SSWR Project Charter
Nutrients – Project 1 (4.01)

Project Title: Reducing Impacts of Harmful Algal Blooms

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Project Start Date: 10/01/2015

Project End Date: 09/30/2019

Executive Summary

Though harmful algal blooms (HABs) may occur naturally, ecosystem alterations from human activities appear to be increasing the frequency of some HABs. HABs can have a variety of ecological, economic and human health impacts. As the recent events in Toledo, Ohio demonstrated, the increased frequency, intensity and duration of freshwater HABs can negatively impact drinking water and recreational waters, potentially risking public health. This project will provide stakeholders and decision makers with improved scientific information and tools to more effectively assess and manage HABs and associated toxicity events.

Research Project Description

The project research will provide information and tools that improve the ability of local, state and national stakeholders to manage the risks posed by HABs. The EPA's (The Agency's) research needs regarding HABs are driven by one major legislative driver and by four key science questions:

Legislative Driver: The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014 (HABHRCA 2014)

This legislation directs the Agency to engage in research on the ecology and impacts of freshwater HABs and in forecasting, monitoring and event response to HABs in lakes, rivers, estuaries (including their tributaries), and reservoirs.

Science Question 1: What management strategies have the greatest impact on reducing the risk of HABs?

Management strategies appropriate for risk prevention, control or mitigation may vary as a function of factors such as the time scales, spatial scales, and micro-organism speciation over which they are applied. In the long term, HAB prevention, through the reduction of nitrogen and phosphorous loading into receiving waters, is the gold standard for reducing HAB risk. The groundwork for HAB prevention is being laid in Projects 2.2 (development of nutrient thresholds) and 2.3 (nutrient management practices). However, a well-researched HAB prevention strategy may require decades to develop and implement. As a result, a complete management portfolio requires the inclusion of risk management strategies that can be implemented over time scales as short as one bloom season. These strategies can be classified into reservoir management, recreational area management and drinking water treatment process development, improvement and optimization.

Science Question 2: What are the human health, ecosystem and socio-economic impacts of bloom events?

Despite broad, and decades-long, agreement that HAB-generated toxins possess the ability to cause harm in humans and animals, the body of formal health-effects knowledge still contains significant gaps: high-dose animal studies have been completed only for a small subset of known toxins, chronic and low dose effects for all toxins are poorly characterized in humans and animals, and there exists little knowledge of the differential impacts of toxins on susceptible subpopulations.

HABs have the potential to affect aquatic ecosystems. Gaps in the following research areas need to be addressed: food web disturbances resulting from toxin production and hypoxic areas, toxicity thresholds for sentinel species, and the potential for toxin bioaccumulation in fish populations, both wild and aqua-cultured.

On the economic side, anecdotal evidence of HAB-driven direct economic harm is accumulating. Also significant, but more difficult to quantify, are the negative economic effects caused by reduced public confidence in the safety of privately and publicly managed water assets. An accurate assessment of economic effects is a critical factor in helping to ensure that any Program Office action or recommendation is both cost-effective and protective of public health.

Science Question 3: What causes blooms and how do we improve our ability to model the phenomenon under current and future conditions?

Assessment of risks to human health or ecosystem integrity due to HABs is hampered by our currently limited ability to determine the likelihood of HAB events. Office of Research and Development (ORD) research efforts in this project will work to improve HAB forecasting abilities by enhancing the understanding of HAB event drivers and by incorporating that understanding into improved predictive models of HAB occurrence. Particular efforts will be made to better understand the effects of increasing water temperatures on bloom occurrence.

Science Question 4: What monitoring protocols, analytical methods, and assessment methodologies are most effective for characterizing bloom events and their precursors.

The Agency is in a position to catalyze efforts to provide the necessary tools to quickly, accurately and inexpensively measure the concentrations of toxins and toxin-producing organisms present in source, recreational and treated waters. These tools fall into two broad categories: (1) methods for microbiological and chemical analysis and (2) protocols for developing site-specific monitoring programs, including metrics and benchmarks to support regulatory decisions and watershed management, for example, a benchmark for chlorophyll-a below which we do not anticipate the formation of HABs and/or microcystin.

Project Impact

The project will provide stakeholders and decision makers with improved scientific information and tools to assess, predict and manage the risk of HABs, associated toxicity events and the ensuing ecological, economic and health impacts. The project directly addresses legislative mandates, Agency research needs, Agency Program Office initiatives, National Water Program (NWP) needs and community and other stakeholder needs as follows:

- Improve the science of HAB and toxin detection by developing HAB-specific analytical methods and sampling strategies.
- Assist the NWP in developing new HAB indicators, sampling designs and protocols for use in national scale assessments.
- Develop improved approaches to understanding the interactive effects of increasing water temperatures and nutrient loads on HAB development and toxin production.
- Develop improved models to project risk of HABs under warming climate scenarios.
- Improve understanding of the human health and ecosystem effects resulting from toxin exposure.
- Provide drinking water treatment system operators with improved methods for detecting and treating toxins in order to limit or prevent human exposures.

Project Scope

This project will be focused on four intertwined research areas that cut across other ORD Research Programs. These programs include efforts by the National Homeland Security Research Center (NHSRC) for modeling and sensor applications, providing support for HAB research under Safe and Healthy Communities Project Charter 2.63 to Tribal Nations, high-throughput toxicity testing within the National Center for Computing and Toxicology (NCCT), Safe and Sustainable Water Resources (SSWR) Topics 1(Watershed Sustainability), 2.2 (Nutrients - Improve Thresholds and Targeting Actions) and 2.3 (Nutrients – Management Practices), the National Aquatic Resource Survey (NARS), and the Air, Climate and Energy (ACE) program. The research areas are described below and align with, and expand on, the brief introductions provided in the Project Description section.

<u>Area 1: Management strategies.</u>

Research needs exist to develop new, market ready treatment technologies, and to optimize existing technologies for the removal of toxins present in drinking water systems. Ideally, these methods would minimize capital, maintenance, and operational expenses, and be scalable to such a degree that they could be implemented in communities ranging from large and wealthy to small and economically marginalized. Active collaborations with water managers and other private and public sector stakeholders will help ensure these goals are met and streamline transfer and adoption of viable management strategies and technologies. Work in this area would be predicated on the assumption that there are no significant policy or institutional barriers to adoption.

In the area of drinking water treatment, removal effectiveness for various unit operations have been documented for a subset of the small group of toxins for which commercial standards are available. However, knowledge gaps exist for (1) the large set of toxins for which standards are currently unavailable, and (2) how to implement process and operational changes for maximum protection and cost effectiveness under a variety of site-specific constraints.

In the area of reservoir management, existing research indicates that modifications of reservoir hydrology may help to reduce the frequency, intensity, duration and toxicity of bloom events. However, the efficacy of these efforts is site specific, and gaps remain in the knowledge of the optimal method(s) to apply for any given set of reservoir conditions. ORD scientists and engineers will develop a scientific basis for the development and application of reservoir management strategies. In the domain of recreational area management, the primary research needs are the development of body contact exposure standards for the entire suite of known toxins as well as the development of scientifically based guidance for optimal sampling strategies.

<u>Area 2: Health, ecosystem and economic effects.</u>

One of the strongest drivers for changes that may be required to prevent future HABs, and/or mitigate those that occur, is the threat of serious adverse health effects in exposed populations. Research gaps to evaluate sources and routes of human exposures and their potential toxicity will need to be addressed. When HABs and toxins occur in drinking water and recreational water sources, exposed human and animal populations will need to be evaluated for health effects. The identification of exposure biomarkers that are simple to obtain are necessary for timely evaluation of exposure levels. The types of toxicity (critical organ system, chronic, developmental, and reproductive) are not known for most identified toxins and these potential endpoints will be the focus of research efforts. Mammalian effects from exposure to widespread fish toxins is also an area that needs focused research efforts, since these widespread compounds have not been evaluated in mammals. The identification of ichthyotoxins and their mechanisms of action are needed since these have had a serious effect on fish stocks, both wild and in aquaculture. The potential of freshwater algal toxins to cause adverse health effects after transport from lakes and streams into the coastal environment, and subsequent bioaccumulation in marine organisms, is known to have occurred and requires further research.

HABs have the potential to affect aquatic ecosystems. Gaps in the following research areas need to be addressed: food web disturbances resulting from toxin production and hypoxic areas, toxicity thresholds for sentinel species, and the potential for toxin bioaccumulation in fish populations, both wild and aqua-cultured.

Questions include: 1) "What are the ecological impacts of algal toxins on aquatic life through direct exposure and through food chain bioaccumulation? 2) How sensitive are real-time biomonitoring systems that use larval fish, daphnia and algae in comparison to traditional toxicity test organisms used in whole effluent toxicity testing? 3) What are the nutrient and other environmental conditions that are conducive to establishment of toxin producing species?

Assessment approaches will include determination of whether algal toxins inhibit zooplankton grazing behavior and population dynamics, as well as the impact on benthic filters; whether simultaneous and sequential exposure to multiple toxins, particularly the combination of multiple cyanotoxins, pose cumulative or synergistic risks to aquatic life; the potential for bioaccumulation, bioconcentration, and biomagnification of different cyanotoxins and other cyanobacterial bioactive compounds in food webs; development of algal reference toxicant tests using the top 4 toxins found during algal blooms; comparison of results of reference toxicant tests using standard species to the results obtained from real-time monitoring systems; and the culturing of toxin producing species under laboratory conditions using various combinations of environmental conditions in order to observe the effect on toxin production.

An accurate assessment of economic effects is a critical piece of the puzzle as the Agency works to craft a response that is cost-effective and protective of public, economic, and societal health. To the best of the authors' knowledge, such an assessment does not currently exist. The assessment would be broken down into two parts:

1. A nationally representative random sample survey to estimate the direct costs generated by HABs: these may include, but are not limited to extra monitoring expenses, water treatment plant upgrades and chemical costs, lost revenue from beach closures and drinking water advisories. The planning and implementation of such a survey, using traditional tools of economic research, represents an opportunity for cross-agency collaboration.
2. A nationally representative random-sample survey to estimate the degree to which public confidence in the safety of drinking water, natural and recreational assets is affected by scientific data, general-audience news from traditional media outlets, and information across the quality spectrum circulated on social media outlets. The motivation for such a survey is the fact that information circulated through these channels has the potential to quickly shape public perceptions, and these perceptions, in turn, drive behavior at the individual and family level with potentially significant negative economic consequences. It is envisioned that such a census would employ data from a variety of information and social media platforms to track the spread of information within a strictly delineated subject area.

Area 3: Temperature impacts and bloom modeling

The scientific community generally agrees that HABs have been increasing in frequency, duration and geographical range. The factors responsible for these postulated increases are thought to include ease of global transport of species, rapid evolutionary response of algal/bacterial species to changing environments, increased nutrient loads in aquatic environments, perturbations in rainfall, and increases in the overall average temperatures of aquatic bodies. These factors all enhance the ability of algal and cyanobacterial species to move, spread and form blooms with increased temporal, locational and spatial dimensions, including different water depths. A contributing factor in bloom formation, or duration, is thought to be increased average water temperatures that provides a suitable environment for algal growth. Both laboratory and environmental studies on harmful bloom dynamics are necessary to understand the extent of effects of increased water temperatures on bloom formation, and tendency of such blooms to generate toxins that may have adverse environmental and health effects.

Improved modeling capabilities are needed for an assessment of the risk associated with HABs under the dynamic of different climate scenarios. An understanding of the species, temporal and spatial dynamics of HABs will improve the capability to anticipate the course of HABs and their potential adverse effects. The vast majority of HABs are not comprised of one species throughout the course of the bloom, multiple species are the usual case, either at the same time or sequentially. Detailed knowledge of the roles different environmental factors play on species identity, toxic vs non-toxic bloom formation, persistence of blooms, and spatial/temporal extent of blooms is needed in order to increase the accuracy of bloom forecasts. This is also true of the types of toxins that will be formed in specific blooms. Together, an increased ability to predict the character of blooms will enable regulatory agencies at the National, State, Tribal and local level to better predict the course of blooms and, therefore, respond appropriately.

Area 4: Analysis and monitoring in fresh and coastal/estuarine environments.

Effective response to HABs must be based on accurate and timely assessments of the species that comprise the bloom, the toxins, if any, that are being produced, and the ecosystem impacts resulting from the presence of HAB biomass.

Morphological, culture-based, molecular biology, and optical sensing (flow cytometry, satellite imaging) approaches have been used to identify and quantify the primary algal, and related bacterial, species in blooms. All of these strategies have strengths and weaknesses. Consequently, it is important to improve existing monitoring and analytical methods, and to develop and validate new cost- and time-effective methods that can be used by Program Offices, Regions, States and other stakeholders.

For ecosystem impacts, existing methods need to be improved, and new methods need to be developed, all with the goal of delivering the greatest possible amount of analytical power into the hands of small, local, laboratories, operating on modest budgets.

For toxins, the accuracy and precision of existing methods needs to be improved for different aqueous matrices (e.g., fresh, treated drinking water, brackish, marine, etc.). Toxin analytical methods need to be standardized and, where possible, simplified in order to promote their adoption across the widest possible range of laboratories. New methods, capable of being employed from a variety of physical platforms, such as lab benches, field kits, buoys and flow-through monitors, need to be developed.

Finally, guidance needs to be developed that allows water managers to set up site-specific monitoring programs that take advantage of the existing suite of analytical methods, and potential *in situ* monitoring networks, in order to maximize protection while minimizing sampling and analytical effort.

In recent years, HAB-driven adverse environmental and health effects have been observed in the estuarine and marine environments of all coastal areas. Adverse health effects have been recorded in humans through direct exposures and consumption of toxin-containing seafood. Serious adverse health effects have also been recorded in marine mammals, fish and birds, some of which are endangered. These effects are largely caused by algal species with toxins that are different from those found in fresh waters. The factors that act to favor the formation of HABs are largely unknown in marine and estuarine (saline) environments. The development of estuarine- and marine-specific analytical methods and indicators is essential for the protection of the environment as well as human populations.

Analytical and monitoring efforts in fresh, estuarine, and marine environments have the potential to generate data sets across a range of temporal and spatial scales. These data sets would encompass direct readings on riparian, lake and coastal bodies of water as well as remote sensing from satellites. The monitoring of HABs is on-going by the Agency, a number of other Federal entities including the US Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), and by State, Local and academic entities. Data from these monitoring efforts exist in both published and unpublished form. The utility of these large data sets depends upon their consistency and availability. Developing a data portal that integrates existing and future data into a programmatic data base would result in a more cohesive HAB program. This portal would allow data sharing, promote collaborative research and speed the development of a comprehensive view of HAB extent throughout the United States. It is recognized that the technical challenges of developing and maintaining a data portal are significant. However, the potential benefits are so significant that laying the groundwork for such a portal is an aspirational goal of this project area.

Contribution to Research Needs Identified in the Nitrogen Roadmap

- Step 1.2: Better data on human health responses, particularly related to nitrate in drinking water and harmful algal blooms.
- Step 1.3: Better data on drinking water and human exposure via nitrosamines, disinfection by-products and cyanotoxins.
- Step 1.5: Need improved data on how climate will alter terrestrial ecosystem sensitivity to N and co-pollutants.
- Step 1.6: Determine how magnitude, frequency and duration of nutrient loading affect expression of impairment for aquatic endpoints.
- Step 2.1: Research providing improved relationships between nutrient source and nutrient-related impairments.

- Step 2.4: Research on exposure-response for terrestrial and aquatic ecosystem components in relation to nitrogen and co-pollutant deposition.
- Step 3.1: Development of rapid, cost-effective technologies for monitoring of water quality response to management actions.
- Step 5.2: Improved ability to tie quantitative biological responses in a rigorous fashion to quantitative loads or concentrations of nutrients in natural water bodies.

Project Structure

The project structure is described in Figure 1. Each of the four project areas will have linkages to the other areas. Ultimately, management-oriented outcomes are desired and, as a result, management occupies the central portion of the figure. The exact linkages between project areas will be described in more detail once the project has been populated with tasks and sub-tasks.

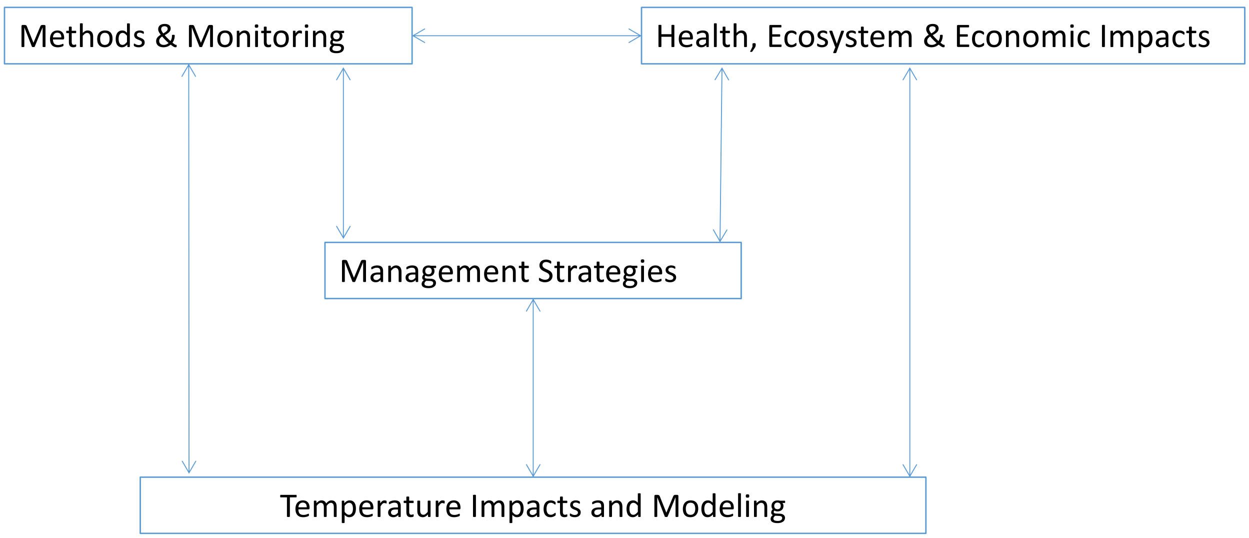

Figure 1: Project structure

Measure of Success

The success of this project can be measured by the extent to which the research provides timely and effective information, models and tools that allow stakeholders to accurately assess, predict and manage HABs and toxicity events in drinking water, recreational waters and other surface waters. The extent to which the research products are successfully used in national- to local-scale assessments of HABs, in HAB event response situations or implemented in various prevention, control and mitigation strategies would be an important measure of success and could be trackable. Where feasible, multi-sector collaborations will be established to foster and help track the development, transfer and adoption of viable models, tools and technologies. While it may be unrealistic to completely prevent HABs from ever occurring again, the project can be successful by working collaboratively with our stakeholders to protect public health and surface waters by reducing the risk of exposure to HAB toxins. EPA's success in meeting the legislative mandates set forth under HABHRCA will depend in large part on the success of ORD research in this project.

Stakeholders (outside ORD)

The project will require close coordination and collaboration within the Agency. Entities within the Agency may include, but will not be limited to: Office of Water (OW), Office of Science and

Technology (OST), Office of Wetlands, Oceans and Watersheds (OWOW), Office of Ground Water and Drinking Water (OGWDW), Office of Air and Radiation (OAR), Regional offices and EPA staff on the HABHRCA Interagency Working Group. In the federal family, coordination and collaboration with the National Oceanic and Atmospheric Administration (NOAA), US Geological Survey (USGS), US Fish and Wildlife Service (USFWS), US Army Corps of Engineers (USACE), Centers for Disease Control (CDC), National Institutes of Health (NIH), US Department of Agriculture (USDA), Food and Drug Administration (FDA) and the National Aeronautical and Space Administration (NASA) will be important since many have ongoing HAB programs and/or are subject to legislative mandates under HABHRCA. At the local level, the project will need to engage and inform state agencies, tribal communities, public water providers, the agriculture community, local governments, academic institutions, technology developers, economic development organizations, technology innovation clusters and the general public. Collaborations with these stakeholders will be employed to foster innovation, improve technology transfer, streamline adoption, and accelerate the deployment of commercially viable models, tools and technologies.

Outputs

Title: Science and tools that advance the ability of stakeholders to more effectively, and economically, characterize and manage (prevent, control and mitigate) risks posed by HABs.

Brief Description: This output will provide innovative and practical information, new conceptual and predictive models, and new methods, indicators and other tools to more effectively assess, predict and manage HABs and their risks in drinking water, recreational waters and other surface waters.

Intended user/audience: The output will be developed in various formats to provide guidance and technical assistance to national, state and local water resources managers, public health officials, and drinking water treatment operators and spur technology transfer to the private sector and others. Management tools will cover the range of temporal and spatial scales from local HAB management to national scale nutrient or climate related efforts.

This project will support the development of a variety of research sub-task products, including, but not limited to products specific for each of the tasks. These would include methods for sampling, analyzing and assessing a variety of algae and toxins in several matrices, studies of sensors and their applicability for predicting or detecting HABs, or the conditions that might give rise to these. Another group of products would include computer models that may be used in a variety of applications, including potentially predicting the likelihood of a HAB, examining the conditions that give rise to a HAB that is in progress, or determining if a HAB is in progress. There will also be information concerning the risk of HABs and algal toxins on the ecosystem and human health. Finally, information will be developed to permit the effective management of harmful algal blooms, including information for prevention, control, and mitigation of these. This information will be synthesized through a communications plan that will be in effect for the duration of the project. The target audiences for this information include the Office of Water, Regions, States, Tribal nations, drinking water utilities and a variety of other stakeholders, including importantly, decision makers, consumers of water and technology development and implementation groups among others. Each of these stakeholders may require different modes of communication for effective dissemination of the research products. Possible methods of communication include, but are not limited to:

- Regional science days
- Workshops/Webinars
- Interactive website
- Guidance documents
- Scientific reports
- Communication material and training
- Prediction tools
- A framework document for implementing recommended actions
- Technology demonstrations

Assumptions and Constraints

- Research may be constrained by personnel and resource limitations.
- The balance of emphasis between marine and freshwater HABs needs to be resolved.
- Projects with technology transfer, adoption and deployment components will require collaboration with technology developers.

2015 BOSC Review

SSWR Project Charter
Nutrients – Project 2 (4.02)

Project Number and Title: SSWR 4.02 Science to Inform the Development of Nutrient Thresholds and Targeting Actions

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Project Start Date: October 1, 2015
Project End Date: September 30, 2019

Executive Summary
This project will advance the science needed to inform decisions to prioritize watersheds and nutrient[1] sources for nutrient management and define appropriate nutrient levels for the nation's waters, two important elements of EPA's framework for managing nutrient pollution. The project will support efforts by the EPA National Water Program[2], the National Ambient Air Quality Standards program, and their partners in state and local government to restore and protect the nation's surface and groundwater resources by reducing impacts resulting from nutrient pollution, thereby sustaining ecosystem and human health. While nutrients are critical

[1] "Nutrient" and "Nutrients" refer to nitrogen and other pollutants typically associated with nitrogen, as outlined in the Nitrogen and Co-pollutant Research Roadmap, and include nitrogen and phosphorus, the two major plant nutrients that are most associated with eutrophication in aquatic ecosystems. For brevity, this document will use simply "nutrients."
[2] The National Water Program (NWP) encompasses the EPA Office of Water and related Regional offices.

for the production of food, feed, and fiber across the US and globally, in excess, inputs of nutrients to watersheds from multiple sources have been linked to a host of ecosystem impacts including changes acidification of lakes and streams and eutrophication of downstream estuaries. Research will support a sustainability strategy based on consideration of environmental outcomes and links to economic and social outcomes as developed in other projects within the Office of Research and Development. The project will implement novel field and laboratory-based studies, state-of-the-art modeling and other research syntheses to make significant progress toward important and challenging areas of scientific uncertainty related to nutrient management. The project will generate new scientific information, analysis tools, and science communications that advance the science and increase accessibility of scientific information to decision-makers.[3]

Research Project Description

EPA has recognized that nutrient pollution is one of the most widespread water quality problems facing the US and that it has far-ranging consequences for environmental condition, economic prosperity, and human health and well-being. The Agency and its partners have made significant progress in recent decades addressing nutrient pollution, particularly by recognizing and understanding the causes and consequences and beginning to implement regulatory controls and other management actions that reduce nutrient loading. In some watersheds, the trajectory of nutrient loading has turned downward due to nutrient management, with documented benefits for water quality and aquatic life (e.g., Greening and Janicki, 2006; Murphy et al. 2011; Boynton et al. 2013). There is an urgent need to accelerate this progress to meet the ongoing environmental challenges posed by nutrient pollution while maintaining socioeconomic benefits of nutrients. Having the right scientific information available and readily accessible to policy makers would help meet this need, while supporting better solutions that contribute to sustainability goals.

Two key policy challenges associated with nutrient management are (1) prioritizing watersheds and nutrient sources for nutrient management actions, such as nitrogen and phosphorus loading reductions, and (2) setting quantitative thresholds for management such as load reduction goals, secondary air quality standards, total maximum daily loads, nutrient or other water quality criteria, or quantitative goals for biological indicators of aquatic life use. This project will provide science that supports the efforts of the National Water Program (NWP) and the National Ambient Air Quality Standards (NAAQS) Program by addressing the most difficult and complex science questions associated with these challenges. Key research areas are drawn from the "Nitrogen and Co-Pollutant Research Roadmap", the Nancy K. Stoner memo (US EPA, 2011), and from stakeholders and include:

- Identification of nutrient-sensitive human and aquatic life uses of water resources and useful quantitative indicators of status or condition;

[3] The terminology in this project charter (e.g., "threshold", "endpoint") is used to describe supportive science for decision-making; however, definitions of terms should be considered in their scientific context and therefore do not imply direct translation to regulatory language.

- Quantitative relationships between nutrient loading and quantitative effects on water quality and nutrient sensitive uses in aquatic ecosystems across a range of temporal and
spatial scales;
- Quantification of sources, fate and transport of nutrients in watersheds, groundwater, watersheds, and airsheds.

Progress in these key research areas will address a variety of policy-related research needs, including quantifying the status of human and aquatic life uses and overall condition of aquatic ecosystems, resolving anthropogenic nutrient effects from natural conditions, predicting downstream water quality impacts or benefits associated with nutrient management decisions in watersheds and airsheds, characterizing aquatic life responses to temporally-varying nutrient loading and water quality, and understanding and predicting responses to nutrients in the context of other drivers (e.g., climate warming, coastal acidification, hydrologic changes). The project will advance the state-of-the-science using new tools and technologies such as remote sensing, continuous monitoring, genomics and bioinformatics, multi-media simulation modeling and geospatial data analysis.

Project Impact
Impairment of water quality and associated impacts to human and aquatic life uses resulting from nutrient pollution continue to be widespread. Despite progress toward nutrient management, pressures associated with human population and interactions with other stressors such as climate change will ensure that nutrient management continues to be an important environmental challenge for years into the future. This project will accelerate progress toward implementing nutrient management strategies by providing the NWP with better and more accessible scientific information to support two important elements of their framework for nutrient management: prioritizing watersheds for nutrient management and defining appropriate nutrient and related water quality and aquatic life thresholds for the nation's waters. By focusing on complex and challenging problems and delivering coherent and accessible scientific information, the results from this project will complement and support scientific analysis and policy development being pursued within the NWP and the NAAQS Program. Broader and accelerated progress on nutrient management will turn the tide in the direction of reduced nutrient impacts and improved water quality, meeting future needs for healthy water resources and the benefits that they provide.

Project Scope
This project will encompass research to generate, apply and synthesize data, methods, models,

scientific analyses and tools to inform: (1) prioritization of watersheds for management of nutrients and (2) development of nutrient-specific[4] water quality and aquatic life thresholds to support future efforts for effective assessment and management of nutrients in surface and ground waters. "Management of nutrients" means actions to prevent, limit, reduce, or mitigate "nutrient impacts," which refers to impacts to human health and human and aquatic life uses of water resulting from anthropogenic nutrient pollution. This project will address nutrient effects in or involving both ground water and surface waters, the latter of which includes streams, rivers, lakes, reservoirs, estuaries, and coastal waters. The project may consider all nutrient sources, including those resulting from air emissions and subsequent deposition to land or water. Research will emphasize spatial and temporal scales that most readily inform nutrient management, with the expectation that a logic path is developed for all research in the project whereby the results to be generated will inform nutrient management.

Research within this project will primarily seek to understand and quantify water quality and aquatic life responses or "endpoints" that are sensitive and specific to nutrient pollution. The project will develop indicators and methods to better assess and relate the potential for adverse impacts involving these endpoints, both locally and in downstream waters, to nutrient pollution. The project may address (1) whether responses to nutrient management approaches and thresholds of nutrient levels are different for protection of high quality waters versus recovery of impaired or degraded waters and (2) the extent to which threshold ecological responses to nutrient levels are present, for both high quality waters and recovery of degraded aquatic ecosystems. The project will therefore provide supportive science for those developing nutrient criteria, Total Maximum Daily Loads (TMDLs), condition assessments, etc. The project will also address how nutrient responses interact with other environmental changes such as climate change (warming, hydrologic change) and coastal acidification. The project is expected to identify nutrient thresholds for aquatic life health across multiple water body types and spatial scales and potentially combine information regarding sources, transport and fate with risk assessment information from the Human Health Risk Assessment (HHRA) program to identify thresholds for human health effects resulting from nutrient pollution.

Research to support prioritizing waters for restoration, management, and actions will focus on providing scientific information and analysis tools needed to evaluate a matrix of tradeoffs associated with different management action scenarios. These could include how to quantify and evaluate exposure and risk of nutrient impacts associated with delaying action and conversely, the potential environmental benefits associated with prioritizing action. Research could provide supportive scientific research toward how to resolve the relative economic and environmental benefits of remediating degraded waters (including watersheds with high

[4] "Nutrient-specific" refers to water quality thresholds that are useful and meaningful for managing nutrients (e.g., to meet water quality standards), as opposed to those water quality or aquatic life thresholds that may be most applicable to other stressors such as toxic contamination.

nutrient intensity) vs. prioritizing protection of high quality waters and their watersheds. Research on prioritization may also address methods for jointly weighing environmental risks with scientific uncertainty and other factors (e.g., economic costs, social preferences) that could impact the potential for a successful restoration action.

Out of Scope. Several areas of related and potentially important research are considered out of scope for this project. Although nutrient thresholds may consider the potential for harmful algal blooms (HABs), research specifically addressing the increased potential for HABs due to nutrient pollution is excluded because it will be addressed in Project 4.01. Research evaluating selection of nutrient management technologies (e.g., BMP selection or placement) could inform targeting, but is also addressed in other research (e.g., SSWR Project 4.03) and therefore out of scope. Cost-benefit analyses of nutrient management practices will also be conducted elsewhere (e.g., SSWR Project 4.03, 3.04, and 3.05). Finally, although research within this project will be designed to inform policy development, policy recommendations will not be made.

Project Structure and Rationale
The project will be structured into three task areas. Each task area will combine data acquisition and analysis, review and synthesis of existing research, modeling, and analyses and will consider how climate change (e.g., warming, hydrologic change, coastal acidification) will affect results. The project will address multiple spatial scales (e.g., multi-scale watersheds) and temporal scales (e.g., daily, seasonal, annual). The three task areas within this project include:

A. Nutrient-sensitive endpoints and indicators (***Task Area A: Indicator Development***)
B. Quantification of responses to nutrient pollution and recovery following remediation (***Task Area B: Ecosystem Response and Recovery***)
C. Quantification of nutrient sources, transport and contributions to near- and far-field effects (***Task Area C. Nutrient Sources and Relative Contributions to Impairment***)

Task Area A. Improved Nutrient Indicator Development: This task area includes research that identifies and quantifies endpoints and indicators that are sensitive to nutrient exposure in a variety of water body types, including freshwater (e.g., streams, rivers, lakes, reservoirs, ground water and drinking source waters) and estuarine and coastal marine systems. Indicator development in this task area will provide science to support development of condition assessments, support research relating exposure and response in Task Area 2, and inform regulatory actions. Research will seek to significantly improve data and information to evaluate nutrient effects on a variety of time and space scales and links to SSWR projects 3.01, 3.04, and 4.01. Research in this area could include:

- Application of emerging technologies such as genomics and bioinformatics to characterize aquatic life (with potential links to SSWR Project 4.01);
- Application of new monitoring technologies to water quality and aquatic life (e.g., continuous monitoring, satellite remote sensing, aircraft, or AUV based monitoring, photographic or video monitoring);
- Evaluation of indicators for different regions of the US and for different water body types (e.g., west coast estuaries, artificial reservoirs, different stream orders, black-water or turbid streams);
- Evaluation of indicator responses across different temporal and spatial scales.
- Evaluation of appropriate endpoints and indicators associated with nutrient-enhanced coastal acidification.

Task Area B. Ecosystem Response and Recovery: This task area includes research that seeks to relate nutrient sources, transport and exposure to response of nutrient-sensitive endpoints, whether local or downstream, in order to identify thresholds for management. This task area will include development of improved ecosystem- and watershed-scale multi-media models (e.g., air-land-water) to evaluate nutrient management options and support decision making. The task area may include also single media model approaches, in addition to field and laboratory based research, needed to resolve ecosystem process or other questions that informs development of thresholds or supports development of models for that purpose. Research in this task area could include:

- Development and deployment of an improved community water quality modeling infrastructure[5] to improve application of simulation models to relate nutrient sources, exposure and effects in watersheds and associated coastal marine systems.
- Application of multi-media watershed models to evaluate potential benefits of nutrient management within airsheds, watersheds, and in downstream waters. Research to evaluate sensitivity and exposures to nutrient loading and recovery potential following remediation (e.g., post-hoc case studies following nutrient reductions).
- Integration and application of models and empirical (e.g., field, mesocosm) data to advance understanding on the condition and functional ecological responses to nutrient thresholds and how these responses vary across watersheds scales, temporally, and to changes in management and climate change.

[5] Community modeling refers to simulation models that are developed collaboratively by the scientific community or other user base for the benefit and application of all. Community models are generally freely available and open-source. A modeling infrastructure refers in aggregate to a collection of software, data resources, model inputs, etc. that facilitates increased use of models by end-users.

- Application of models to better understand interactions involving nutrient loading and climate change (climate warming, hydrologic change) in watersheds and coastal waters (with potential linkages to SSWR Project 4.01).
- Evaluation of the risk of aquatic life impacts associated with an interaction between nutrient pollution and acidification in estuarine and coastal marine ecosystems.

Task Area C. Nutrient Sources and Relative Contributions to Impairment: This task area includes research to identify the major sources of nutrients that create the greatest impairment to human and aquatic life uses. Research in this area contributes mainly to the goal of informing prioritization of watersheds and sources for management actions. A key research focus will therefore include analyses of the sources and relative contributions of nutrient loadings that affect specific priority areas at multiple spatial scales (e.g., small watersheds, regions).

Specific scientific research goals in this task include:

- Improved methods to evaluate role of anthropogenic nutrient input in expression of coastal acidification.
- Improved methods to estimate ambient air concentration to deposition ratios on a broad scale.
- Methods to improve source attribution estimates for nutrients at multiple spatial scales (e.g., ecoregion, watershed), including separation of natural versus anthropogenic nutrient sources.
- Formal assessment of strengths and weaknesses of models for use in source attribution (examples include but are not exclusive to CMAQ, SWAT, SPARROW, NANI/NAPI, VELMA, HAWQS) to provide guidance on appropriate use for particular management or regulatory needs.

Measure of Success

This project will be successful if it provides significant new scientific information and improved access to scientific information (e.g., via analysis tools) to inform development of water quality, aquatic life, and other thresholds for nutrient management and prioritization of watersheds and sources for management actions, thereby accelerating progress toward effective management of nutrient pollution. The project will be most successful if the information provided is comprehensive in scope, informing development of policies related to protection of ground water (including drinking source waters) and surface waters, as well as management of nutrients from all sources, including air deposition, point sources, and non-point sources. Finally, success will hinge on effective translation and communication of the information and tools developed in the research, and that they are used to better achieve the objectives of the relevant stakeholders.

Stakeholders

This project should be of interest to government offices or agencies responsible for implementing nutrient management programs, or other groups with an interest in nutrient management. The EPA program offices most responsible for implementing Clean Water Act programs are in EPA's Office of Water: water quality criteria, water quality standards and effluent guidelines within the Office of Water/Office of Science and Technology (OW/OST), point source permitting within the Office of Wastewater Management, non-point source controls and TMDLs within the Office of Wetlands, Oceans and Watersheds (OW/OWOW), and drinking water source protection in the Office of Ground Water and Drinking Waters. Specifically, OW/OST develops and recommends methods for determining numeric nutrient criteria and works closely with EPA regions and states to encourage and provide assistance to the development and adoption of nutrient related regulatory controls. OW/OWOW is responsible for assessing the condition of the nation's waters and has a need for useful indicators of condition and associated thresholds to classify condition (e.g., good, fair, poor) across multiple water body types (e.g., streams, rivers, reservoirs, estuaries). OWOW also administers the National Estuary Program (NEP), a place-based program to protect and restore water quality and ecological integrity of estuaries. Managing nutrient impacts is a key aspect of NEPs. Source area analyses for nutrient loadings will also be important to EPA's Office of Air and Radiation (OAR). OAR implements the secondary NAAQS program, which evaluates nitrogen deposition effects on ecosystems and sets ambient air quality standards to protect those ecosystems including water bodies. This project should also be of interest to (and will be developed with consideration of research efforts conducted by) other Federal agencies that have a water quality mission related to monitoring and managing nutrients and water quality, including US Geological Survey (e.g., USGS National Water Quality Assessment Program), National Oceanic and Atmospheric Association (NOAA; Coastal Hypoxia Research Program), the National Park Service, other Federal Land Managers, and US Department of Agriculture and interagency programs such as the Interagency Hypoxia Task Force for the Mississippi/Atchafalaya River Basin, and the National Water Quality Monitoring Council. State and tribal governments and local or regional water management districts or agencies are primarily responsible for managing nutrients in their state waters, and technology developer and consultants are often brought in to assist with these efforts. Therefore, these entities should also be interested in this project.

Output

Title: **Methods, tools, data and scientific analyses to inform prioritization of watersheds for management of nutrients, set nutrient specific water quality and aquatic life thresholds**; and demonstrate and communicate new metrics, management approaches and use of monitoring data to verify the expected benefits from applying nutrient reduction management practices.

Brief Description: The EPA (ORD and partners) developed a draft "Nitrogen and Co-pollutant Research Roadmap" which identified key areas where critical gaps and opportunities exist for agency-based nutrient research. The report established six "Science Challenges" to achieve the goal of nutrient reduction. The Science Challenges are the means by which a management goal is translated to a science objective and a general research path (i.e., the essential steps needed to achieve an air or water quality goal). This output directly addresses two Science Challenges: 1) Where are the high priority areas to target for nitrogen and co- pollutant load reduction and 2) What information is needed to set nitrogen and co-pollutant reduction goals for priority areas? Efforts will also inform, to a lesser degree, the challenge of addressing whether we are achieving the nutrient reductions and ecosystem and human health benefits that we expect.

Delivery Date: September 30, 2019

Intended User and Audience: EPA's Office of Water/Office of Science and Technology (OW/OST), OW Office of Wetlands, Oceans and Watersheds (OW/OWOW), Office of Air and Radiation (OAR)

Key Products Identified

Product 1 (Task Area A): Nutrient sensitive endpoints for aquatic ecosystems and associated quantitative indicators.

Brief Description: This product will include research results (translated and packaged reports and manuscripts) that describe nutrient sensitive aquatic life endpoints and associated indicators that can be used to inform development of science-based decisions to prevent and reduce nutrient impacts.

Delivery Date: September 30, 2019
Intended User and Audience: OW/OST, OW/OWOW, OAR/NAAQS

Product 2 (Task Area B): Data, data analysis, research results, models, and tools to characterize aquatic life use responses to nutrients and associated water quality thresholds.

Brief Description: This product will include research results (translated and packaged reports and manuscripts), models, and modeling infrastructure that describe approaches and quantification of nutrient impairment levels that result in systemic aquatic ecosystem changes in select multi-scale watersheds across the US. Models and model-based tools will support development of nutrient management on a broad scale.

Delivery Date: September 30, 2019

Intended User and Audience: OW/OST, OW/OWOW, OAR/NAAQS

Product 3 (Task Area C)*:* Analysis to inform the identification and prioritization of watersheds for nutrient management.

Brief Description: This product will include approaches and research results (translated and packaged reports and manuscripts) locally and nationally that identify priority nutrient sources and watersheds for targeted management.

Delivery Date: September 30, 2019

Intended User and Audience: OW/OST, OW/OWOW, OAR/NAAQS

Key Resources

Assumptions and Constraints

The success of this project will require availability of sufficient personnel with expertise in water quality modeling and computer science. ORD currently has relatively little expertise in this area and is dependent on contractual or other support (e.g., EMVL) for computer science and supercomputing support. Overall level of FTE and other resources will set potential scope for research. Collaboration is necessary with ACE for multimedia modeling and air deposition loading analyses, with SHC for ecosystem services valuation of management alternatives, and potentially with the HHRA program for human health endpoints and nitrogen deposition effects science syntheses.

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Murphy, RR, WM Kemp, and WP Ball. 2011. Long-Term Trends in Chesapeake Bay Seasonal Hypoxia, Stratification, and Nutrient Loading, doi: 10.1007/s12237-011-9413-7.

US EPA. 2011. Memorandum from Nancy K. Stoner, Acting Assistant Administrator, US EPA Office of Water to US EPA Regional Administrators (Regions 1-10): "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions", March 16, 2011.

SSWR Project Charter
Nutrients – Project 3 (4.03)

Project Title: Science to Improve Nutrient Management Practices, Metrics of Benefits, Accountability and Communication

Project Leads: Jana Compton PL, Chris Nietch Deputy DPL

PL's L/C: NHEERL/WED, NRMRL/WSWRD

Project Development Team Members: Chris Nietch (NRMRL/WSWRD), Jana Compton (NHEERL/WED), Mary Reiley (OW/OST), Randy Waite (OAR/OAQPS), Matt Heberling (NRMRL/STD), Joe Schubauer-Berigan (NRMRL/LRPCD), Tara Greaver (ORD/NCEA), Sarah Lehmann (OW/OWOW), Jake Beaulieu (NRMRL /WSWRD), Julie Hewitt (OW/OST), John Wathen (OW/OST), Brian Hill (NHEERL/MED), Todd Doley (OW/OST), Ellen Cooter (NERL/AMAD), Autumn Oczkowski (NHEERL/AED), Ken Forshay (NRMRL/GWERD), Hale Thurston (NRMRL/STD), Grace Richardson (OW/OST), Chris Impellitteri (NRMRL/WSWRD), Richard Lowrance (NRMRL/GWERD), Chris Clark (ORD/NCEA), Dale Manty (ORD/NCER), Phil Zahreddine(OW/OW)

Project Start and End Dates: FY16-FY19

Executive Summary

Nutrient enrichment of the Nation's water bodies continues to be a significant risk to human health and ecosystems. Our current management strategies for point and non-point source nutrient reductions are inadequate to protect and meet the expected increased future demands of water for consumption, recreation, and ecological integrity. Research in this project is focused on the management of nutrient sources, loads and concentrations, within the context of changing sources and demands and expected impacts on social, economic and environmental systems. The proposed research will be focused in four major areas: 1) Tools to inform the application of innovative management practices, 2) Modeling approaches for consideration of policy options, specifically including economic evaluations and ecosystem services, 3) Monitoring and modeling approaches for verification of nutrient reductions associated with management practices, including cost effectiveness, adoption rate, co-benefits and unintended consequences, and 4) science to enable effective communication. To put it simply, **this project is about developing tools and conducting the required science to increase the adoption rate of nutrient management practices**. The goal is to demonstrate transferable modeling techniques and monitoring approaches to enable water resource professionals to make comparisons among nutrient reduction management scenarios across urban and agricultural arenas. and alongside estimates of nutrient source loads from WWTPs, septic systems, industrial point sources, air deposition and other non-point sources as well as native features of watersheds at multiple scales and across media (air, land, water). This project produces the applied science to allow better management of nutrient loadings to the Nation's water bodies leading to the full restoration of designated uses and adequately protect and meet the future demands for clean water for consumption, recreation and ecological integrity.

Research Project Description

Nutrient release to the environment continues to impact aquatic systems in the US. Though current point and non-point source pollution policies and management have produced substantial results, they are inadequate to protect and meet the expected future demands for water for societal and ecological uses, including the added pressure of changing land use and climate, growing population centers, and continued nutrient inputs. The emphasis of this project is to evaluate ways to reduce the unwanted impacts of nutrients through management processes (including natural ones) that enhance the conversion of excess nutrients to stable forms (e.g., complete denitrification of reactive N to N_2; complexation and burial of P), focus on recovery and recycling of the excess and reduce new inputs of fixed nitrogen and mined phosphorus to ecosystems. We emphasize a multi-media approach to capture unintended consequences and co-benefits, which can be equally as important as direct benefits. A critical component of this research is that it builds upon the collaboration already underway with other Federal and State Agencies. This work addresses Science Challenge 3 and 4 (BMP effectiveness) and also 5 and 6 (Assessing and Reporting on Effectiveness) within the Cross-ORD Nitrogen Roadmap.

Project Impact

The release of nutrients to U.S. streams, lakes, groundwater and coastal ecosystems has increased tremendously from human actions during the last century. For example, nearly 65% of the N fixed from the atmosphere each year is leaked as bioavailable forms to the environment, and more than half of this N makes its way into aquatic systems. These nutrients are introduced via agricultural activities, fossil fuel combustion, urban land use and waste management. While changes in policies have reduced reactive nutrients in some places and from some sectors, overall there are still eight thousand plus water bodies that are impaired by nutrients. They rank as the 2nd highest cause of impairment contributing to the degradation of 19% of the waterbodies on the Nation's 303D list, and this does not take into consideration indirect causes related to nutrients. We continue to see harmful algal blooms (HABs), hypoxic events, and drinking water contamination associated with nutrients affecting communities across the US.

The research needs related to nutrient management effectiveness are substantial. At present, we do not have enough information to determine if adoption of current management practices resulted in the human health and ecological benefits anticipated. We need a multi-media approach for evaluating the success of management practices. We do not have sufficient metrics to understand how people respond to different incentives or a vision of how to best communicate the benefits of adopting nutrient management practices to initiate change.

In this project, we seek to inform more sustainable management of nutrients by developing approaches that can be used by partners and stakeholders to stem the tide of nutrient release using a multi-sector, multi-scale, systems viewpoint. Our goal is to inform policies across scales that will lead to cost-effective reductions in nutrient release, including the ability to document the water quality benefits and co-benefits associated with these reductions. *This project produces the applied science to allow better management of nutrient loadings to the Nation's water bodies toward the full restoration of designated uses and the adequate protection and meeting future demands for sustainable clean sources of water.*

Project Scope

Research efforts will focus on improved technologies and management practices to reduce nutrient loadings from multiple sources at the watershed scale. Management practices may include reducing net inputs of nutrients, improving the efficiency of nutrient use (correct rate, place, timing, and form in agriculture), removal of nutrients along flow paths to aquatic systems, and re-use/re-capture using innovative interception and treatment technologies. Research may place additional focus to approaches for decreasing the release of nutrients through revising the wastewater collection and treatment paradigm, improving watershed nutrient removal, reducing air emissions and adapting to future conditions such as climate change, expanding populations, and population shifts to areas with insufficient water resources. Nutrient management research will be scalable to watersheds and include a systems approach for considering multi-media impacts and the co-benefits as water quality improves. The research will yield results that can be applied to designated use attainment at smaller scales (e.g., HUC12), while being applicable to whole watershed systems. The intent of this project is to focus on the demonstration of management practice effectiveness at watershed or larger scales than that of the individual practice or the individual field/lot/POTW.

In order to increase the adoption rate of these innovative management practices at larger scales, research is needed to support a broad selection of policy considerations (regulatory and voluntary); for example, market-based approaches, incentive programs, and watershed education and outreach. This project augments research underway with the USDA, States, and other stakeholder groups designed to inform programs, policies and management decisions to reduce loadings of nutrients from agricultural sources. Collaboration with Office of Air and Radiation will be critical to increase linked approaches and methodologies for the abatement of atmospheric (stationary and mobile source) deposition of NO_x and NH_3 to watersheds and regions. Collaboration with OW to address surface water, groundwater, and drinking water perspectives is a critical component of the research in monitoring, implementation and communication. The questions from the Programs, Regions, and States driving the scope of this research area are the following:

How do we use regulatory and voluntary approaches to promote more innovative and effective management practices to reduce nutrient pollution?

How do we verify, value and communicate the effectiveness of nutrient reduction policy and management?

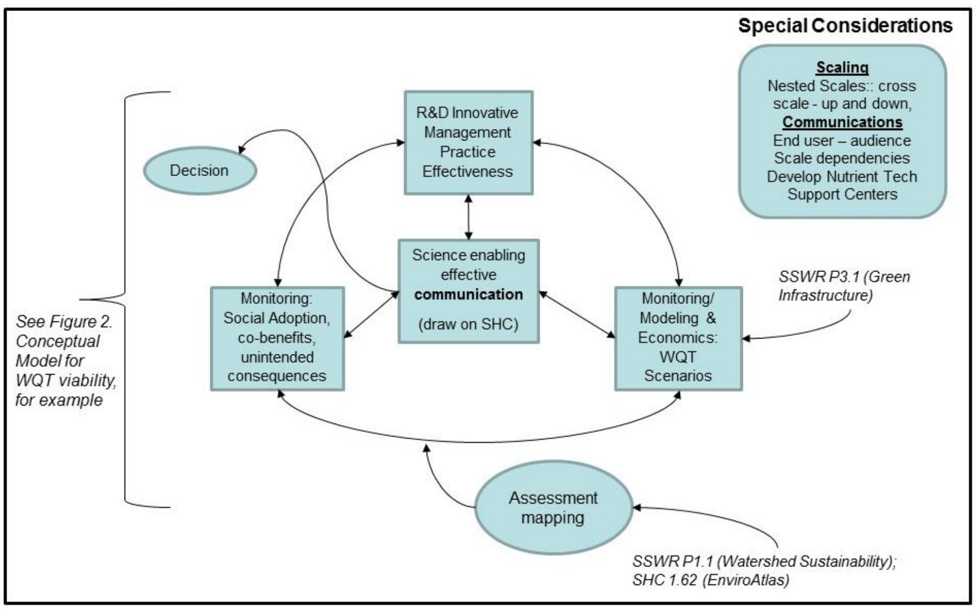
Project Structure and Rationale

Within this project, the following ***four task areas*** will be the focus for research:

1) Tools for the application of innovative management practices,
2) Modeling and multimedia approaches for consideration of market-based policy options, specifically including economic evaluations and ecosystem services,
3) Monitoring and modeling approaches for verification of nutrient reductions associated with management practices, including cost effectiveness, adoption rate, co-benefits and unintended consequences, and
4) Science enabling effective communication.

Figure 1 outlines the structure of the research and the cross-connections among the tasks. We envision that communication will be central to this work, because effective communication of results is essential to adoption and implementation of management practices. Below we outline some examples of the kinds of research we anticipate within each task area.

Figure 1. General structure of SSWR Project 4.03.



Task Area 1. Tools for the assessment of innovative management practices. The focus of research here is on tools development allowing for the demonstration or estimation through modeling of what implementation of nutrient management practices mean for watershed wide nutrient loading (or concentrations). Demonstration of the effectiveness of management practices at broader spatial scales than would be typically considered for an individual practice is the emphasis. For instance, while demonstrating the effectiveness of an advanced technology for nitrogen removal and recovery at a POTW would represent a current and relevant research need, it would not represent the type of the research addressed in this project until those reductions were scaled to the watershed where the POTW resides, and done so in a framework that could include determining how to compare the associated cost with the costs and benefits associated with alternatives. We anticipate that this task area will draw upon existing efforts that have or will apply nutrient management practices intended to reduce nutrient loads to aquatic systems. SSWR Topics 5 (Green Infrastructure) and 6 (Water Systems) capture nutrient removal research in engineered systems.

Other, or similar efforts may involve reviewing and applying existing multimedia models for management practice scenarios for their value in decision support. We need transferable modeling techniques and monitoring approaches that would allow water resource professionals to make comparisons among nutrient management scenarios within and across urban and agricultural areas and alongside estimates of nutrient source loads from WWTPs, septic systems, and other native features of watersheds. Research in this task area helps build a watershed or landscape systems approach rather than a field-by-field or reach-by-reach approach. Potentially applicable research could come from the use of the one-environment model used for the Gulf of Mexico to explore alternative management scenarios, connecting nutrient endpoints with other media (air and land) processes.

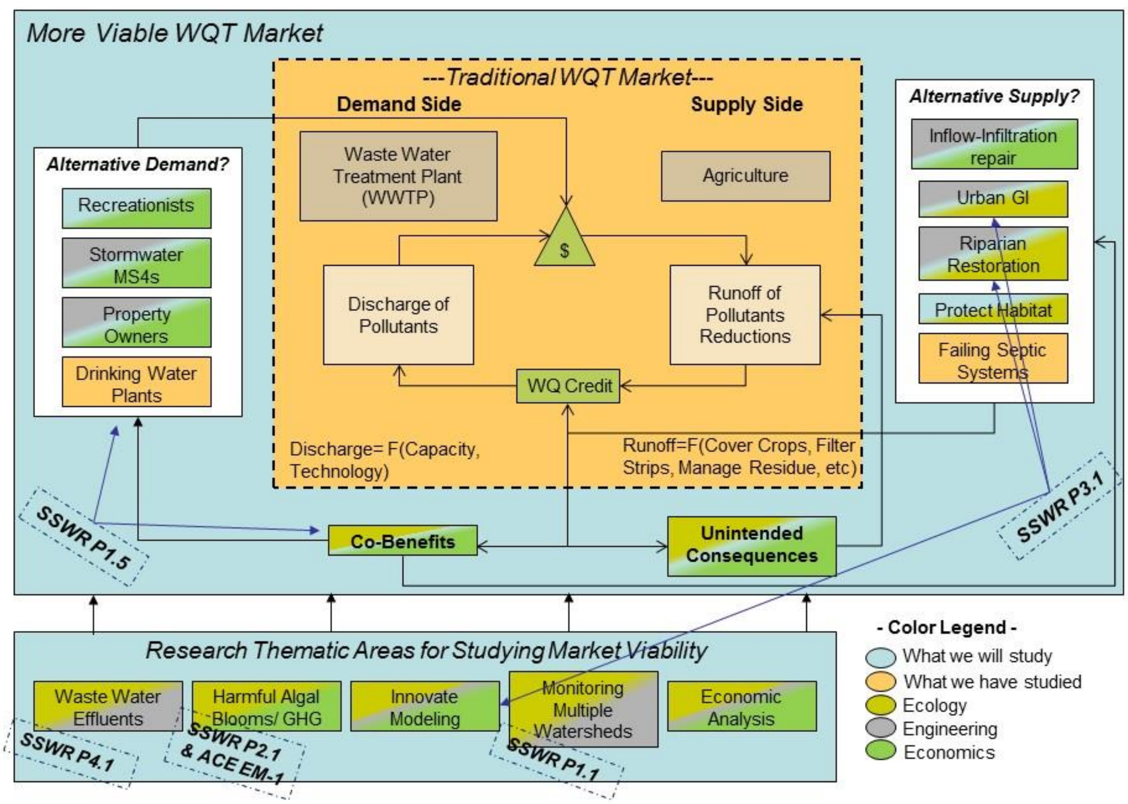


Figure 2. Example conceptual framework for integrating research in Task Area 2.

Task Area 2. Modeling approaches that allow for consideration of market-based policy options. Economic approaches for nutrient reduction, such as market mechanisms and incentives, require research. Studying the feasibility of bringing alternative participants into more viable markets for nutrient trading is an example of the type of research needed. Although the methodology for estimating a drinking water treatment plant's incentive for protecting source water vs. treatment on-site has been developed in P1.2 in the previous SSWR RAP, there is more work needed to make better linkages to nutrient loadings and concentrations for consideration of source water protection. Additional non-traditional participants such as recreational interests, NGOs, homeowners, and stormwater utilities also need to be considered. Figure 2 depicts a conceptual framework linking potential non-traditional participants in a trading market and the research areas requiring focus in order to understand market viability. For example, recreational users who face beach closings due to harmful algal blooms (HABs) and local property owners that live near small streams with excessive nutrient loadings and/or reservoirs with problems of HABs also have an incentive to purchase nutrient reduction from upstream agricultural producers. The incentives are examined by estimating the economic value of changes to nutrient loading in streams or changes in the number of HABs due to nutrient abatement. Developing markets between rural and urban sources (stormwater utilities) is also gaining interest. Many of these economic approaches still have to be examined for co-benefits. For instance, what is the impact of addressing nitrogen on co-pollutants, e.g. phosphorus, in a market-based approach?

Another critical co-benefit of nutrient reduction is the linkage with greenhouse gas emissions (GHG). This will specifically be addressed in this task by first, establishing a quantitative link between nutrient loading and GHG emissions for mid-latitude reservoirs. This research links with EPA-ORD's Air, Climate, and Energy Research (ACE) Program in Project EM-1: Methods for Measurement to Inform Policy Decisions (Task Title: Development of measurement methods and statistical models to predict emissions from impounded waters (reservoirs)). Once the links have been established, the concomitant GHG decreases will be valued for inclusion in the market feasibility evaluation. Leveraging with the Social Cost of Carbon estimates will help guide how we include the GHG-Nutrient linkages in the market analyses.

Task Area 3. Monitoring and multimedia modeling approaches for verifying reduction. This research should include approaches to verify the projected nutrient reductions afforded by management practices and consider cost effectiveness, adoption rate, co-benefits and unintended consequences. We recommend that research in this task area include identification of areas where a large scale nutrient reduction effort is ongoing or definitely planned. The goal is to foster the understanding of the systems of best practices that most effectively address nutrient issues and the breadth of implementation that is needed before positive results can be expected and measured at different scales (watersheds or basins) and for different endpoints (e.g., target nutrient concentrations, loads, biological response, etc.). This research would address the driving question: can we effectively summarize the expected results from BMP specific projects to promote several key activities on a broad-scale or at least for large portions of the country).

There is a shortage of information to characterize how aquatic systems, particularly coastal systems and groundwater, respond to nutrient reductions in general, and even less on how systems respond to non-point source reductions. It will take a long time (years) to monitor/assess the response, which means that datasets are needed that span years. Only through more systematic analysis of long-term datasets will better understanding be gained on the net impacts of multiple-stressors and cumulative impacts. We propose to build on existing programs to create a formal inventory of nutrient release to the environment and response of aquatic ecosystems. While partnering with effort in SSWR P4.02, the focus here is placed on response to management actions. To this end considerations need to be given to the appropriate spatial and temporal scales of monitoring and that the best indicators are being tracked. This may require adjustment to existing programs. Such a nutrient inventory will help define the marginal impacts of greater nutrient pollution. With these we can approximate the benefits of nutrient limitation while the longer term realities management implementation are awaiting documentation. Resources put forth here would partner with EPA monitoring programs (such as the National Aquatic Resource Surveys (NARS), Clean Air Status and Trends Network), and would take advantage of other existing monitoring programs (USGS, USDA, NOAA, NADP, NWQMC).

Other examples of research in this task area could include effort that builds upon previous work conducted under the SHC program comparing sales-derived estimates of nitrogen inputs with extension recommendations to gauge what local farmers are actually applying. This work requires collaboration with other agencies (e.g. USDA, USGS, states). Identifying areas where outreach and education could improve nutrient use efficiency could be coupled with focused monitoring activities to document subsequent decreased multi-media nutrient release. Similarly, work with the state and region to quantify nitrate loading from fields to groundwater informs nutrient management and large-scale empirical models used to study scenarios of N use (and soon P use) reductions at the national scale. Additionally, research could evaluate changes in ecosystem services due to management implementation, which would link to the ORD Sustainable and Healthy Communities Project 4.61 as well as SSWR 3.4 which quantifies the benefits of water quality improvements.

Task Area 4. Science enabling effective communication and technology transfer. We recognize that there may not be enough ongoing communication and outreach research capacity within ORD and thus we expect that this research would proactively partner with universities and other federal and state entities (e.g., USDA-NRCS, Soil and Water Conservation districts) that have active programs in this area. While we identify communication as a central theme within each of the research activities expected in this project, we envision this specific task area focusing on the science enabling communication as primary research necessary to increase the adoption of nutrient management practices at appropriate scales and within a programmatic framework that can measure effects. Ultimately our goal is to develop approaches that contribute to the local to national dialog about improving nutrient use and release to the environment.

Discussions related to what research approaches might characterize the nature of work in this specific task area have included speculation on the application of case studies to develop benchmarks for communication and outreach efforts that have been effective in changing pollution management. A specific example references the educational outreach activities of local agricultural extension services, where a university extension hosts workshops to educate farmers on the use of conservation practices and includes follow-up tracking of the resultant changes in farmer practices. We propose that this task develop similar types of outreach activities connected to EPA's nutrient research. Several of these workshops could be assessed using a "synthesis among case studies approach" to help define best communication practices leading to increased adoption rate. Communication tools that focus on nutrient treatment, reduction, trading and other associated costs could be immediately useful to states and tribes during stakeholder involvement.

Another potential area of focus includes improving the effectiveness of EPA staff in 'getting the message across'. This might take on the form of specific training in communication and stakeholder interactions. We acknowledge this may be a new area for many ORD science staff, or that different researchers have different levels of experience in this area. Thus, training and workshops to improve the ability for EPA staff to learn and apply this new knowledge could be a part of this task area. We also envision message studies with focus groups – what gets their attention and action? And this work should include a literature review of communication research with findings applicable to EPA and State efforts.

Measure of Success

The success of this project will be measured based on how well the research provides better science *to* ***document progress towards reduced nutrient loading and concentrations across media, over time, including approaches to document cost effectiveness, co-benefits, and unintended consequences.*** New metrics may be needed to assess all of these aspects of progress. The extent to which the use of research products developed in this project documents changes in practices and resulting changes in nutrient release to the environment would prove a sound measure of its success that will be tractable. The project succeeds if the scientific approaches developed here can be effectively communicated so that users at all scales can design their own sustainable nutrient management programs.

Stakeholders (outside ORD)

This work should be conducted with up front involvement of relevant program offices, including OWOW, OW NARS program staff, OST, OGWDW, OAR programs, OAQPS, NCEE and OSP, EPA STAR grant-funded nutrient centers and EPA Regional staff. Where feasible, multi-sector collaborations will be established to foster and help track the development, transfer and adoption of viable models, tools and technologies. In the local efforts, there will be additional community-level stakeholders that could include state, city and county governments, state agriculture and public health staff, Groundwater Management Areas, Soil and Water Conservation Districts, technology developers, technology innovation clusters, economic development organizations, utilities, fertilizer companies, watershed councils and EPA regional staff. Connection to other relevant federal agencies is also critical. For example, potential collaborators include USGS national programs and regional science centers, USDA programs such as NRCS, FSA, ERS, and ARS as well as the new USDA regional climate hubs, and USACE divisions and basin-wide programs. We also anticipate working with the Regional Technical Advisory Groups on nutrient issues that have formed in each EPA Regional office in conjunction with OW-OST.

Output

Methods, tools, data and scientific analyses to inform prioritization of watersheds for management of nutrients, set nutrient specific water quality and aquatic life thresholds; and **demonstrate and communicate new metrics, management approaches and use of monitoring data to verify the expected benefits from applying nutrient reduction management practices.**

This output represents work from SSWR 4.02 and this project SSWR 4.03. The work in project 4.03 applies mainly to the text in bold.

Key Products Identified

Task Area 1: Management Practice Effectiveness

- Synthesis document for considering the effectiveness of management practices at large watershed scales. FY 18
- Tools demonstration for estimation through modeling what implementation of nutrient management practices mean for watershed wide nutrients. FY19
- Technical support documentation for considering sustainable management approaches that applies improved technologies in order to reduce nutrient loading. This product should consider multi-media pathways that go beyond current regulatory approaches. FY19

Task Area 2: Monitoring-Modeling-Economics

- Approaches to consider additional participants and feasibility for more viable water quality trading markets that include co-benefits and potential unintended consequences. FY 19
- Approaches for incorporating carbon and nutrient budgets in linked lotic-lentic economic trading markets for determining co-benefits associated with greenhouse gas emissions (N_2O, methane, and net C storage) and harmful algal blooms. FY 19

Task Area 3: Monitoring for verification of nutrient reductions

- Coupled evaluation of the changes in nutrient inputs to the US landscape with monitoring results from the national surveys (HUC 12 scale). FY17
- Build on existing programs to create a formal inventory of nutrient release to the environment at HUC12 scale (collaborative with e.g., USGS, USDA, NADP, NWQMC). FY19
- Case study demonstration of results of a nutrient reduction approach to decreasing nitrate concentrations in groundwater. FY19
- Approaches for monitoring/measuring co-benefits, unintended consequences (e.g., emissions of N that redeposit elsewhere). FY19

Task Area 4: Communication science

- Communication training to improve effectiveness for EPA staff. FY18
- Literature synthesis applicable to EPA and state organization efforts. FY 19

- Findings from Messaging Focus Groups. FY19
- Case studies and benchmarks of effective communication and outreach effort. FY19

Collaboration
Because this project brings together the state of the art on nutrient-related management, monitoring, modeling and outreach, it relies on intersecting with other components of research programs in ORD, and across agencies. We identify some of these key intersections here.

Other SSWR research: This effort should be closely linked with the research in SSWR Project 4.02, which is about developing thresholds for impairment and prioritizing watersheds for nutrient management, and SSWR Project 4.01, which focuses on the drivers, impacts and management associated with harmful algal blooms. Project 4.03 would conceptually pick-up where these others end, building upon the work, increasing the incorporation of management and social and economic factors to support nutrient decisions on the ground. This effort would apply the economic information (non-market valuation for water quality changes that includes nutrients) coming out of SSWR Project 3.05 (National Water Quality Benefits Collaboration). For example, if we knew that X% reduction in N to a lake would result in a Y% increase in property values (after accounting for the translation functions, in this case, water clarity, perhaps), we could use this information to quantify the benefits to be used by both the water and air programs associated with the management practices. This effort should also draw upon the watershed case studies included in the SSWR Project 1.1B (Previous SSWR RAP), in particular drawing on the site-specific studies related to nutrients. Model evaluation and development efforts included in SSWR Project 5.01 (Green Infrastructure) that focus on mechanistic techniques for simulating GI scenarios for nutrient removal at multiple scales will be leveraged to accomplish the research discussed in both the first and second task areas. Furthermore, considering that waste capture and re-use are key components of this work, SSWR Topic 6 research on treatment and resource recovery will be critical to consider and incorporate in the watershed-scale evaluations. These linkages are also depicted in figures 1 and 2.

Other EPA research: Application of the one-environment models and scenario results emerging from coupled ACE-SSWR-SHC research is expected to bring a large watershed approach to this project. Research on integrated nitrogen management from SHC 4.61 will also be useful, as will case study information from SHC 2.61 "Ecosystem Goods and Services" (for example study of the demonstrated reductions in nutrient release to Tampa Bay could inform our project). Large-scale monitoring of nutrient reductions also will necessitate using information from the EnviroAtlas (SHC 1.62). Relevant research and studies recently completed, underway, or planned in OW, OAR, and Regions will be accessed and considered.

Other Agency Research: See Stakeholder section above.

Assumptions and Constraints
- We assume research will yield results that can be applied to designated-use attainment, while being applicable to whole watershed systems. A focus on demonstration of

management practice effectiveness at larger scales beyond the individual practice or the individual field/lot/POTW is a must.

- There will be nutrient information in the non-market valuation work in SSWR P 3.05.
- There will be large watershed case studies where management practices have been applied at a density to be effective and scalable.
- There will be opportunities to evaluate innovative nutrient management practices in conjunction with states and other federal agencies.