiaries. Second, they are estimating the damage cost associated with nutrients at the national scale. Lastly, they are developing the individual N footprint calculator; an institutional footprint calculator is being piloted at 18 colleges and universities.

Dr. Matt Heberling spoke about the National Water Quality Benefits work, which is a project involving OW, OP, and ORD. The project will expand the set of benefits that the OW can use in its cost-benefit analysis. This collaboration has regional representation and is hoping to add an OAR representative. They are hoping to address some of their data gaps by partnering with OP and NCEA to assess human health endpoints and with SHC to quantify ecosystems services.

After the panel the following issues were discussed:

- Possibility for the national damage assessment to be incorporated into the Report on the Environment and provide a time series dataset.
- The reason why the SolarBees deployed in Falls Lake did not work.

COMMUNICATION

***Panelists:** Mary Reiley (OW/OST), Vicki Sandiford (OAR), Amy Shields (Region 7)*

Ms. Mary Reiley shared that despite all the communications work they are doing to change stakeholders' perceptions about the impact of implementing reduction activates, many stakeholders still worry about the cost and the negative impacts on the agricultural industry. She pointed out the following needs:

- To demonstrate technology is able to achieve reductions and the cost for technology is decreasing;
- To incentivize the development and optimization of technology; and
- To research and understand the type of outreach, education, language, assistance, and incentives that will engage the public. One initiative they are using is NSmart, which is a program to work with utilities and recognize them for their implementation of new approaches.

Ms. Vicki Sandiford presented about their efforts to increase EPA's outreach to students in K-12. The goals of EPA's outreach program are to elevate awareness of what EPA does, to provide education by supplementing school curriculum, and inspire students to enter careers in the field of science. She shared the need for more hands on activities, like the scientist-created "Generate" board game that teaches students about the trade-offs between energy consumption, carbon footprint and economic costs.

Dr. Amy Shields spoke about coordinating communication with state environmental and health agencies. She highlighted the relationships between state partners and municipal utilities, agriculture, and community groups. One-on-one conversations and hands-on demonstrations are needed to engage local stakeholders. She also shared about the challenges they face:

- Stakeholders are not using best management practices;
- Manure management is a huge issue where large number of CAFOs need EPA/USDA national solutions; and
- Nutrient pollution problem is not a static concern, but continues to worsen.

After the panel the following issues were discussed:

- The possibility of EPA having an across-agency annual science project/competition similar to the 4H annual science day.
- The need for a comprehensive communications plan across the agency that would enable the agency to be more strategic in identifying who to talk to and how to engage them in conversation. This includes leveraging social media channels.

- The need for engagement among non-traditional community groups like garden clubs and civic organizations.

CONCLUSION

Anne Rea (ORD/IOAA)

Dr. Anne Rea led a group discussion regarding next steps for the Nr and co-pollutants activities. Overall themes included the need for better understanding of important and emerging research areas, continued collaboration and communication, and connecting ORD with program office and regional needs.

Emphasized Research Areas

The group identified the following areas to prioritize:

- Linkages between nutrients and HABs (especially cyanobacteria).
- Interactions between nutrients and climate.
- Biodiversity and biogeochemical cycle feedbacks between nutrients and climate.
- Integrated approaches that allow decision-makers to make trade-offs (regulatory, voluntary, incentives, markets, etc.).
- Dose-response functions for ecological endpoints and ecosystem services.
- Measurement Model Fusion—using an integrated approach for data fusion.
- Integrating monitoring across media—air/water/soil.
- Issues of scaling—national, regional, local; right model to use for the right scale.
- Model interoperability—integrating not linking models.

Increasing Internal Communication

Face to face meetings are essential and should be made a priority. A method for addressing this could be adding an additional day or session to national meetings for scientists to discuss research (i.e. Society of Environmental Toxicology and Chemistry (SETAC), Society of Toxicology (SOT), ACE: Jamboree, SSWR: L'eau Down, SHC: Communique). **Anne Rea** will compile a list of upcoming meetings or seminars so that scientists can stay connected. Another suggestion included quarterly meetings (via webinar), a series of working meetings that bring scientists together to solve an issue on a particular topic, a monthly update via a newsletter, and the use of social media (i.e., Twitter) to share links to databases and scientific reports accessible to the regions. **Mario Sengco** shared his experience with Citizen Science OW and **Blake Schaeffer** reported he received positive feedback using EPA twitter @ORD to share research. Several participants agreed that the sharing of contact information, even down to the project level, will aid personal connections.

Upcoming meetings where relevant Nr topics and scientists will already be present include:

- 2017 SETAC nutrient/nitrogen session (**Mary Reiley**) plus poster session (Minneapolis);
- Special session at American Geophysical Union—cross media climate;
- SOT 2017 (New Orleans), 2018 (DC);
- Coastal Estuary Research Foundation 2017 (Providence, RI); and
- Society of Freshwater Science 2017 (Raleigh)
- Ecological Society of America 2017 (Portland, OR)

Addressing External Communication

Mary Reiley and **Jim Hagy** emphasized the need for improved public communication strategies and the barriers to get the science to the policy makers. There was discussion to create a small working group to develop a model on the process and help translate information to the public.

Next Steps/Action Items

A proposed workshop on *Joint Agency Opportunities in the Science and Management of Nr & Co-Pollutants*, would assist in the development of collaborative research and management partnership between agencies. Other goals of this workshop include:

- Increasing coordination across agencies, build upon interagency coordination.
  - White House nutrient challenge
  - NOAA-EPA-USGS algal bloom monitoring network
  - Hypoxia Task Force
  - Water quality trading coordination
  - EPA-USDA food waste reduction initiatives
  - Air/USDA connection
  - Critical Load Database & Agencies
- Representatives from federal agencies, academia, industry partners in agriculture, energy and wastewater, and non-governmental organizations as well as key partners from the International Nitrogen Initiative, US Global Change Research Program, Biogeochemistry Interagency Working Group, and The National Socio-Environmental Synthesis Center.
- Products will include a workshop summary publication, communication materials, and a database of ongoing Agency nutrient-related projects.

Anne Rea will share the workshop presentations, Regional Science Liaison contact list, and workshop contact information with all participants. She will use information shared and communicated during this workshop for the Roadmap Annual Report (public release October 3), input in to the Board of Scientific Counselors (BOSC) Review of Annual Report (November 1 teleconference), and the next Research Action Plan.

Other ideas generated from workshop participants included:

- Distribution of the Recent Water Research Newsletters (OW).
- Increased discussion or seminars on the project areas on Day 1 of agenda (SSWR/SHC/ACE).
- Increased use of keywords in Scientific & Technical Information Clearance System through lab Matrix Interface's communicate to PIs and Lab Technical Information Managers.
- Distribution of the Project Lead Directory.

APPENDIX A: AGENDA

DAY 1: Wednesday, August 31, 2016 | C111 A-B

1:00 – 1:15 pm **Arrive and Check-In**

1:15 – 1:45 pm **Welcome and Charge for Meeting**
Anne Rea (ORD/IOAA)

1:45 – 3:00 pm **The Need for Intra-Agency Coordination on Nutrient Science and Management**
- SAB N Perspective ***Jana Compton (ORD/NHEERL)***
- OW Perspective ***Mary Reiley (OW/OST)***
- OAR Perspective ***Randy Waite (OAR/OAQPS)***
- Regional Perspective ***Carole Braverman (Region 5)***
- Cross-ORD N Perspective ***Anne Rea (ORD/IOAA)***
- Overview of ORD Nr and Co-pollutant Portfolio: Draft Analysis ***Chris Clark (ORD/NCEA)***

3:00 – 3:15 pm **BREAK**

3:15 – 4:30 pm **Nitrogen and Co-pollutant Research in the ORD Research Programs and Program Offices**
3 minute "lightning talks" 5 slides max, hard cut off at 3 minutes. 5-minute discussion after each section. | **Mary Reiley (OW/OST), moderator**

Sources/Inputs
- N Inventory ***Robert Sabo (ORD/NCEA)***
- Air Inputs ***Donna Schwede (ORD/NERL)***

Fate/Transport
- SWAT Modeling and Nutrients ***Chris Nietch (ORD/NRMRL)***
- GHG Emissions from Aquatic Systems ***Jake Beaulieu (ORD/NRMRL)***
- Agriculture and Groundwater Nitrate ***Jana Compton (ORD/NHEERL)***
- Remote Sensing of Water Quality ***Blake Schaeffer (ORD/NERL)***

Effects and Benefits
- Nutrient Criteria and Effects ***Dana Thomas (OW/OST)***
- NOx/SOx ISA ***Tara Greaver (ORD/NCEA)***
- Nutrient Effects Research ***Jim Hagy (ORD/NHEERL)***
- HABs and Human Health ***Elizabeth Hilborn (ORD/NHEERL)***
- N Deposition Effects ***Chris Clark (ORD/NCEA)***
- Water Quality Benefits ***Matt Heberling (ORD/NRMRL)***

Systems Modeling
- N Inputs from the Landscape ***Ellen Cooter (ORD/NERL)***
- Nutrient Modeling ***Jim Hagy (ORD/NHEERL)***

4:30 – 5:30 pm **Poster Session and Ad Hoc Research Discussion**

6:15 pm **Group Dinner at BabyMoon Café (10-minute drive from EPA)**
100 Jerusalem Drive, Ste 106 Morrisville, NC 27560
http://www.babymooncafe.com/menu/

DAY 2: Thursday, September 1, 2016 | C111 A-B; C112 (breakout)

9:00 – 9:15 am **Welcome and Logistics for Day 2**
Mary Reiley (OW/OST)

9:15 – 10:15 am **Intra-Agency Challenges Panel Discussion – Connecting Program Office and Regional Needs to ORD Research on N and Co-pollutants**
15-minute Panel Discussion. | Richard Lowrance (ORD/NRMRL), moderator

- **OAR Connections** – What science is missing? How can we better connect the research to OAR needs? ***Bryan Hubbell (OAR/OAQPS), Jason Lynch (OAR/CAMD)***
- **OW Connections** – What science is missing and how can we better connect to OW needs? ***Mary Reiley (OW/OST), Mario Sengco (OW/OST)***
- **Regional Connections** – What science is missing and how can we better connect to regional needs? ***Carole Braverman (Region 5)***

10:15 – 10:30 am **BREAK**

10:30 – 11:30 am **NCER Nutrient Centers**
Ben Packard (ORD/NCER), moderator

- **Colorado State University** Center for Comprehensive, OptimaL, and Effective Abatement of Nutrients ***Mazdak Arabi***
- **Water Environment and Reuse Foundation** National Center for Resource Recovery and Nutrient Management *Christine Radke and Lola Olabode*
- **University of South Florida** Center for Reinventing Aging Infrastructure for Nutrient Management ***James Mihelcic***
- **Pennsylvania State University** Center for Integrated Multi-scale Nutrient Pollution Solutions ***James Shortle***

11:30 am – 1:00 pm **LUNCH** ***MUST LEAVE AUDITORIUM FOR ANOTHER GROUP RESERVATION***

1:00 – 1:15 pm **Break Out Group Charge**
Jana Compton (ORD/NHEERL)

1:15 – 3:45 pm **Breakout Sessions, Science Coordination, and Gaps**

- **Sources** – All Nr forms including but not limited to ammonia, background N sources and "other forms of N" (e.g. organic) that directly contribute to total N loads
  John Walker (ORD/NRMRL), Robert Sabo (ORD/NCEA), Ginger Tennant (OAR/OAQPS)
- **Fate/Transport** – Airshed, watershed and stream modeling
  Brenda Rashleigh (ORD/NHEERL), Tanya Spero (ORD/NERL), Heather Golden (ORD/NRMRL)
- **Effects** – Quantitative thresholds for change
  Jason Lynch (OAR/CAMD, freshwater), Chris Clark (ORD/NCEA, land), Jana Compton (ORD/NHEERL, human health and economics), Bryan Hubbell (OAR/OAQPS)
- **Integration** – Systems level modeling and "cross media" processes that often are lost when we silo the science/policy by media or source
  Ellen Cooter (ORD/NERL), Val Garcia (ORD/NERL), Randy Waite (OAR/OAQPS)

3:45 – 4:00 pm **BREAK**

4:00 – 5:00 pm **Breakout Group Reports: Sources, Fate/Transport, Effects, Integration**
10 minutes + 5 minutes Q/A each | **Jana Compton (ORD/NHEERL), moderator**

5:00 pm **ADJOURN DAY 2**

DAY 3: Friday, September 2, 2016 | C111C

9:00 – 9:05 am **Welcome and Logistics for Day 3**
Randy Waite (OAR/OAQPS)

9:05 – 10:35 am **Panel Discussion – Connecting to Program Office and Regional needs**
5-minute panel comments followed by 15-minute discussion. | Randy Waite (OAR/OAQPS), **moderator**

- **Policy Solutions** – Connections to water and air quality goals, criteria and standards, *especially incentives*, trading programs and connections to energy and food decisions and policy. Connections to industry and consumer decisions
  Panelists: Randy Waite (OAR/OAQPS), Scot Hagerthey (ORD/NCEA, Nitrate ISA), Dana Thomas (OW/OST)
- **Technical Solutions** – Nutrient management and restoration/mitigation downstream of sources
  Panelists: Rick Greene (ORD/IOAA, Hypoxia Task Force perspective), Yongping Yuan (ORD/NERL), Allison Costa (OAR/OAQPS)
- **Economic Benefits, Ecosystem Services and Human Health** – Connecting to N and Co-pollutants
  Panelists: Mario Sengco (OW/OST), Jana Compton (ORD/NHEERL), Matt Heberling (ORD/NRMRL)
- **Communication** – Better articulation of what is meant by "communication," defining the target audience, identifying barriers to change
  Panelists: Mary Reiley (OW/OST), Vicki Sandiford (OAR/OAQPS), Amy Shields (Region 7)

10:35 – 10:45 am **BREAK**

10:45 – 11:15 am **Group Discussion: Next Steps for Recommendations/Implementation of Nr & Co-pollutant Roadmap in the Near-Term; BOSC Review**
Anne Rea (ORD/IOAA), Mary Reiley (OW/OST), Randy Waite (OAR/OAQPS)

11:15 – 11:45am **Lightning Responses from 8-10 Workshop Attendees**
*3 minutes, one slide max (slides not required). *Be prepared, as we might ask any of the attendees to give a lightning presentation. |* **Jana Compton (ORD/NHEERL), moderator**

- What did you learn from the meeting? What messages will you take home for your work or your program? What inspired you? What are the biggest challenges? What is missing?

11:45 am – 12:00 pm **Closing Remarks and Next Steps**
Anne Rea (ORD/IOAA), Mary Reiley (OW/OST), Randy Waite (OAR/OAQPS)

12:00 pm **MEETING ADJOURNS**

APPENDIX B: LIST OF PARTICIPANTS

Mazdak Arabi – ***CSU, Denver, CO***
mazdak.arabi@colostate.edu

Jesse Bash – ***ORD/NERL***
bash.jesse@epa.gov

Jake Beaulieu – ***ORD/NRMRL***
beaulieu.jake@epa.gov

Carole Braverman – ***Region 5***
braverman.carole@epa.gov

Chris Clark – ***ORD/NCEA***
clark.christopher@epa.gov

Jana Compton – ***ORD/NHEERL***
compton.jana@epa.gov

Ellen Cooter – ***ORD/NERL***
cooter.ellen@epa.gov

Allison Costa – ***OAR/OAQPS***
costa.allison@epa.gov

Chris Davis – ***OAR/OAQPS***
davis.christopher@epa.gov

Emmi Felker-Quinn – ***OAR/OAQPS***
felker-quinn.emmi@epa.gov

Katie Foreman – ***OW/OGWDW***
foreman.katherine@epa.gov

Brett Gantt – ***OAR/OAQPS***
gantt.brett@epa.gov

Val Garcia – ***ORD/NERL***
garcia.val@epa.gov

Heather Golden – ***ORD/NRMRL***
golden.heather@epa.gov

Tara Greaver – ***ORD/NCEA***
greaver.tara@epa.gov

Rick Greene – ***ORD/IOAA***
greene.rick@epa.gov

Scot Hagerthey – ***ORD/NCEA***
hagerthey.scot@epa.gov

Jim Hagy – ***ORD/NHEERL***
hagy.jim@epa.gov

Matt Heberling – ***ORD/NRMRL***
heberling.matt@epa.gov

Jeff Herrick – ***ORD/NCEA***
herrick.jeffrey@epa.gov

Elizabeth Hilborn – ***ORD/NHEERL***
hilborn.e@epa.gov

Bryan Hubbell – ***OAR/OAQPS***
hubbell.bryan@epa.gov

Toni Jones – ***OAR/OAQPS***
jones.toni@epa.gov

Ann Keeley – ***ORD/NRMRL***
keeley.ann@epa.gov

Meredith Lassiter – ***ORD/NCEA***
lassiter.meredith@epa.gov

Jim Lazorchak – ***ORD/NERL***
lazorchak.jim@epa.gov

John Lehrter – ***Univ. of South Alabama***
jlehrter@southalabama.edu

Jiajia Lin – ***ORD/NHEERL***
lin.jiajia@epa.gov

Richard Lowrance – ***ORD/NRMRL***
lowrance.richard@epa.gov

Jason Lynch – ***OAR/CAMD***
lynch.jason@epa.gov

April Maxwell – ***ORD/NCEA***
maxwell.april@epa.gov

Lydia Mayo – ***Region 4***
mayo.lydia@epa.gov

Patricia McGhee – ***ORD/IOAA***
mcghee.patricia@epa.gov

Megan Mehaffey – ***ORD/NERL***
mehaffey.megan@epa.gov

James Mihelcic – ***Univ. of South Florida***
jm41@usf.edu

Anne Neale – ***ORD/NERL***
neale.anne@epa.gov

Walt Nelson – ***ORD/NHEERL***
nelson.walt@epa.gov

Meghann Niesen – ***OW/OST***
niesen.meghann@epa.gov

Chris Nietch – ***ORD/NRMRL***
nietch.christopher@epa.gov

Chris Nolte – ***ORD/NERL***
nolte.chris@epa.gov

Lola Olabode – ***Water Environment & Reuse Foundation***
lolabode@werf.org

Ben Packard – ***ORD/NCER***
packard.benjamin@epa.gov

Molini Patel – ***ORD/NCEA***
patel.molini@epa.gov

James Pauer – ***ORD/NHEERL***
paeur.james@epa.gov

Christine Radke – ***Water Environment & Reuse Foundation***
cradke@werf.org

Brenda Rashleigh – ***ORD/NHEERL***
rashleigh.brenda@epa.gov

Anne Rea – ***ORD/IOAA***
rea.anne@epa.gov

Mary Reiley – ***OW/OST***
reiley.mary@epa.gov

Kristin Riha – ***OAR/OAQPS***
riha.kristin@epa.gov

Robert Sabo – ***ORD/NCEA***
sabo.robert@epa.gov

Vicki Sandiford – ***OAR/OAQPS***
sandiford.vicki@epa.gov

Kathryn Saterson – ***ORD/NHEERL***
saterson.kathryn@epa.gov

Suesan Saucerman – ***Region 9***
saucerman.suesan@epa.gov

Blake Schaeffer – ***ORD/NERL***
schaeffer.blake@epa.gov

Rich Scheffe – ***OAR/OAQPS***
scheffe.rich@epa.gov

Donna Schwede – ***ORD/NERL***
schwede.donna@epa.gov

Mario Sengco – ***OW/OST***
sengco.mario@epa.gov

Denice Shaw – ***ORD/IO***
shaw.denice@epa.gov

Amy Shields – ***Region 7***
shields.amy@epa.gov

James Shortle – ***Pennsylvania State University***
jss15@psu.edu

Michelle Simon – ***ORD/NRMRL***
simon.michelle@epa.gov

Courtney Skuce – ***ICF***
courtney.skuce@icfi.com

Travis Smith – ***OAR/OAQPS***
jtravis.smith@epa.gov

Catherine Smith – ***ICF***
catherine.smith@icfi.com

Tanya Spero – ***ORD/NERL***
spero.tanya@epa.gov

Alan Talhelm – ***ORD/NCEA***
talhelm.alan@epa.gov

Ginger Tennant – ***OAR/OAQPS***
tennant.ginger@epa.gov

Dana Thomas – ***OW/OST***
thomas.dana@epa.gov

Hale Thurston – ***ORD/NRMRL***
thurston.hale@epa.gov

Nicole Tucker – ***OW/GWDW***
tucker.nicole@epa.gov

Alan Vette – ***ORD/IOAA***
vette.alan@epa.gov

Randy Waite – ***OAR/OAQPS***
waite.randy@epa.gov

John Walker – ***ORD/NRMRL***
walker.johnt@epa.gov

Karen Wesson – ***OAR/OAQPS***
wesson.karen@epa.gov

Ashley Williams – ***ICF***
ashley.williams@icfi.com

Katherine Worden – ***ICF***
katherine.worden@icfi.com

Jeff Yang – ***ORD/NRMRL***
yang.jeff@epa.gov

Yongping Yuan – ***ORD/NERL***
yuan.yongping@epa.gov