B O S C
Board of Scientific Counselors

February 29, 2016

Thomas Burke, Ph.D.
Deputy Assistant Administrator
Office of Research and Development
U.S. Environmental Protection Agency

Dear Dr. Burke:

On behalf of the Board of Scientific Counselors (BOSC), I am pleased to provide you a review report of the Office of Research and Development's (ORD) Strategic Research Action Plans (StRAPs) and the cross-cutting program Roadmaps for Environmental Justice and Global Climate Change.

The BOSC was reconstituted in 2014 with an Executive Committee and five subcommittees aligned with each of the National Research Programs (part of the Human Health Risk Assessment program is reviewed in conjunction with the Chemical Safety for Sustainability program). Each of the subcommittees met during 2015 culminating in an Executive Committee meeting in December 2015. This report represents the cumulative effort of the subcommittees and the Executive Committee.

We anticipate that this report will assist ORD in evaluating the strength and relevance of the research programs and aid in guiding future course adjustments to the program. Generally, we were impressed with the responsiveness of the research programs to revising the StRAPs, and found the programs to be on track to meet their objectives. We found the Environmental Justice Roadmap to be a good foundation and recommend that it continue to be developed; we found the Global Climate Change Roadmap to be less mature, and recommend that it continue to be revised and developed. We will be happy to provide any additional information concerning the review or answers to any questions you may have.

Sincerely,

Deborah L. Swackhamer, Ph.D.
Chair, Board of Scientific Counselors

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REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

BOSC Executive Committee

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Tom Tracy, Designated Federal Officer

January 8, 2016

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

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LIST OF ACRONYMS

ACE	Air, Climate, and Energy
BOSC	Board of Scientific Counselors
CalEnviroScreen	California Communities Environmental Screening Tool
CSS	Chemical Safety for Sustainability
EJ	Environmental Justice
EJSM	Environmental Justice Screening Methodology
EPA	Environmental Protection Agency
FACA	Federal Advisory Committee Act
FTE	full-time equivalent
GCC	Global Climate Change
HHRA	Human Health Risk Assessment
HSRP	Homeland Security Research Program
IRIS	Integrated Risk Information System
ISA	Integrated Science Assessment
MVD	"Making a Visible Difference"
NEJAC	National Environmental Justice Advisory Council
NIEHS	National Institute of Environmental Health Sciences
NOAA	National Oceanic and Atmospheric Association
NPD	National Program Director
ORD	Office of Research and Development
PPRTV	Provisional Peer-Reviewed Toxicity Value
RP	responsible party
SAB	Science Advisory Board
SHC	Sustainable and Healthy Communities
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) Board of Scientific Counselors (BOSC) provides advice and recommendations to EPA's Office of Research and Development (ORD) on technical and management issues related to its research programs. It is one of several Federal Advisory Committees that provide advice to EPA, and it specifically focuses on the evaluation of the science conducted internally by ORD to support their mission.

In January 2015 the BOSC and the EPA Science Advisory Board (SAB) presented the EPA Administrator with a joint assessment of the strategic directions of the Agency's research and preliminary reviews of the Strategic Research Action Plans (StRAPs) of the national research programs. The research programs then revised their StRAPs in response to this joint report.

The BOSC was rechartered in 2014 to consist of an Executive Committee that oversees five subcommittees devoted to each of the national research programs (part of the Human Health Risk Assessment program is reviewed in conjunction with the Chemical Safety for Sustainability program). Over the last six months, each of the subcommittees met with ORD senior staff, and the respective National Program Director (NPD), and scientists for the relevant research area. They reviewed the revised StRAPs and responded to a series of Charge Questions provided by ORD. The Charge Questions were high-level questions to elicit feedback on the program's research direction and focus, and on the effectiveness of the programs in engaging partners and stakeholders at the appropriate time in the research cycle. There were five Charge Questions in common across the subcommittees, and several program-specific Charge Questions unique to each subcommittee.

The BOSC Executive Committee met in Washington, DC on December 8-10, 2015 to review, summarize and synthesize the five subcommittee draft reports. Certain "common threads" emerged from the subcommittee reports, and they are presented here along with the summaries of the subcommittee reports. The full subcommittee reports are attached to this report as appendices. In addition, the BOSC Executive Committee reviewed the draft Roadmaps for two of the cross-cutting ORD programs, Climate Change Research and Environmental Justice Research. The other two cross-cutting programs, Integrated Nitrogen and Children's Health, were reviewed in a previous BOSC report. The assessments of these programs, and answers to Charge Questions from ORD, are provided in this report.

This report represents the final stage of BOSC review of the planning process that ORD has undergone since its reorganization of its science enterprise into a matrix of six national programs that are implemented by ORD scientific staff across its laboratories. BOSC will turn its attention to reviewing and evaluating the implementation of its StRAPs and Roadmaps in the future.

REVIEW OF NATIONAL RESEARCH PROGRAM STRAPS

Introduction

The BOSC subcommittees were constituted to provide targeted review and assessment of ORD's national research programs. The subcommittees correspond to the research programs, and include subcommittees on Homeland Security (HSRP); Air, Climate and Energy (ACE), Chemical Safety for Sustainability (CSS), Sustainable and Healthy Communities (SHC), and Safe and Sustainable Water

Resources (SSWR). The research, non-service aspects of Human Health Risk Assessment (HHRA) are also reviewed by the CSS subcommittee. Because they are a small piece of the overall HHRA program, it was decided that their review could be done more efficiently in conjunction with CSS. Each subcommittee was populated with 7-12 professionals with a range of expertise and backgrounds.

Each subcommittee met with senior ORD staff, the NPD, and scientific staff from their corresponding national program. They responded to a series of Charge Questions provided by ORD, based on their meeting and supporting documentation including the revised StRAP. The final subcommittee reports in full form are in the Appendices of this report. Summaries of the important points and key recommendations from these reports are provided below.

In general, the subcommittees found that the StRAPs are effective planning documents. The research programs are all on target with their strategic goals, and they have a high likelihood of achieving these goals in the timeframe that was laid out. The BOSC Executive Committee, in reviewing the StRAPs and the subcommittee reports, would like to commend the senior leadership of ORD and the NPDs for having moved so quickly to the newly organized matrix model that ORD has embraced. The BOSC Executive Committee also notes that the StRAPs represent a much greater degree of integration across the various research areas, reducing the "silo" effect as was intended.

The BOSC Executive Committee, in reviewing the subcommittee reports, found that observations or recommendations emerged that were common to most or all of the subcommittee reports. These have been provided below, prior to the summary recommendations of each subcommittee report.

The subcommittee summaries highlight recommendations specific to their corresponding research programs. The subcommittee recommendations that were common across programs are not repeated, but are found in "Common Threads", below.

Common Threads Across Research Programs: Observations and Recommendations

The recommendations below were common across several or all of the research programs, indicating that they may of particular interest to ORD to address as a whole. The BOSC recommends that ORD should:

1. Clearly define what is meant by "partners", "stakeholders", and "(end-) users". These definitions (but not the actual entities) should be consistent across the research programs and used consistently in all written documents, including the StRAPs.
2. Identify the specific partners and others (see above), and clearly document the process used to engage them in each part of the research process, for each of the research programs. For instance, certain partners should be engaged in problem formulation, and others may more appropriately be engaged in research planning or implementation. A table that has partners, stakeholders, etc. and their roles at each of the stages of the research cycle would be instructive and assist in planning. Finally, ORD should develop measures to evaluate the effectiveness of these engagements. The BOSC offers its participation and assistance in developing such measures for ORD.
3. Develop measures of success for outputs and outcomes for each program area. This includes both quantitative indicators and qualitative information. These indicators should be easily measurable, track progress closely, and widely accepted by EPA, partners, stakeholders, and the decision makers. Collectively, the indicators should be comprehensive; that is, all important outputs should be captured by an indicator.
4. Identify specific needs and research questions within and across programs that can be addressed by social scientists, and identify the specific disciplines within the social sciences that would best fill these

needs. Across the EPA ORD Programs and Cross-cutting Roadmaps reviewed by the BOSC, there are repeated calls for "more social science" or increasing research capacity in the social sciences. While the programs recognize this overall need, in most cases "social science" is not further defined. Greater specificity is needed to articulate the questions that are emerging that require input from particular social science disciplines or research that would benefit from social science methodologies. Once these needs are identified by ORD, the BOSC is willing to assist programs in moving forward in how to operationalize these needs.

5. Develop a consistent, multidirectional communication strategy across all of ORD to inform, educate, and encourage interactions with partners, stakeholders, users, end-users, and clients. These parties should be engaged at the various stages of the research cycle, including problem formulation, research planning, implementation, and work product development. Different stakeholders and partners may be involved at different points in the research cycle where their engagement would have the most impact – not to direct the research agenda but to provide their perspective on what research products are most needed and how they will be used. We recognize that there are various communication tools being used by ORD, but a clear and consistent communications strategy needs to be articulated. Research translation needs to be a critical part of this strategy (see next bullet).
6. Further develop and enhance efforts in research synthesis and translation. The need for synthesis and translation of the results of program research is critical in order to support policy decisions, particularly as the programs participate in more public engagement. The BOSC applauded program involvement in translational efforts and urged continued investment in these efforts. They recognize that part of the current culture change in the Agency is to enhance the ability of researchers to understand their work in a larger context and learn how to communicate research results to non-specialists. While some project investigators might have expertise in translating and/or synthesizing research results, it is not necessarily desirable to require all investigators to engage in translation and/or synthesis efforts. The programs might benefit from identifying and/or training the appropriate people (scientific full-time equivalents (FTEs)) best suited to synthesis and/or translation of research work. Rewards and incentives should be in place, because synthesis and translation work does not necessarily result in peer-reviewed publications, yet the impact on policymakers and the public can be substantial.
7. Strengthen, enhance, and invest in more effective within-Agency interactions. The success of ORD is highly dependent on conducting good science *and* on how well their research meets the needs of their Program Office and Regional Office partners. The BOSC recognizes that there are processes in place to provide interactions between ORD and its partners, such as Regional Liaisons, webinars, etc., but these efforts are inconsistent in the degree to which they are effective. ORD is encouraged to build these efforts into a more robust and integrated program, one that is institutionalized and not dependent on the enthusiasm of key individuals. It is important for all partners to contribute to and have ownership of the ORD research process. Dedicated staff and budgeting for collaboration will enhance the participation of EPA partners in problem formulation, the design of research and the successful use of research results at the regional and program levels.
8. Continue to nurture and expand cross-program and transdisciplinary integration. Efficiencies and synergies appear possible beyond current interactions among the programs. For example, data collected by CSS may be useful for the tools developed by SHC. The focus on addressing emerging issues in HSRP may provide insights to the other programs in how to balance long-term research with more emergent issues that arise. The expertise developed in SHC in community engagement could be useful to the HSRP program in transferring their tools to the local level.
9. Maintain alignment between research that is focused on short-term goals and long-term objectives, as both are relevant in different contexts ranging from remediation and containment to improving human health outcomes and achieving long-term well-being. In addition, ORD should maintain the

alignment between research that is responsive to partner needs and research that is proactive and motivated by forward-thinking research questions that may anticipate future partner needs. Despite their different motivations and temporal horizons, these various research threads should be mutually informative. Short-term research can help identify long-term questions; intermediate outcomes and products of long-term research can be used to solve short-term questions.

10. Continue to develop innovative decision support tools by drawing on partner and stakeholder engagement to improve dissemination, utility, evaluation, and adaptive improvements of tools. Decision support tools are important in many program areas. Each research program should consult with the specific stakeholder(s) to ensure that the tools will address their needs, as well as be usable, helpful and effective.
11. Increase efforts to integrate tools with attention to interoperability and the ability for tools to inform each other and to answer research questions. A common theme voiced across the research programs was the need for interoperability among the various databases and analytical tools. Many of the tools use different platforms that limit interoperability. This can increase the costs of adding capabilities to the tools through extensions and/or integration. This also increases long-term maintenance and support costs and raises the tools' collective complexity and training requirements.
12. Make necessary investments to increase IT capacity. Keeping abreast of advances in calculation capabilities, hardware and software advances, and highly-skilled IT staff (such as informatics specialists) are essential to the successes of ORD. Each of the programs, to more or less of a degree, is impeded by IT deficiencies. The leadership of CSS requires bioinformatics experts and computing capacity for the vast "big data" generated by screening and evaluation; SSWR, and ACE are hampered by the inability to link models and tools; and HSRP has cyber security concerns. Such investments are an integral component to the continued success of each program, and if not made, can be a barrier to future successes.

Summary and Synthesis of Key Recommendations

Air, Climate, and Energy (ACE)

Overall, the ACE Subcommittee found that the vision and objectives in the ACE StRAP are clearly articulated and the research topics and project areas are planned and organized appropriately. As a general conclusion, the Subcommittee agreed that the ACE plan provides a structured vision and actionable design to guide an ambitious research portfolio that delivers the science and engineering solutions the Agency needs to meet its priorities and fulfill its legislative mandates, with a specific focus on three stated objectives:

1. Assess impacts;
2. Prevent and reduce emissions; and
3. Prepare for and respond to changes in climate and air quality.

The results of ACE program research support policies that have far-reaching positive impacts across the nation, including reducing health risks from air pollution, preparing for the impacts of climate change, and advancing more resilient and sustainable communities.

In view of the increasing need to prioritize the allocation of resources, the Subcommittee endorses maintaining high priority on core areas of research that ACE partners, the states, and other users rely heavily on, for example, emissions characterization, monitoring methodologies, and atmospheric/climate science. In this vein, the Subcommittee noted the need for developing new or replacing outdated federal reference methods for ambient pollutants; continuing the development of small, inexpensive sensors

suitable for criteria pollutants as well as emerging air pollutants such as ammonia; and continuing support of air dispersion model development in the areas of source attribution, dry deposition, and speciation profiles.

The Subcommittee applauds the ACE focus on building on core strengths to support the evaluation of climate change impacts. The Subcommittee highlighted the increasing importance of understanding and predicting climate change-related human health effects, such as those associated with wildfires. This particular example illustrates the opportunity to leverage core ACE strengths in air emissions and modeling and to integrate with ongoing and planned research on climate change-related human health and environmental effects performed by ORD, other Federal agencies, and non-governmental organizations. As heat exposure and humidity play key roles in climate change-related health effects, the Subcommittee also noted the importance of including temperature and humidity in air quality modeling used to evaluate climate change impacts at all scales, from local to national and larger. Finally, the Subcommittee identified the need for measuring and/or modeling the changing patterns of pollen exposure as a research area that aligns well with ACE's strengths and the program's stated objective to prepare for and respond to changes in climate and air quality.

On the topic of research planning and problem formulation, the Subcommittee applauds the ACE program for the breadth and diversity of approaches used for engaging partners. The Subcommittee suggests that program planning and implementation might also benefit from more direct involvement by one or more states at the problem formulation stage. The states serve a key role in both providing and using information generated by the ACE program, yet their interests and points of view are not always fully represented by EPA's Regional Office partners. Direct involvement by one or more states should help ensure an on-the-ground perspective on needed tools and the ultimate implementation of research accomplishments into use and operations.

The Subcommittee is sensitive to the tension between the increasing needs of ACE's partners and constrained resources. In this environment, it is important to ensure the continuation of sufficient funding for program reviews by external experts, peer review, and other quality assurance activities to maintain a high quality product. The Subcommittee believes that the ACE program is highly focused on quality assurance; however, the Subcommittee would benefit from greater knowledge of quality assurance procedures in place for different types of ORD projects.

In conclusion, the Subcommittee believes that the ACE StRAP articulates and organizes an ambitious but achievable research program that aligns with EPA's objectives and mandates to protect air quality and take action on climate change. The Subcommittee looks forward to continuing to serve as a resource to the ACE program on technical and management issues related to its research programs.

Sustainable and Healthy Communities (SHC)

The Subcommittee generally found the vision and objectives in the StRAP to be clearly conveyed and the topics and project areas to be planned and organized appropriately. As a general conclusion, the Subcommittee acknowledges the consistent focus on sustainability across SHC activities, and commends the systems orientation of the programs within the SHC. The Subcommittee also recognizes the challenges of the integration across environmental science and social science disciplines, and the application across multiple spatial and temporal scales that sustainability science requires.

The Subcommittee recommends SHC continue to develop its conceptualization of sustainable and healthy communities. EPA in general, and SHC specifically, have an opportunity to be global leaders in sustainability, and in defining core principles of wellbeing, community, and resilience. The development

and dissemination of an integrated framework for how to think about sustainable and healthy communities could be nationally and globally transformative.

Furthermore, the Subcommittee recommends expanding SHC's conceptualization of relationships between ecological and human health and wellbeing away from unidirectional articulations toward non-linear, multi-directional relationships. This shift in conceptualization requires the integration of systems thinking into the development of projects and tools, and may involve the integration of causal and feedback loops, scenario building, and system dynamics models. Furthermore, the Subcommittee recommends that SHC expand the time horizon for investigating the interactions of ecological and human health and community wellbeing.

The Subcommittee recommends greater integration across projects, topics, and scales in the outputs, products, and tools produced by SHC. Integration is critical for understanding sustainable and healthy communities, particularly given the scope of SHC. Greater attention could be given to considering the needs, skills, and capacity of the range of users of products and tools produced by SHC, and to ensuring that these products and tools can be customized and scaled to capture key interactions influencing community experiences and decision making.

However, this level of integration represents a kind of paradigm shift in focus from traditional, linear models of community and environmental health. To that end, the Subcommittee recommends that SHC continue to build capacity for greater integration that this paradigm shift requires. In particular, the Subcommittee recommends hiring additional staff with expertise in the social and economic sciences, and in complex socio-ecological systems. SHC could also consider expanding the use of shared staff appointments across research topics and the other research programs.

In order for the Subcommittee to more fully understand the effectiveness of partner engagement and the implementation of decision-support tools in diverse situations, we recommend that future meetings of SHC and the Subcommittee provide opportunities for greater interaction with staff from centers and labs, as well as stakeholders in partnering regions and communities.

The Subcommittee recommends further that SHC compile a catalogue of tools that would include information on each tool such as the topic that the tool supports, the geographic scale of the tool, and a projection of the period of time the tool will be supported. It is further recommended that SHC increase its effort to integrate tools with attention to interoperability and ability for tools to inform each other and to answer research questions. The Subcommittee further recommends continued development of innovative decision-support tools by drawing on partner and stakeholder engagement to improve dissemination, utility, evaluation, and adaptive improvements of tools.

Another important recommendation from the Subcommittee is to systematically and comprehensively evaluate and document feedback from partners and other users of SHC tools in order to examine the effectiveness of decision-support tools. Meta-analytical work to assess efficacy of tools across diverse community types, along with qualitative narrative development of experiences, would be highly useful. Community typological work may be useful in informing selection of cases, rather than *ad hoc* application of tools for communities most able to engage. It appeared to the Subcommittee in the September 2015 meeting that more has been done in terms of evaluation and adaptive development than was apparent in the documentation provided. It may be that engaging a contractor for this systematic evaluation would be useful.

In conclusion, the Subcommittee believes that the activities of SHC are well aligned with the mission of the Program, and that SHC staff members have demonstrated considerable progress toward the

objectives of conducting research and delivering products that improve the capability of EPA to carry out its responsibilities.

Safe and Sustainable Water Resources (SSWR)

EPA has done an admirable job of aggregating and developing the 2016–2019 StRAP that addresses some of the greatest challenges facing the nation's water resources. SSWR is to be commended for its efforts to build partnerships with the Regions and address needs the Regions are experiencing. Based on the SSWR StRAP, the SSWR is expected to make good progress toward the research objectives in the 2016–2019 time frame.

The SSWR Subcommittee is of the opinion that internal ORD's coordination apparently is better defined and well documented while that is not the case for outside partners and stakeholders. Based on the available information, the Subcommittee feels that some important stakeholders are missing from consultations. The Subcommittee strongly suggests that a detailed mechanism should be in place for coordinating with external stakeholders and should include database of STAR grantees along with research areas and topics, topics and projects selection process and criteria, progress measurement and intermediate metrics.

It was difficult for the Subcommittee to gauge the research needs prioritization process. For example, the draft StRAP lacks discussion on relevant large-scale EPA and other federal programs (e.g. endocrine disruptor screening program, silico and high-throughput in vitro toxicology); there was no mention of consultation with National Institutes of Health, and EPA's own ToxCast Program. Consultations might have occurred but they were not included in the StRAP. So ORD should explicitly discuss how interactions took place on these large efforts within EPA and beyond.

On nonpoint source pollution, apparently there is a weak linkage between the 319 Grants Program and ORD, so a research-level analysis of 319 projects reveals mixed success; hence, there is a need to strengthen this relationship either by ORD conducting hands-on research or by ORD providing coordination and planning support to assist 319 staff in improving research elements of their projects. Further, rigorous analysis of project performance is recommended.

The prioritization of some key issues like decaying infrastructure, disinfection byproducts, and potable water reuse is not entirely transparent. Similarly, salt management, distribution system corrosion, green infrastructure, resource recovery, etc. seem tangentially related to research priorities. Therefore, it is highly recommended that SSWR find more tangible and transparent mechanisms to engage all partners and stakeholders to identify and prioritize research areas and projects.

The development of water simulation models has been a strength of EPA; indeed most of the water quality simulation models in use today are models that have developed through EPA. These models generally have been constructed with a focus on process description, but unfortunately there has been little consideration of uncertainty analysis as a standard component of these simulation models. The Subcommittee is of the view that model utility can be improved by routine assessment of prediction uncertainty. One approach to interoperability of models and tools is to build a comprehensive model that includes and links water and socioeconomic simulations. An alternative approach is to build an uncertainty model with consideration of seamless integration with other models. Similarly, measures of success can be identified at several levels, such as number of downloads and /or number of cited applications of each model, number of attendees at modeling short courses, and number of approved Total Maximum Daily Loads (TMDLs) based on EPA-supported models.

Concerning resource recovery and water reuse, SSWR plays a vital role in assessing cumulative human health and environmental impacts in contaminants in treated resource water and bio solids. Further, SSWR can help change the current mindset through adopting the new term "Resource Water[1]" instead of "Wastewater". The Subcommittee strongly recommends that SSWR should continue to play a central role in assessing cumulative human health and environmental impacts of contaminants in reclaimed water and biosolids. SSWR, however, should consider whether a specific technology is best developed within EPA or within the private sector. In general, government research is best focused on emerging technologies that can require considerable study before moving into private research and development.

The Subcommittee found that the various efforts undertaken by SSWR to convey to stakeholders the results and utility of its research programs can be generally categorized as efforts in communication about risk and risk management. The risks of interest pertain to human and ecological health and to the viability and sustainability of water systems and watersheds. SSWR is encouraged to consult several reports on this topic that are detailed in Appendix 1.c to improve these efforts.

Chemical Safety for Sustainability and Human Health Risk Assessment (CSS/HHRA)

CSS

The CSS research program is a showcase of EPA innovation; it has the potential to be truly transformative of the work of EPA and of entire fields of science. The program's research is directly responsive to the recommendations of the National Research Council on toxicity testing (2007). The research objectives are ambitious, and the program is on track to meet their objectives in the 2016–2019 timeframe.

The ToxCast project is a central effort within the CSS research program and it has provided a plethora of useful data. However the assays were originally designed for the evaluation of pharmaceuticals rather than for chemical risk assessment. The program recognizes this weakness and is developing assays to enhance high throughput and medium throughput evaluation. The Committee was encouraged to learn about new assays recently developed for thyroid dysregulation and for neurotoxicity. New assay development needs to continue in order to address gaps in the chemical evaluation effort.

CSS faces significant challenges as it scales up its research efforts. For example:

1. Transitioning from qualitative modeling to quantitative modeling of adverse outcome pathways could provide more effective integration of high-throughput testing data with risk assessment, but it would require significantly more data, including dynamic data with respect to both concentration, time and change in environmental conditions.
2. Extrapolating across species will be necessary for ecological risk assessment, but will also require extensive additional data, including molecular target assays across species and genomic data on a variety of representative organisms as well as experimental data.
3. Determining the combined effects of chemicals in mixed systems will also be important but will require a major focus on interactions among multiple chemicals and substances such as nanomaterials.

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[1] Resource water (wastewater or sewage in old terminology) is a complex mixture of water and inorganic and organic solids in the form of inert material, ammonium, nitrate, phosphorus, etc. Reclaimed water, on the other hand, is just one of the components of the resource water; other extractables may include biogas, biosolids, nutrients, and heavy metals. Resource water is a more appropriate terminology to reflect economic benefits.

Virtual tissue models have the potential to be important for predicting biological responses in relevant species, but in the absence of a contribution back to chemical evaluation or adverse outcome pathways they could be perceived as an academic exercise. For these reasons, case studies could be helpful in demonstrating that biological activity in ToxCast translates to biological properties in virtual tissue models, and in turn to apical endpoints *in vivo*. Selection of new ToxCast compounds should consider real-world data on chemical exposures as well as the requirements of modeling, including tissue and QSAR models. It will be important to have data on a wide array of chemical structures to appropriately build and test the models. The Subcommittee also supports the use of program resources to develop and improve exposure models.

The CSS lifecycle analytics effort is extremely ambitious; the effort has many strengths and has the potential to be successful. Success will depend, in part, on having toxicity screening data on a large pool of chemicals and other compounds, and having a strong program in computational chemistry and biology that can help develop capability to predict adverse outcomes for new or emerging chemical systems. Another area of active research that requires attention is the incorporation of metabolic capacity, or testing of metabolites, in the screening programs, as metabolites may be the toxic entity for many chemicals.

As CSS research projects are updated and refined, CSS should implement a system to clearly communicate to users when changes are made to databases and tools, and to describe the nature of such changes. An ongoing investment in training and educating the user community on CSS data and tools will remain critically important in order to assure that the research will be used appropriately to help protect human health and the environment.

HHRA

The Committee was favorably impressed by the breadth and depth of the HHRA Research Program. The program provides a service that is cross-cutting and fundamental to informing decisions both within and outside the Agency. HHRA is moving forward to implement important recommendations of the National Research Council on risk assessment (2008), and is propagating an open and transparent approach to efficient use of technological tools for risk assessment. The Committee especially commends the HHRA program for its work on understanding susceptibility and vulnerability, including through the application of genetic and epigenetic data, as well as its work to incorporate non-chemical stressors into cumulative risk assessment. EPA partners highlighted the key role of HHRA in emergency response, with several recent examples demonstrating substantial support to EPA regional offices.

Key recommendations for the HHRA research program include a need to develop acute or non-lifetime reference doses/reference concentrations for some chemicals, as feasible and warranted by the decision context. HHRA should also explore using CSS tools to develop preliminary risk-based screening levels for data-poor chemicals that have been detected in communities, in water, or at contaminated sites. The HHRA online tools could benefit from a guidance document or navigation guide that considers the different levels of expertise of the intended users. HHRA outreach efforts should also include the National Institute of Environmental Health Sciences (NIEHS) Superfund Research Centers as a way of propagating risk assessment research into the Regions.

Homeland Security Research Program (HSRP)

The Subcommittee found that the HSRP StRAP clearly defines strategic goals and objectives over the next few years. The topics and project areas are well planned and organized. However, HSRP is often is called to respond in a timely and efficient manner to unforeseen hazards and disasters, such as the Ebola

outbreak, cyberattacks on water utilities, and the Elk River chemical spill. It is difficult to plan for resource use during these emergencies, however without doing so, the ability to make progress on all objectives is threatened. The Subcommittee recommends that the Program develop a process and strategy that allows responses to, and prioritization of, unforeseen and emerging needs while ensuring that good progress can be made on StRAP research objectives.

In addition, because of the severity of the threat of cyber-attacks, the Subcommittee recommends that the Program's research schedule should be modified to prioritize cyber security research ahead of other areas to counter the continuous and ever-increasingly sophistication of cyber-attacks that plague utilities. As utilities interconnect formally disconnected systems to increase efficiencies, they create an ever expanding attack surface – often without understanding the impact and risks. As very few utilities have staff prepared to deal single-handedly with chemical or biological attack remediation, knowledge of cyber security is limited in the utility space; consequently research and guidance is needed from HSRP.

HSRP has done a good job transitioning research to the end user, particularly through the development of validation tiers for chemical sampling and chemical analytical processes, tracking visits to tool websites to assess popularity, and the collection of Selected Analytical Methods which appears to be widely used. The Subcommittee recommends that the Program develop tools for end users that can be routinely operated and maintained, and have 'multi-use' or 'all hazards emergency response' capabilities where appropriate. For example, with regard to Water Quality Surveillance & Response Systems, develop a plan for supporting deployed tools with future updates, and minimize the number of development platforms to improve interoperability and functionality. In addition, the Subcommittee recommends that HSRP develop validation and/or readiness measures to establish awareness and manage expectations among end users of the expected performance of the analytical tools, decontamination response methods, and software tools produced by HSRP.

In conclusion, the Subcommittee recognizes that the activities of the HSRP are well aligned with the mission of the Program and that HSRP staff members have shown considerable progress toward the objectives of conducting research and delivering products that improve the capability of EPA to carry out its homeland security responsibilities.

REVIEW OF CROSS-CUTTING ROADMAPS

Introduction

In addition to its six national research program areas, ORD has established four cross-cutting programs. The goal of these cross-cutting programs is to improve effectiveness and efficiency by integrating research that is found in several of the research programs, i.e. integrate across the "stove-pipes" of the research programs. These four cross-cutting programs are Integrated Nitrogen, Children's Health, Climate Change, and Environmental Justice. Each program prepared a Roadmap planning document. The BOSC reviewed the former two Roadmaps previously (provide reference), and provides a review of the latter two below.

In general, the BOSC Executive Committee is pleased to see that ORD has made progress on establishing these important, integrative, cross-cutting programs. We found that the Roadmaps for Environmental Justice and Global Climate Change would benefit from continued attention to improvement. The Environmental Justice Roadmap needs minor revisions to tighten and improve its problem statement, additional detail on how it selects priority research areas, and a more systematic method for identifying gaps and outcomes. Several other recommendations are articulated below. The BOSC Executive

Committee recommends that the Global Climate Change Roadmap be revised significantly, and be reviewed again by the BOSC. Comments and recommendations to contribute to the improvement of the Global Climate Change Roadmap are found below.

Environmental Justice

Charge Question

How effective is the draft Environmental Justice Research Roadmap in presenting a problem statement, elucidating key research topics and important scientific gaps appropriate to the mission of the EPA, capturing relevant research in each of the six programs, and identifying areas of integration across the six programs?

General Comments

The BOSC was impressed overall with the Environmental Justice Research Roadmap and finds that it presents an ambitious and relevant cross-cutting research agenda. In general, the BOSC cautions that use of the term "minority" as used in the Roadmap is often not appropriate, especially when it is used to describe communities or regions where the relevant population actually represents a majority. It is more accurate to refer to communities at social and economic disadvantage or to be specific about issues relevant to race or ethnicity. Members of the BOSC also noted that the references include only two academic peer-reviewed papers, and no references to the extensive literature, from both social science and biological science perspectives, on the topics of environmental justice and wellbeing. Including a few selected influential publications would signal EPA's awareness of the breadth and depth of scholarly literature in the environmental justice arena.

In addressing the charge, the Committee divided the charge question into five sub-questions, which are addressed individually below.

How effective is the draft Environmental Justice Research Roadmap in presenting a problem statement?

The problem statement is presented in two places in the report and the two statements do not appear to be well aligned with each other. The "problem formulation statement" (p.4) is a broad statement of the goal of ORD research addressing environmental justice (EJ); the goal should be preceded by a statement that identifies and articulates the existence of EJ problems, such as the presence of environmental health disparities, greater risks facing particular populations, and/or greater exposure to the potential impacts of climate change, none of which are presented in the "Background" section of the Roadmap. The "expanded problem statement" (p.8) includes a recognition that "environmental risks are often greater for low-income and minority communities" due to proximity to chemical toxicants and non-chemical stressors, and the statement offers suggestions for the causes of these stressors, such as inadequate housing, transportation, and resource access. This latter broad problem statement, however, does not easily translate into a clear and concise justification for the science challenges agenda that is presented immediately below. The two problem statements could be harmonized to better articulate a single, concise problem statement that motivates the research roadmap. In addition to the above discrepancies, the issues discussed in the expanded problem statement relate to research in many other agencies and academic institutions. Hence, it would be helpful to more clearly articulate ORD's unique role and contribution to the EJ research agenda.

Recommendations

1. The BOSC recommends revising the problem statement by putting all relevant discussion in one place, and including three key components:
   a. a clear articulation of the threats posed by the problem(s) similar to that in the 'expanded problem statement';
   b. a strong justification for a cross-cutting research roadmap within the areas of expertise represented at ORD related to environmental justice; and
   c. a purpose statement that is similar to the statement on p.4 but more focused.

How effective is the draft Environmental Justice Research Roadmap in elucidating key research topics appropriate to the mission of the EPA?

The EJ Roadmap identifies four science challenges that form the basis for the key research topics. The research topics fit appropriately in an EJ Research Roadmap, as they are clearly within ORD's expertise, they are related to the interface between environmental justice and scientific research, and they address priority issues for many EJ communities. However, the research topics may not reflect the full breadth of environmental justice issues and their drivers, and it is not immediately clear to the BOSC how these four issues were selected and prioritized. For example, research related to tribal sustainability and wellbeing is given particular emphasis as a scientific challenge and research topic, but issues of sustainability and well-being in other under-resourced and challenged communities (such as those with significant incidences of poverty, racial and ethnic minorities, political disenfranchisement, and other marginalized communities) are not called out in the same way. The BOSC recognizes that other communities will be included in research programs, particularly as they relate to research topics such as decision-support tools for identifying concerns, understanding environmental health disparities, and community-scale vulnerability to climate change. But the articulation of the key research topics does not include this level of specificity, nor does it address the scope of potentially targeted communities or the process for identifying these communities. There may be reasons for devoting an entire area of focus to the Tribes, but the reason for this is not immediately clear on reading the Roadmap. Neither is it clear why the EJ Roadmap excludes specific areas of research targeting other EJ communities, or the issue of contaminated sites, which is of ongoing central importance and is discussed further below.

The second research topic ("Improving our understanding of environmental health disparities and developing methods and data for assessing cumulative risks") includes a brief discussion of some of the social and environmental determinants of health, including chemical exposure, but the characterization of the drivers of environmental injustice appears to be oversimplified and incomplete. Figure 2 ignores other drivers that are likely to impact EJ outcomes, such as poverty, income inequality, political marginalization, linguistic isolation, lack of awareness, and poor infrastructure. Although it is clear that the EPA has little purview over many of these drivers, they should be included in the discussion as relevant to the research program, along with a recognition by ORD that the EPA cannot possibly tackle many of these other drivers that are clearly outside the EPA's mandate and purview. The narrow emphasis on the built environment, social environment, and biological factors does not appear to fully address the causes of exposure to risk that affect health and wellbeing in a comprehensive way. Further, we suggest consideration of the contested nature of environmental justice issues, particularly health impacts of environmental contamination and toxic exposure. While illuminating the multiplicity of factors driving disadvantaged conditions, the power dynamics often leave the burden of proof on overburdened communities.

Recommendations

1. Describe in the Roadmap how the four priority research areas were selected.
2. Expand Figure 2 and the text to incorporate a description of the broader array of social and economic drivers of environmental injustice.

How effective is the draft Environmental Justice Research Roadmap in elucidating important scientific gaps appropriate to the mission of the EPA?

Key scientific gaps have been identified in the EJ Roadmap. The activities in the table provided by the National Environmental Justice Advisory Council (NEJAC) as well as the three gaps highlighted in the report (Community Engagement, Outcome Assessment, and Training the Next Generation) are indeed gaps deserving of attention, and these have been well articulated in the EJ roadmap.

Community engagement in the formulation of scientific research agendas is definitely needed. However, we caution against over-promising in this arena. Long-term engagement is the most effective way to involve communities, yet engaging long-term with multiple communities in formulation of a research agenda is a highly resource-intensive endeavor. Developing a systematic process for such engagement (and benefitting from SHC's experience and existing relationships in this regard) will help ORD to focus and prioritize. The development of a clear way to identify overburdened communities leading to an environmental justice community typology to differentiate the highly varied circumstances along different timelines of experience might be helpful for targeting representative EJ communities for engagement.

Outcome assessment is also a key gap as indicated. Mapping scientific gaps and assessing efforts to address them over time will help articulate alignment with EPA goals as well as to measure success. Metrics and measures for tracking community improvements as well as declines are essential elements of this gap. Many indicators and tools exist within EPA and the wider research and academic community, such as the Human Wellbeing Index and Environmental Quality Index in SHC, as well as the EJ Screen, the Environmental Justice Screening Methodology (EJSM) and the California Communities Environmental Screening Tool (CalEnviroScreen), and these methods could be incorporated into assessments of environmental justice efforts over time.

Training the next generation is a clear part of improving sustainability and the environmental justice outlook for communities. This involves providing training opportunities in communities, but also systematically training new scientists to be mindful of the complexities of environmental justice. Social science is clearly articulated as a scientific need throughout ORD programs and this will be systematically improved by a long-term focus on interdisciplinary learning and inclusion of social science principles and methods throughout ORD programs, and particularly throughout Environmental Justice endeavors. Finally, as EPA develops and trains scientists and communities in tools and resources related to EJ, it will be important to plan for the long-term sustainability of the effort, either through the Agency, or more appropriately via knowledge transfer and ownership to other entities perhaps at the local level.

One important area that is omitted from the Roadmap is research related to contaminated sites. The Roadmap explicitly excludes this topic (p. 10) and instead refers to the SHC StRAP for more on this. This is unfortunate, as the issue of contaminated sites is of central importance to EJ research, there is much that ORD has to offer on this topic, and there is a great need for more research in this area. As one example, EPA partners often struggle to identify responsible parties (RPs) to clean up contaminated groundwater or sites. There is a need for better forensic chemistry to trace contaminants to their sources and thereby help to reduce protracted litigation, expedite cleanup, and increase cost recovery. As another example,

there are often chemicals identified (or tentatively identified) at cleanup sites that are of unknown toxicity. Such chemicals may be in soil or water in communities, and in some cases remediation plans leave these chemicals in place due to the lack of regulatory cleanup numbers. Improvements in toxicity screening in the CSS program, and the incorporation of such screens into preliminary risk assessments in the HHRA program, have enormous potential to address this potential threat to communities that live near cleanup sites. For these reasons, the BOSC recommends including some additional discussion of contaminated sites in this document. Recommendations from the BOSC to the SHC program on expanding conceptualization and research on contaminated sites to broader community wellbeing issues may be helpful in this regard.

We note a few additional science gaps deserving of attention within the EJ Roadmap. It might be tempting to avoid focusing on issues that fall beyond the regulatory mandate of the EPA, such as food scarcity or quality issues or problems of poverty and poor housing, but we suggest that a full array of complex drivers and processes are important for systems understanding and research within EPA's EJ efforts. One such issue that strikes us as a gap is the need to describe and acknowledge multi-scalar, social structural factors, such as economics, income inequality and political and power dynamics (we note that the figures in the Roadmap are largely devoid of economic considerations). To be clear, the BOSC recognizes that integration of social science into development of research action plans and programs, while critical and necessary to enhancing the likelihood of positive and effective outcomes, does not imply that EPA can address all drivers of EJ and impact outcomes across the board.

We suggest that more science could be helpful in differentiating between mitigating problems in existing environmentally overburdened communities and preventing such situations in the future. Preventing future environmental justice problems in communities requires a systems understanding of the underlying driving forces so that they can be monitored and avoided. Mitigation of current issues requires a different set of tools and resources. However, both are likely dependent upon community engagement.

Recommendations

1. Develop methods to more systematically assess gaps and measure outcomes over time to evaluate progress.
2. Incorporate social science principles and methodologies throughout EJ endeavors across ORD.
3. Plan for long-term sustainability of ORD EJ efforts, including in plans for knowledge transfer and maintenance of tools and databases.
4. Include discussion of contaminated sites and connections to broader community wellbeing as part of the EJ Roadmap.

How effective is the draft Environmental Justice Research Roadmap in capturing relevant research in each of the six programs?

The BOSC is not exhaustively familiar with the research going on throughout the six programs, and is therefore not necessarily best equipped to answer this question with confidence. It is possible that there is research going on in one or more of the programs that may be relevant and of which the BOSC is not aware. However, it appears that the relevant research at ORD is captured effectively in Appendix A, Table A1 of the Roadmap. This table is an extremely useful compilation of the EJ-related research at ORD, and is a valuable addition to the Roadmap. Table A2, which summarizes Science to Achieve Results (STAR) extramural research in Environmental Justice is also useful, as is Appendix B. Taken together, the Appendices demonstrate an impressive array of research and partnerships.

The report quite effectively notes important and relevant research in SHC related to Environmental Justice and engaging communities. The relevance of the CSS research is possibly under-stated in the Roadmap. The statement on p. 23 on CSS refers generically to the program's role in 'assessing new products' and 'prioritizing chemicals for IRIS assessments', but these are not the most relevant or important uses of the CSS data. In fact, 'assessing new products' does not have obvious direct EJ relevance, and CSS data are not currently being used in IRIS assessments. More directly relevant to EJ is the role for CSS in screening data-poor chemicals and thereby providing data to potentially inform provisional risk assessments. This role includes toxicity screening of chemicals detected at contaminated sites, in groundwater or in surface water in communities. CSS also has the ability to test mixtures, which is an important way of beginning to evaluate cumulative impacts.

The role of the HHRA research program is not properly characterized on p. 23. The Roadmap refers to the Integrated Risk Information System (IRIS) program and the Integrated Science Assessments (ISAs), but fails to mention the Provisional Peer-Reviewed Toxicity Values (PPRTVs), and the role of the Superfund technical support centers within the HHRA program. In addition to the important work the HHRA program is doing on cumulative risk assessment (which is mentioned in the Roadmap), it is also working to generate preliminary risk assessments for data-poor chemicals, including through use of CSS work products. This work has direct relevance to communities facing exposures to multiple contaminants.

Table 2 is a useful summary of the contribution of each research program to the overall EJ research activities. The BOSC felt, however, that the contributions of certain programs may be under-represented in that table. In particular, the BOSC was surprised not to see a check mark for SSWR for Tribal Science, and perhaps also for SSWR and Health Disparities and Cumulative Risk.

Recommendations

1. Describe the roles of the CSS and HHRA programs in screening and developing provisional risk numbers for previously untested contaminants.

How effective is the draft Environmental Justice Research Roadmap in identifying areas of integration across the six programs?

The Roadmap is fairly effective in identifying areas of integration across the programs, especially in the Cross-Agency "Making a Visible Difference" (MVD) strategy, the area of cumulative risk assessment, and in climate adaptation. There is also significant potential for integration in the three cross-cutting areas identified in the Roadmap as research gaps (community engagement, assessing outcomes, and training the next generation). Activities on these three 'gap' areas would require significant cross-program integration.

There are several other areas for integration that are not articulated in the Roadmap. These include rapid response, exposure science, and socio-ecological disparities. EPA has extensive Emergency Response and Management activities, in which ORD is actively involved. Many emergencies affect EJ communities, in part because many EJ communities are located in areas that are vulnerable to chemical spills, explosions, fires, and other disasters. It may be beneficial for EPA to consider articulating an EJ component to their emergency response preparedness research and response activities.

Exposures to potentially hazardous substances are a common concern in EJ communities. Some of the themes in the Roadmap relate to exposure science, including rapid sensor technologies, and some of the decision support tools. There is exposure science research going on in all the programs within ORD, and it

may be fruitful to consider ways to better integrate the exposure science research across program areas and media. Such an effort would be relevant to EJ, but may also be beneficial beyond EJ issues.

The awareness of the links between human health and ecosystem services is an important and growing area of research. This issue is mentioned in the Roadmap as it relates to Tribal Health, and to some degree also to climate justice. However, the connections between human and ecological health (e.g., the "One Health" concept), and the issue of socio-ecological disparities is an important cross-cutting theme that is relevant to several program areas and might be an additional area to consider for potential integration.

Recommendations

1. Consider articulating an EJ component to emergency response and preparedness research and activities.
2. Consider ways to better integrate exposure science research across program areas and media.
3. Consider developing the connections between human and ecological health, and the issue of socio-ecological disparities as a cross-cutting theme.

Global Climate Change (GCC)

Charge Question

How effective is the Draft Global Climate Change Research Roadmap in presenting a problem statement, elucidating key research topics and important scientific gaps appropriate to the mission of the EPA, capturing relevant research in each of the six programs, and identifying areas of integration across the six programs?

General Comments

There was agreement among the BOSC members that the GCC Roadmap represented a substantial effort. However, we still find some deficiencies in the Roadmap overall. Based on our responses to the Charge Question and our other comments and observations, we would appreciate the chance to review the next revision of the Roadmap.

We appreciate that the climate program of EPA is part of a much larger enterprise involving many partners across the Administration. As a result, it is a constant challenge to make progress on some goals if they are dependent on outside Agency partners, such as the National Oceanic and Atmospheric Association (NOAA) or the U.S. Geological Survey (USGS). However, this also makes it a challenge for the BOSC to determine where EPA can make a value-added contribution to climate change research and where they can make a significant difference. It would be extremely helpful to create a figure that shows, for a given medium (e.g. water) what the impacts of climate change might be (e.g., decreased flows, flooding, changes to evapotranspiration and the hydrologic cycle, changes to water quality and to TMDL studies, increases in hazardous algal blooms, changes in pollutant transport, etc.). For each of these impacts, indicate which are under the primary responsibility of EPA (water quality, TMDLs), and which are less so (changes in flows) – and then link these to the work plan in the Roadmap. This would not only be illustrative, but perhaps help guide planning in the future. In that regard, the figure could be used to illustrate how the Climate Change Roadmap research topics were selected as key topics, making sure that the reasons for selection are transparent.

The Roadmap, while largely complete, would benefit greatly from a rewrite and careful editing. It suffers from redundancies in the text, a lack of cohesion and flow, and numerous typos and incomplete sentences. It appears to have been the product of many authors pasted together. The document would greatly benefit from a rigorous copy-edit. The lack of clarity and differentiation between the Needs and Current Research, and the Gaps, was to some extent due to the format ORD requested them to follow, but the distinction between these two sections could be greatly improved.

Comments on Answers to Charge Questions

How effective is the draft Climate Change Research Roadmap in presenting a problem statement?

In essence, the extended problem statement is not effective. It would be helpful if the problem statement were directed toward EPA's particular focus on climate change. We suggest the phrase "way of life" be replaced with "wellbeing" given that is the accepted terminology. Further, there is no mention of climate change adaptation in the problem statement.

How effective is the draft Climate Change Research Roadmap in elucidating key research topics appropriate to the mission of the EPA?

While there was general agreement on the topics that were identified in the Roadmap, several key topics were missing, for example:

1. invasive species, new pests introduction including effects on pesticide use;
2. post-disaster debris management, with focus on research on effective and safe approaches; and
3. human health effects of mold.

Throughout the report, the emphasis is on impacts, but missing are the interactions between/among impacts, as well as the adequacy of local governance and infrastructure capacity. In short, the report seems focused on the sensitivity and exposure (impact) side of vulnerability, ignoring adaptive capacity in natural systems and in human systems. The report was missing social drivers and impacts (behavioral, attitudinal, and governance) that have direct implications for mitigation of air and water changes.

In places, research topics are identified without sufficient explanation of their relevancy to climate change. For example, on page 17 of the Roadmap the bullet "Life cycle assessments related to materials management" is identified below the topic of "wildfires at contaminated sites" without any explanation of how life cycle assessment might be used in that situation. Further down page 17, the Roadmap mentions "ongoing research on the potential leakage of biofuels into groundwater" with no explanation concerning the climate change relevancy of this research.

Cookstoves are briefly discussed at several points, but how widely are cookstoves used in the U.S.? If cookstoves are an EPA priority, then the Roadmap should explain how the cookstove issue is part of EPA ORD's purview. Thus, although this issue is more widespread for people abroad, the report should note that the cookstoves are an Administrator priority, and thus provide greater context for this priority.

Adaptation is the main focus of the climate change roadmap. However, the Science Challenges and research topics (particularly for water, air, human health, and ecosystems) are all framed in terms of understanding the impacts. A research program focusing on adaptation to climate change would presumably need to go beyond understanding impacts, to examine the range of adaptation strategies in terms of their cost-effectiveness, cultural acceptability, efficiency, etc.

A few final observations are:

1. identification of needs should be an articulated process, and
2. multimedia (i.e., water, air, soil, freshwater, and the entire environmental system, including people) interactions of the science challenges need to be incorporated in the Roadmap.

How effective is the draft Global Climate Change Research Roadmap in elucidating important scientific gaps appropriate to the mission of the EPA?

The Roadmap emphasizes mitigating emissions from energy production from fossil fuels. There does not appear to be an integrated strategy for focusing on emission reductions. For instance, little or no attention is given to the role of forests, agriculture, industrial activities (e.g., cement), and buildings in reducing emissions for effective mitigation of the impacts of climate change.

There is considerable attention on water quality and air quality impacts of climate change. Given that management of water quality and air quality is often a local endeavor, more attention to the adaptive capacity and infrastructural capacity of associated utilities and jurisdictions is warranted. Water supply is also a local issue and climate change impacts and adaptation are complicated by water rights.

With respect to gaps, the document highlights social science as a general gap, but greater specificity would be highly valuable. As currently written, this is a vague (but important) research gap. In addition, co-benefits of mitigation and adaptation are a gap that warrants discussion.

Most EPA-supported research does not begin with complete ignorance of a topic of interest; rather, there is a base of knowledge that is expected to be built upon with proposed new research. Consider that much is already known about how high temperatures affect meaningful endpoints in aquatic systems. This knowledge results simply because surface water temperatures vary around the globe. While it must be acknowledged that studies of subtropical aquatic ecosystems may not be highly reliable indicators of how surface water temperature increases will affect aquatic ecosystems in temperate climates, they should provide some *a priori* understanding. Perhaps this knowledge base should be a starting point for some of the climate change research, rather than starting from a base of little understanding, as appears to be the case in the Climate Change Research Roadmap.

How effective is the draft Climate Change Research Roadmap in capturing relevant research in each of the six programs?

The Climate Change Research Roadmap identified many research activities in the six programs that might be expanded to include climate change assessments. However, for many of the identified program projects, the Climate Change Roadmap provided few or no details concerning how these projects might be modified to include climate change research. Thus, it is not clear that the authors of the Climate Change Research Roadmap have had much interaction concerning the feasibility of this collaborative research with the six programs.

For example, text could be added relating the impacts of climate change on ecosystem goods and services/ecological integrity and the SHC tools used for assessing these impacts (e.g. make deeper connections to the SHC work being conducted in ecological health and wellbeing).

How effective is the draft Climate Change Research Roadmap in identifying areas of integration across the six programs?

As a cross-cutting program, the Climate Change Research Roadmap should describe integration among the six ORD research programs. The Roadmap does a reasonable job in identifying research needed in

SSWR and in ACE, but given the overarching focus on climate change impacts on ecological and human wellbeing, the connection with SHC's research and tools is worth more attention.

More text is needed to underscore the opportunity for integration with SHC and SSWR in terms of the impacts of climate change on ecosystems and land, specifically on impacts such as flooding and sea level rise. For example, there is a greater incidence of mold related to the greater incidence of flooding expected from climate change; EPA could play a role in this research. The Global Climate Change Program should also work with SHC to determine how to better interact with communities. In addition, there is an opportunity to integrate with the Centers for Disease Control and Prevention (CDC) on the issue of invasive species which is a climate change and human health and wellbeing issue, and to integrate with HHRA in the emission reduction program.

A redraft of the Climate Change Research Roadmap should include the role CSS has on water quality and human health, specifically the chemical and microbial elements that may be relevant to climate change that are outlined on page 11 of the Roadmap.

APPENDICES: INDIVIDUAL SUBCOMMITTEE REPORTS

CONTENTS

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

Appendix A: BOSC Air, Climate, and Energy (ACE) Subcommittee

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January 16, 2016

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

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LIST OF ACRONYMS

ACE	Air, Climate, and Energy
BOSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
CIMA	Climate Impacts, Mitigation and Adaptation
CO_2	Carbon dioxide
DAA	Deputy Assistant Administrator
DOI	Department of Interior
EC	Executive Committee
EM	Emissions and Measurements
EPA	Environmental Protection Agency
FACA	Federal Advisory Committee Act
FTE	Full-time equivalent
MDST	Modeling and Decision Support Tools
NAAQS	National Ambient Air Quality Standard
NIH	National Institutes of Health
NMP	NAAQS and Multipollutant
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OAQPS	Office of Air Quality Planning and Standards
ORD	Office of Research and Development
PI	Principal Investigator
PM	Particulate matter
$PM_{2.5}$	Fine particulate matter
RFA	Request for Application
RISA	Regional Integrated Sciences Assessment
RH	Relative humidity
RTP	Research Triangle Park
SEE	Sustainable Energy Evaluation
STAR	Science To Achieve Results
StRAP	Strategic Research Action Plan
Tas	Surface air temperature
USDA	United States Department of Agriculture

BACKGROUND

Protecting human health and the environment from the impacts of a changing climate and air pollution in a sustainable manner are central challenges in the 21st century. These challenges are complicated by the interplay between air quality, climate, and energy options, both existing and emerging. The U.S. Environmental Protection Agency (EPA) Office of Research and Development's (ORD) Air, Climate, and Energy (ACE) research program plans, conducts and communicates use-inspired research in each of these areas. Understanding the interconnections between air pollution, climate change, and today's dynamic energy sector is important in order to develop innovative and sustainable solutions for improving air quality and addressing causes of and impacts associated with climate change. The results of ACE program research efforts support policies that have far-reaching positive impacts across the nation, including reducing health risks from air pollution, preparing for the impacts of climate change, and advancing more resilient and sustainable communities.

The ACE Strategic Research Action Plan, 2016-2019 (ACE StRAP) outlines a four-year strategy for delivering the research results and solutions needed to: support EPA's mission to protect human health and the environment; fulfill the Agency's legislative mandates; and advance the cross-Agency priorities identified in the FY 2014-2018 EPA Strategic Plan (EPA Strategic Plan). The ACE StRAP is built on the needs of Agency partners and stakeholders and the application of cutting-edge science.

ORD developed this StRAP to help guide the ACE program in meeting its ambitious objectives, building upon the original ACE vision released in June 2012. The current StRAP evolved through close collaboration with EPA Program and Regional partners, input from the laboratories and centers working with ACE, and interactions with external stakeholders.

The ACE StRAP is intended to assist ORD managers and scientists to better:

- Prioritize research to focus on key areas where ACE will help lead the science;
- Demonstrate how research will be translated and actively delivered for use in Agency decision making;
- Evaluate the impacts of ACE outputs on partner needs; and
- Explore and incorporate collaboration and leveraging opportunities across National Programs and help engage external stakeholders.

The six, highly integrated national research programs of ORD are each guided by a strategic research action plan. Collectively, those plans provide a structured vision and actionable design to guide an ambitious research portfolio that delivers the science and engineering solutions the Agency needs to meet its priorities and fulfill its legislative mandates on behalf of the American people. Collectively, the plans establish an efficient, innovative, and responsive program of government-sponsored environmental and human health research.

CHARGE QUESTIONS AND CONTEXT

The Subcommittee was charged with three questions that were provided to all five subcommittees (charge questions 1, 2, and 3) and two questions specific to the ACE StRAP (charge questions 4 and 5), as follows:

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

The StRAPs are designed to clearly convey the vision and objectives of the research program, and to describe, at a high level, the research topics, and major outputs planned for 2016-2019. Upon receiving recommendations from the SAB and the BOSC EC, as well as from EPA partners and others, ORD has further developed the StRAPs, including refining the objectives and topics, and providing more clarity. At an operational level, each research program is aiming to accomplish its objectives through research spanning physical, biological and social sciences and through numerous ORD laboratories, centers, and STAR grantees all across the country. In addition, ORD has heeded the advice of the SAB and BOSC in past years to do more to integrate research across the six programs, across EPA and with other Federal partners. Given these complexities, we recognize there are likely several reasonable approaches for organizing the research to best accomplish the objectives.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

ORD works with EPA partners to design the research programs to meet Agency priorities. The first step in this process is problem formulation which provides the foundation of the research. Although it can be tempting to jump to a list of research priorities, problems that are well defined lead to the most effective research efforts and solutions. The problem formulation stage of research planning lays the groundwork for the StRAPs and is the reference point for any changes in priorities as budgets change and new issues emerge. Problem formulation occurs at many different levels including the articulation of issues in the EPA Strategic plan; meetings with EPA partners including regular staff-to-staff meetings; workshops and conferences where states, regions, policy and science staff describe the problems they face; and discussions among senior managers at EPA. In addition, each National Program Director reaches out to EPA partners in a variety of targeted ways to agree on problem definition.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

ORD places a very high value on working closely with EPA partners to design the research programs to meet Agency priorities. During the preparation of the StRAPs, the programs were guided by the EPA Strategic Plan and undertook a variety of activities to actively engage partners, both to understand their priorities and to elicit their input on research directions. These include many regular meetings with EPA policy and regional staff, communities of practice for specific scientific disciplines throughout the Agency, annual two day meetings led by the NPDs, annual senior level meetings with EPA Assistant and Regional Administrators, and formal requests from ORD's Deputy Assistant Administrator (DAA) for science to receive comments from across the Agency twice during the year of StRAP development.

In addition to the up-front work with EPA partners to understand their research needs for the upcoming year(s), ORD also needs to be flexible enough to address top priority, unanticipated needs or environmental crises that emerge at any given time. The research program will describe interactions with EPA partners, present examples of recent responsiveness to unexpected events, and explain how they work with EPA partners to accommodate acute needs while resources are limited.

Specific to ACE: Charge Question 4. Please comment on the quality of the products delivered by the program. Are there additional approaches that could be taken by the program to ensure that its products are of high quality?

Specific to ACE: Charge Question 5. How well have we translated research findings and understanding for the end-users? How can we improve our ability to translate research findings and understanding for end-users in the future?

STRAP OBJECTIVES AND PRIORITY RESEARCH TOPICS

As articulated in the Draft StRAP, three ACE research objectives flow from the Agency priorities and provide a platform that encompasses the breadth and diversity of the science research issues and questions arising within the Agency's air-climate-energy domain. They are:

Assess Impacts

Assess human and ecosystem exposures and effects associated with air pollutants and climate change at individual, community, regional, and global scales (Research Objective 1);

Prevent and Reduce Emissions

Provide data and tools to develop and evaluate approaches to prevent and reduce emissions of pollutants into the atmosphere, particularly environmentally sustainable, cost-effective, and innovative multipollutant and sector-based approaches (Research Objective 2); and

Prepare for and Respond to Changes in Climate and Air Quality

Provide human exposure and environmental modeling, monitoring, metrics and information needed by individuals, communities, and governmental agencies to take action to adapt to and mitigate the impacts of climate change, and make public health decisions regarding air quality (Research Objective 3).

These three research objectives were used to frame ACE research topics into five specific areas that focus the scope and nature of the research to achieve the objectives:

- **Topic 1**: National Ambient Air Quality Standards (NAAQS) and Multipollutant (NMP);
- **Topic 2**: Emissions and Measurements (EM);
- **Topic 3**: Modeling and Decision Support Tools (MDST);
- **Topic 4**: Climate Impacts, Mitigation and Adaptation (CIMA); and
- **Topic 5**: Sustainable Energy Evaluation (SEE).

Air pollution related research is the largest component of the ACE Program. Research efforts related to climate change and energy are together roughly one third of the clean air component although both are envisioned to grow during the timeframe of the current StRAP.

PROCESS

To help assist in this process, the EPA's Board of Scientific Counselors (BOSC) ACE Subcommittee was provided the Draft StRAP about a week prior to the ACE Subcommittee meeting that took place on June 18-19, 2015, RTP, NC. The Draft StRAP outlines the ACE research program at a strategic level [Air, Climate, and Energy Strategic Research Action Plan, 2016-2019 (Draft – May 2015)]. The ACE Subcommittee: 1) received five charge questions from EPA ORD; 2) reviewed background materials provided by ORD; 3) met with the ACE National Program Director in RTP and listened to ACE presentations; 4) deliberated as a group on the charge questions; and 5) divided into small groups to draft initial responses to each charge question.

The Subcommittee small groups completed drafting specific responses to each charge question after the June 2015 meeting. The Chair and Vice Chair of the Subcommittee prepared an initial draft of the Subcommittee report based on charge question responses provided by the small groups, circulated the initial draft report to all Subcommittee members, and asked for review comments. The report was revised in several iterations based on Subcommittee member comments and discussions during teleconferences. A draft of the Subcommittee report was submitted to the BOSC Executive Committee on September 24, 2015. The recommendations of the ACE Subcommittee in the draft report are based on material provided to us prior to the June 2015 meeting, presentations made during the two-day meeting, and deliberations during the meeting and after the meeting in teleconferences.

The full BOSC Executive Committee met on December 8-10, 2015 in Washington, D.C. to review and discuss the ORD research program StRAPs. The Chair and Vice Chair of the ACE Subcommittee are members of the Executive Committee and participated in the meeting. The ACE National Program Director, Dan Costa, and the members of the BOSC Executive Committee discussed the ACE Subcommittee charge question report on the afternoon of December 8, 2015, asked clarifying questions, provided perspective, and offered comments to the ACE Subcommittee Chair and Vice Chair.

The ACE Subcommittee Chair and Vice Chair revised the charge question report in response to questions and comments raised during the BOSC Executive Committee meeting and submitted the final report to the Executive Committee on January 16, 2016.

RECOMMENDATIONS

Overall, the ACE Subcommittee found that the vision and objectives in the ACE StRAP are clearly articulated and the research topics and project areas are planned and organized appropriately. As a general conclusion, the Subcommittee agreed that the ACE plan provides a structured vision and actionable design to guide an ambitious research portfolio that delivers the science and engineering solutions the Agency needs to meet its priorities and fulfill its legislative mandates, with a specific focus on the three stated objectives: 1) Assess impacts; 2) Prevent and reduce emissions; and 3) Prepare for and respond to changes in climate and air quality. The results of ACE program research support policies that have far-reaching positive impacts across the nation, including reducing health risks from air pollution,

preparing for the impacts of climate change, and advancing more resilient and sustainable communities. The Subcommittee unanimously praised the quality of research produced by the ACE program that each subcommittee member was most familiar with and finds the breadth and depth of the research to be extremely impressive.

Subcommittee responses to each charge question follow. The recommendations provided by the Subcommittee in response to each specific charge question are meant to complement and supplement ongoing and planned ACE program research, and thereby enhance ACE products. The recommendations do not necessarily identify deficiencies in the program; rather, in some cases the point of a recommendation is to endorse the importance of research that is already ongoing or planned and that the Subcommittee feels should receive continuing support should funding levels require selected paring of programs.

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

At the most general level, the topics and project areas are organized appropriately to make good progress on the research objectives in the StRAP. Alignment of topics and project areas with research objectives at several specific points, however, would be stronger with some additional considerations and/or reconfigurations.

One of those specific points is the planned increased research work around climate change threats, impacts, and responses. The human health and environmental impacts of climate change are a crucial part of EPA's expanding focus on greenhouse gas reductions – climate change mitigation – and adapting human and natural environments to specific climate change threats. Health impacts associated with climate change are an increasingly important topic; and EPA is cooperating and collaborating with other agencies, e.g. National Institutes of Health (NIH) and Centers for Disease Control and Prevention (CDC).

For this reason, climate change-related human health effects and environmental impacts modeling should be emphasized more explicitly throughout the program. For example, as climate continues to change and these changes accelerate, wildfire risk is increasing, most notably in the western United States (including Alaska). ACE should, for example, emphasize or extend several aspects of its planned research to integrate objectives associated with air emissions and modeling related to wildfires and the known effects on air quality and human and environmental health. Work on climate change-related human health effects naturally crosses many Federal agencies and non-Federal partners, but EPA's mission requires it to have a crucial, and potentially central, role. This supports ACE Objective 1: Assess Impacts.

Heat exposure is the most direct and largest current health risk factor related to climate change effects, but humidity also plays a key role in thermal comfort. The National Oceanic and Atmospheric Administration (NOAA) human health heat index, for example, uses surface air temperature (Tas) and relative humidity (RH) in computing apparent temperature, one measure of heat stress. For this reason, climate change and air quality modeling research and products from ACE should expand work to include temperature and humidity in future projections at all scales relevant to impacts and vulnerability studies. This also provides a useful means to include progress and products provided by the successful ACE air quality model development work to the new work on climate change.

Pollen release and transmission and associated allergic diseases are sensitive to carbon dioxide (CO_2), temperature, and precipitation, all of which are projected to continue changing in the near and far future

as a function of climate change. However, little research has been done to date to measure and/or model changing patterns of pollen exposure and health effects in the United States. Given ACE's suite of capabilities, this would likely be another fruitful focus area. This supports Objective 3, the call for environmental monitoring and metrics needed to adapt to the impacts of climate change.

The Subcommittee suggests that the alignment of research objectives with projects and outcomes would be more strongly grounded if EPA provided a more detailed description of resource allocation, even with the complexities of splitting out funding components that are mixed across sources, locations, and timelines.

The Subcommittee strongly approves of the rebalancing of ACE objectives to increase its emphasis on products to be delivered to internal EPA clients and partners, but encourages the Agency to continue to include time and support for Principal Investigator (PI)-initiated research to prepare EPA for future needs which may not yet be apparent to its partners and clients. ACE should also retain flexibility while implementing its plan to provide fast turn-around products, even in preliminary form, to its internal partners and clients when crucial needs arise. For example, a 'Rapid Response' program and plan of action needs to be implemented that will allow EPA to address rapidly emerging environmental, climate, and health related issues; this could require an enhanced communication process for ACE inside ORD and the wider EPA to receive and evaluate requests for rapid response actions.

These recommendations should lead ACE to further emphasize those areas associated with climate change and multi-pollutant research. The ACE Subcommittee suggests that ACE consider looking at its levels and balance of intra- and extra-mural research to help ensure that ACE can meet its increased obligations to deliver products to its partners and clients in addition to traditional peer-reviewed research publications.

In several aspects, research related to emissions from oil and gas extraction is not as well integrated within the ACE agenda as it might be, appearing more as separate and distinct projects rather than part of a cohesive program. This example emphasizes the need for more articulation of how the systems approach is being implemented across all the ACE research objectives and project areas.

The Subcommittee remains unsure of the appropriate level of increased social science research in ACE and repeats the caution expressed by the Office of Air Quality Planning and Standards (OAQPS) Health and Environmental Impacts Division Director that this should remain a smaller part of the research and not reduce the impressive physical, chemical, human health, and biological science work, which is the hallmark of ACE. Social science inputs can perhaps be usefully developed by ACE in consultation with other agencies that have substantial investments already in social science research – National Science Foundation (NSF), etc. At the same time, the Subcommittee recognizes that ACE is responding to long-standing requests to make its science research products more readily available for implementation and decision support across EPA and the Nation, and that its response should be conditioned by findings of social science research into which forms of communication are most effective. The Subcommittee suggests that consideration be given to the extent of that social science research inside the ACE program and to where it could be more efficient to leverage social science findings from other relevant agencies and programs.

Recommendations

1. The Subcommittee endorses an increased emphasis on climate change-related research on human health effects, such as those associated with wildfires, and environmental impacts modeling and recommends expanding climate change and air quality modeling research to include temperature and humidity. The Subcommittee also suggests that ACE look for strategic research opportunities for characterizing climate impacts on pollen and allergic diseases.
2. The Subcommittee recommends continuing to include time and support for PI-initiated research that might not yet have been identified as a current need by internal EPA partners and stakeholders.
3. The Subcommittee endorses ACE program planning to provide fast-turnaround products, even in preliminary form, to internal partners and clients when crucial needs arise. One aspect that the Subcommittee noted and would like to explore further is the communication process for ACE inside ORD and the wider EPA to receive and evaluate requests for rapid response actions.
4. The Subcommittee recommends reviewing the ACE program balance of intra- and extra-mural research to optimize its ability to meet increased obligations in the face of constrained resources.
5. The Subcommittee requests that ACE articulate how the systems approach is being implemented across all the ACE project areas, including research related to emissions from oil and gas extraction, which is not as well integrated into the ACE program.
6. The Subcommittee suggests that ACE periodically review the balance between ACE-sponsored social science research and the more traditional areas of physical, chemical, human health, and biological sciences, making sure to leverage social science findings from other agencies and programs.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

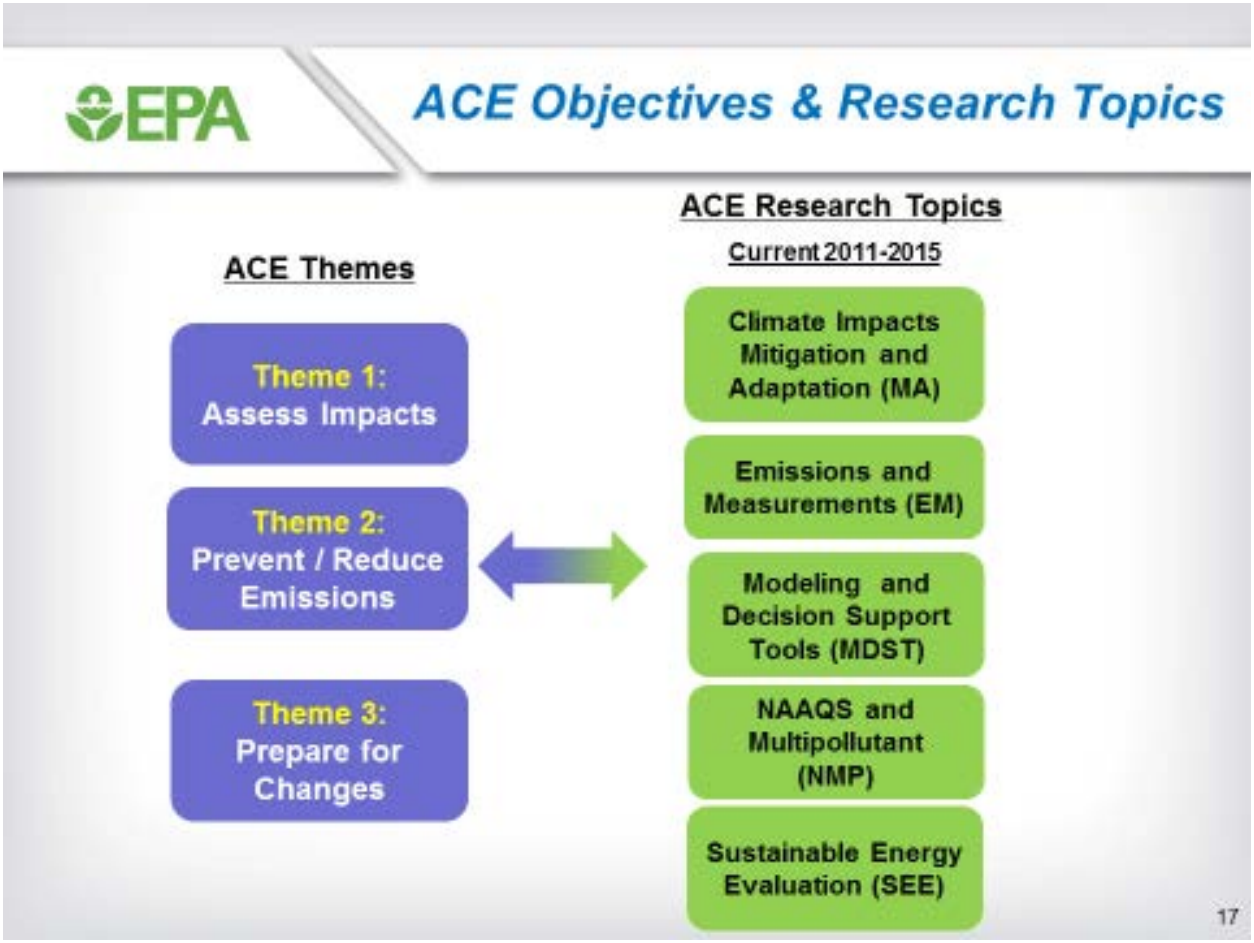
The Subcommittee applauds the ACE program for its breadth and diversity of approaches used for engaging its partners. The approaches used are broad-based and highly effective, but the Subcommittee believes coordination processes could be more efficient. The communication channels and extent to which input in planning is being provided by other offices within ORD, which will be necessary to implement the systems approach, is not clear.

EPA also needs to place more effort, especially in the early stages, to directly involve the states in problem formulation. The states serve a key role in both providing and using information related to the ACE program. Their interests and points of view are not always fully represented by EPA's Regional Offices and the Agency's regional partners. Direct involvement by the states should help ensure an on-the-ground perspective of needed tools and the ultimate implementation of research accomplishments into use and operations.

Using a systems-level approach at all stages of the program, including problem formulation, should help delineate linkages among research elements and partners' needs, create an architecture for research planning and coordination, as well as provide a framework for current and future communications. Figure 1, presented to the ACE Subcommittee during the ACE National Program Director's ACE overview presentation on June 18, 2015, shows the relationships between air, energy and climate and the ways in which the five core themes fit into the new directions. The logic illustrated in this figure is a good foundation to build on using a systems approach to more clearly articulate how the interactions across program areas will be driven, evaluated, and used. It will be important to link the program structure and

investments to the strategic themes and priorities, and this systems framework can illuminate the connections among these elements of the plan. We recognize this may require additional resources (or a reprioritization of current activities) but the development and continued use of a systems approach should have a high priority.

Figure 1[2]



The ACE Subcommittee applauds the stated priority that EPA is placing on coordinating the elements of this program. A systems approach will reinforce program priorities and needs, clarify communications, and point towards new directions across the entire ACE program. This will support the drive to shift the culture in ORD and help focus full-time equivalents (FTEs) on the highest priority challenges. The Subcommittee thinks that ACE is doing a good job in managing the tension between serving near-term user needs and longer-term research priorities, but recommends consideration of dedicated resources for conducting rapid-response research when significant issues emerge not on the planned research agenda. Utilizing an overarching framework and systems approach from the outset can enhance the program and help manage that process and also help maximize the impact of the program on advancing our understanding of interdisciplinary air, climate, and energy problems. For example, more frequent and intense wildfires associated perhaps with changes in climate can lead to local changes in air quality, which can change energy availability or even threaten delivery of energy.

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[2] Costa, ACE 101 BOSC, June 18, 2015

Recommendations

1. The Subcommittee recommends that ACE increase direct involvement of one or more states in the problem formulation stage of research planning.
2. The Subcommittee endorses continuing the development and implementation of a systems approach at all stages of the program, including problem formulation.
3. The Subcommittee requests that ACE provide more information on the extent to which other offices within ORD participate in project planning.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

In general, the Subcommittee feels that ACE has been very responsive and the partners we heard from at the meeting were pleased. We encourage ACE to define partners more broadly to include state air program agencies and regional air planning organizations and to identify a process to include these partners in setting program priorities. It will also be important for ACE to continue to nourish the connection of its PIs and administrators to some of the many and proliferating climate change adaptation and mitigation groups set up around the country as non-profit organizations or offices of other Federal agencies: the NOAA Regional Integrated Science and Assessments (RISAs), U.S. Department of Interior (DOI) Climate Science Centers, and U.S. Department of Agriculture (USDA) Climate Hubs are examples.

The research plan describes very well the transition away from "University of EPA." The research agenda is heavily influenced by OAQPS for historical reasons, proximity of staff, and the large regulatory responsibility of OAQPS. Emissions characterization, monitoring methodologies, and atmospheric science (especially further development of photochemical and receptor models) must continue to be priorities to support OAQPS and state needs. For example, increased emphasis needs to be placed on developing new or replacing outdated federal reference methods for ambient pollutants. ACE should continue to evaluate small, inexpensive sensors (e.g. nitrogen dioxide, ammonia, ozone, fine particulate matter ($PM_{2.5}$), etc.) but must also develop a roadmap for their eventual use for determining compliance with National Ambient Air Quality Standards (NAAQS). Model areas that need continued support include source attribution components, dry deposition, and speciation profiles. At the same time ACE needs to be responsive to the needs of other partners and find a workable balance between its traditional priorities and emerging new demands such as climate change and agricultural air quality. The Subcommittee acknowledges the tension between regional offices, National program needs, and individual scientists' expertise. We encourage ACE to ensure continuity in core areas of research so that projects like methods development do not suffer when key staff retire or leave the Agency. Another challenge is balancing and responding to immediate needs while addressing future research needs and integration across programs. Both the Subcommittee and those partners from whom we heard emphasized the value of synthesis documents.

Recommendations

1. The Subcommittee strongly endorses the value of and the need to continue allocation of resources directed to the synthesis and translation of the results of ACE research to ensure that it is used widely and effectively.
2. The Subcommittee suggests that ACE consider new ways to include states and regional planning organizations more directly as partners.
3. The Subcommittee strongly supports maintaining high priority on core areas of research that ACE partners, the states, and other users rely heavily on, for example emissions characterization, monitoring methodologies, and atmospheric science. In this vein, the Subcommittee specifically noted the need for:
   a. Developing new or replacing outdated federal reference methods for ambient pollutants;
   b. Continuing the development of small, inexpensive sensors suitable for criteria pollutants as well as emerging air pollutants such as ammonia; and
   c. Continuing support of air dispersion model development in the areas of source attribution, dry deposition, and speciation profiles.
4. The Subcommittee notes the need to balance traditional priorities with emerging issues, and urges ACE to ensure continuity in core areas of research (for example when key staff retire or leave the Agency), as those remain relevant to the core missions.

Specific to ACE: Charge Question 4. Please comment on the quality of the products delivered by the program. Are there additional approaches that could be taken by the program to ensure that its products are of high quality?

The Subcommittee recognizes and appreciates the outstanding, high-quality research carried out by ACE, both internal and external to the Agency. The quality of the research outputs has been reflected in refereed journal publications (both the number of publications and the rankings of the journals), in citations, in prestigious awards bestowed to ACE research teams (both intra- and extra-mural), and in the many positive external reviews for ORD products such as the Integrated Science Assessment.

The Subcommittee deliberated on the additional steps ACE can take to maintain this level of high quality research as the ORD engages in more short-term work in response to programmatic and policy needs, as ACE research areas branch into other fields, and as ACE engages in more public outreach programs.

One approach that the Subcommittee recommends is development of a set of multiple metrics to measure the quality of the diverse types of productivity and output from ORD researchers as ACE is extended to additional considerations. It is critical to continue to track the number of publications, quality of publication outlets, the number of citations, and distinguished awards. However, these traditional metrics would best be interpreted in a context of additional measures and with a number of caveats. For example, the impact factors for publications and number of citations can vary substantially from one field to another (e.g., economics *versus* engineering), and as a result, the numbers may not be comparable across fields. Further, numbers alone may not fully reflect research quality and value, and internal and external peer review may be needed to augment such numbers. It is important that peer review activities continue and that they receive sufficient funding within the ACE program to maintain high quality products.

Collaborations with other researchers within ACE and external to ACE are an excellent way to produce high quality work. Appropriate incentives or rewards should be in place for collaborative work, in terms of promotion, awards, etc.

Further, as ACE increases its efforts in outreach and engagement, it is important to make sure that such efforts are built on the solid science that has been the hallmark of the ACE program. It is also important that the outreach and engagement efforts be conducted in a manner consistent with the state-of-the-science approaches, utilizing results from research in communication and engagement. To ensure the quality of outreach and engagement work, ACE may need to develop a set of metrics for such efforts that should be tracked, for example, hits to websites, hours spent in public outreach activities, publications in engagement journals, etc.

It is important to maintain quality standards when ACE generates data in response to short-term needs and from new types of projects (for example, the Village Green project). The Subcommittee would like to see the quality assurance procedures for different types of ORD projects at the next review meeting so that it can provide informed recommendations on additional approaches that could be taken by the program to ensure that its products are of high quality. For example, as ACE further develops a 'Rapid Response' program that provides fast turn-around products, as discussed in the response to charge question #1, it will be important to customize quality assurance procedures for rapid response activities.

To maintain long-term relevance, quality, and utility of ACE research, it is important to periodically review and evaluate the core research areas within ACE. Lack of continuity in externally funded research areas is a concern when, for example, promising research in the Science To Achieve Results (STAR) program does not have the opportunity for continued funding because of changes in Request for Application (RFA) topics. The Subcommittee also heard concern expressed by program office representatives that ACE maintain the continuity of basic science research in core areas that are critical to the plan moving forward in an environment of reduced work force and retirement of senior research staff.

Recommendations

1. The Subcommittee recommends the development of a set of multiple metrics to measure the productivity and output quality of ORD researchers that accounts for differences in fields of research, acknowledges the importance of synthesis and translation work, and rewards collaborative efforts (within ACE and external to ACE).
2. The Subcommittee suggests the development of a set of metrics for outreach and engagement efforts that can be tracked, for example, hits to websites, hours spent in public outreach activities, publications in engagement journals, etc.
3. The Subcommittee noted the importance of ensuring the continuation of sufficient funding for program reviews by external experts, peer review, and other quality assurance activities to maintain high quality product. The Subcommittee believes that the ACE program is highly focused on quality assurance; however, the Subcommittee would benefit from greater knowledge of quality assurance procedures in place for different types of ORD projects.
4. The Subcommittee suggests that ACE consider customizing quality assurance procedures specifically for rapid response activities, which might involve releasing research results in preliminary form, as part of a 'Rapid Response' program and plan of action.

Specific to ACE: Charge Question 5. How well have we translated research findings and understanding for the end-users? How can we improve our ability to translate research findings and understanding for end-users in the future?

The Subcommittee received anecdotal evidence that program and regional offices are pleased with the new ACE structure and with the methods and frequency of communication with ACE. However, we have not communicated with a broad selection of offices in coming to this conclusion.

In answering this question, the Subcommittee wished to have a clear definition of what is meant by "end-user". We concluded that the end-user could be other researchers, ACE partners, policy makers, and the public, a list reflecting a very wide range of interest and capabilities to take and use ORD ACE products. We also recommend that the term "end-users" be replaced by "users" to more accurately reflect the profile of those who use ACE's products and the range of ways that ACE research is used.

The need for synthesis and translation of results of ACE research is critical in order to support policy decisions, particularly as ACE participates in more public engagement. The Subcommittee recognizes that part of the ACE current culture change is to enhance the ability of ACE researchers to understand their work in a larger context and learn how to communicate research results to non-specialists. While some PIs might have expertise in translating and/or synthesizing research results, it is not desirable to require all PIs to engage in translation and/or synthesis efforts. ACE should identify and/or train the appropriate people (technical FTEs) best suited to synthesis and/or translation of research work. Rewards and incentives should be in place, because synthesis and translation work does not necessarily result in peer-reviewed publications, yet the impact on policymakers and the public can be substantial.

Multi-directional communication is essential. Research results must be translated to users; in addition, the users should be involved at the beginning in the research cycle, not to direct the research agenda but to provide their perspective on what research products are most needed and how they will be used. There is opportunity for the technical FTEs who are most involved in synthesis and translation to facilitate this multi-directional communication. Again, rewards and incentives are important for encouraging multi-directional communication.

Recommendations

1. The Subcommittee recommends that ACE identify and/or train staff members who are best suited for synthesis and translation of research and establish rewards and incentives for this kind of research product. Furthermore, the Subcommittee suggests that there is an opportunity to use these staff members to facilitate multi-directional communication, for example, to identify research needs of users, to maximize involvement of users in the problem formulation stage of research, and to provide user support.
2. The Subcommittee suggests that ACE use a broad definition of "end-user" that includes other researchers, ACE partners, policy makers, and the public and that reflects the range of ways that ACE research is used.

SUMMARY LIST OF RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

- **Recommendation 1.1**: The Subcommittee endorses an increased emphasis on climate change-related research on human health effects, such as those associated with wildfires, and environmental impacts modeling and recommends expanding climate change and air quality modeling research to include temperature and humidity. The Subcommittee also suggests that ACE look for strategic research opportunities for characterizing climate impacts on pollen and allergic diseases.
- **Recommendation 1.2**: The Subcommittee recommends continuing to include time and support for PI-initiated research that might not yet have been identified as a current need by internal EPA partners and stakeholders.
- **Recommendation 1.3**: The Subcommittee endorses ACE program planning to provide fast-turnaround products, even in preliminary form, to internal partners and clients when crucial needs arise. One aspect that the Subcommittee noted and would like to explore further is the communication process for ACE inside ORD and the wider EPA to receive and evaluate requests for rapid response actions.
- **Recommendation 1.4**: The Subcommittee recommends reviewing the ACE program balance of intra- and extra-mural research to optimize its ability to meet increased obligations in the face of constrained resources.
- **Recommendation 1.5**: The Subcommittee requests that ACE articulate how the systems approach is being implemented across all the ACE project areas, including research related to emissions from oil and gas extraction, which is not as well integrated into the ACE program.
- **Recommendation 1.6**: The Subcommittee suggests that ACE periodically review the balance between ACE-sponsored social science research and the more traditional areas of physical, chemical, human health, and biological sciences, making sure to leverage social science findings from other agencies and programs.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

- **Recommendation 2.1**: The Subcommittee recommends that ACE increase direct involvement of one or more states in the problem formulation stage of research planning.
- **Recommendation 2.2**: The Subcommittee endorses continuing the development and implementation of a systems approach at all stages of the program, including problem formulation.
- **Recommendation 2.3**: The Subcommittee requests that ACE provide more information on the extent to which other offices within ORD participate in project planning.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

- **Recommendation 3.1**: The Subcommittee strongly endorses the value of and the need to continue allocation of resources directed to the synthesis and translation of the results of ACE research to ensure that it is used widely and effectively.
- **Recommendation 3.2**: The Subcommittee suggests that ACE consider new ways to include states and regional planning organizations more directly as partners.
- **Recommendation 3.3**: The Subcommittee strongly supports maintaining high priority on core areas of research that ACE partners, the states, and other users rely heavily on, for example emissions characterization, monitoring methodologies, and atmospheric science. In this vein, the Subcommittee specifically noted the need for:
  - Developing new or replacing outdated federal reference methods for ambient pollutants;
  - Continuing the development of small, inexpensive sensors suitable for criteria pollutants as well as emerging air pollutants such as ammonia; and
  - Continuing support of air dispersion model development in the areas of source attribution, dry deposition, and speciation profiles.
- **Recommendation 3.4**: The Subcommittee notes the need to balance traditional priorities with emerging issues, and urges ACE to ensure continuity in core areas of research (for example when key staff retire or leave the Agency), as those remain relevant to the core missions.

Specific to ACE: Charge Question 4. Please comment on the quality of the products delivered by the program. Are there additional approaches that could be taken by the program to ensure that its products are of high quality?

- **Recommendation 4.1**: The Subcommittee recommends the development of a set of multiple metrics to measure the productivity and output quality of ORD researchers that accounts for differences in fields of research, acknowledges the importance of synthesis and translation work, and rewards collaborative efforts (within ACE and external to ACE).
- **Recommendation 4.2**: The Subcommittee suggests the development of a set of metrics for outreach and engagement efforts that can be tracked, for example, hits to websites, hours spent in public outreach activities, publications in engagement journals, etc.
- **Recommendation 4.3**: The Subcommittee noted the importance of ensuring the continuation of sufficient funding for program reviews by external experts, peer review, and other quality assurance activities to maintain high quality product. The Subcommittee believes that the ACE program is highly focused on quality assurance; however, the Subcommittee would benefit from greater knowledge of quality assurance procedures in place for different types of ORD projects.

- **Recommendation 4.4**: The Subcommittee suggests that ACE consider customizing quality assurance procedures specifically for rapid response activities, which might involve releasing research results in preliminary form, as part of a 'Rapid Response' program and plan of action.

Specific to ACE: Charge Question 5. How well have we translated research findings and understanding for the end-users? How can we improve our ability to translate research findings and understanding for end-users in the future?

- **Recommendation 5.1**: The Subcommittee recommends that ACE identify and/or train staff members who are best suited for synthesis and translation of research and establish rewards and incentives for this kind of research product. Furthermore, the Subcommittee suggests that there is an opportunity to use these staff members to facilitate multi-directional communication, for example, to identify research needs of users, to maximize involvement of users in the problem formulation stage of research, and to provide user support.
- **Recommendation 5.2**: The Subcommittee suggests that ACE use a broad definition of "end-user" that includes other researchers, ACE partners, policy makers, and the public and that reflects the range of ways that ACE research is used.

SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

Overall, the ACE Subcommittee found that the vision and objectives in the ACE StRAP are clearly articulated and the research topics and project areas are planned and organized appropriately. As a general conclusion, the Subcommittee agreed that the ACE plan provides a structured vision and actionable design to guide an ambitious research portfolio that delivers the science and engineering solutions the Agency needs to meet its priorities and fulfill its legislative mandates, with a specific focus on three stated objectives: 1) Assess impacts; 2) Prevent and reduce emissions; and 3) Prepare for and respond to changes in climate and air quality. The results of ACE program research support policies that have far-reaching positive impacts across the nation, including reducing health risks from air pollution, preparing for the impacts of climate change, and advancing more resilient and sustainable communities.

The Subcommittee unanimously praised the quality of research produced by the ACE program that each subcommittee member was most familiar with and finds the breadth and depth of the research to be extremely impressive. The Subcommittee strongly endorses the value of and the need to continue allocation of resources directed to the synthesis and translation of the results of ACE research to ensure that it is used widely and effectively. Toward this end, the Subcommittee recommends that ACE identify and/or train the scientists that are best suited to synthesis and/or translation of research work and establish rewards and incentives for this kind of research product. Furthermore, there is an opportunity to use those staff members who are particularly proficient at synthesis and translation to facilitate multi-directional communication among ACE, its partners, and other users, for example, to identify research needs of users, to maximize involvement of users in the problem formulation stage of research, and provide user support.

In view of the increasing need to prioritize the allocation of resources, the Subcommittee endorses maintaining high priority on core areas of research that ACE partners, the states, and other users rely heavily on, for example, emissions characterization, monitoring methodologies, and atmospheric/climate science. In this vein, the Subcommittee noted the need for developing new or replacing outdated federal reference methods for ambient pollutants; continuing the development of small, inexpensive sensors

suitable for criteria pollutants as well as emerging air pollutants such as ammonia; and continuing support of air dispersion model development in the areas of source attribution, dry deposition, and speciation profiles.

The Subcommittee applauds the ACE focus on building on core strengths to support the evaluation of climate change impacts. The Subcommittee highlighted the increasing importance of understanding and predicting climate change-related human health effects, such as those associated with wildfires. This particular example illustrates the opportunity to leverage core ACE strengths in air emissions and modeling and to integrate with ongoing and planned research on climate change-related human health and environmental effects performed by ORD, other Federal agencies, and non-governmental organizations. As heat exposure and humidity play key roles in climate change-related health effects, the Subcommittee also noted the importance of including temperature and humidity in air quality modeling used to evaluate climate change impacts at all scales, from local to national and larger. Finally, the Subcommittee identified the need for measuring and/or modeling the changing patterns of pollen exposure as a research area that aligns well with ACE's strengths and the program's stated objective to prepare for and respond to changes in climate and air quality.

On the topic of research planning and problem formulation, the Subcommittee applauds the ACE program for the breadth and diversity of approaches used for engaging partners. The Subcommittee suggests that program planning and implementation might also benefit from more direct involvement by one or more states at the problem formulation stage. The states serve a key role in both providing and using information generated by the ACE program, yet their interests and points of view are not always fully represented by EPA's Regional Office partners. Direct involvement by one or more states should help ensure an on-the-ground perspective on needed tools and the ultimate implementation of research accomplishments into use and operations.

The Subcommittee is sensitive to the tension between the increasing needs of ACE's partners and constrained resources. In this environment, it is important to ensure the continuation of sufficient funding for program reviews by external experts, peer review, and other quality assurance activities to maintain a high quality product. The Subcommittee believes that the ACE program is highly focused on quality assurance; however, the Subcommittee would benefit from greater knowledge of quality assurance procedures in place for different types of ORD projects.

In conclusion, the Subcommittee believes that the ACE StRAP articulates and organizes an ambitious but achievable research program that aligns with EPA's objectives and mandates to protect air quality and take action on climate change. The Subcommittee looks forward to continuing to serve as a resource to the ACE program on technical and management issues related to its research programs.

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

Appendix B: BOSC Chemical Safety for Sustainability (CSS) and Human Health Risk Assessment (HHRA) Subcommittees

Ponisseril Somasundaran, Ph.D. (Chair) *Columbia University*	Rebecca Klaper, Ph.D. *University of Wisconsin, Milwaukee*	Donna Vorhees, Sc.D. *Boston University*
Gina Solomon, MD, MPH (Vice Chair) *California EPA*	Kyle Kolaja, Ph.D. *Cellular Dynamics International*	Katrina Waters, Ph.D. *Pacific Northwest National Laboratory*
Paloma Beamer, Ph.D. *University of Arizona*	Jerzy Leszczynski, Ph.D. *Jackson State University*	Clifford P. Weisel, Ph.D. *Rutgers University*
Chris Gennings, Ph.D. *Virginia Commonwealth University*	Jennifer McPartland, Ph.D. *Environmental Defense Fund*	Mark Weisner, Ph.D. *Duke University*
Dale Johnson, Ph.D. *University of California, Berkeley*	James Stevens, Ph.D. *Eli Lilly*	

EPA Contact
Megan Fleming, Designated Federal Officer

January 19, 2016

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LIST OF ACRONYMS

AOP	Adverse Outcome Pathway
BOSC	Board of Scientific Counselors
CAAC	Chemical Assessment Advisory Committee
CASAC	Clean Air Scientific Advisory Committee
CSS	Chemical Safety for Sustainability
DAA	Deputy Assistant Administrator
EC	Executive Committee
EDSP	Endocrine Disruptor Screening Program
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
HERO	Health and Environmental Research Online
HHRA	Human Health Risk Assessment
HTT	High-Throughput Toxicity Testing
IT	Information Technology
MCHM	4-methylcyclohexanemethanol
MIE	Molecular Initiating Event
NGO	Non-governmental Organization
NPD	National Program Director
OPPT	Office of Pollution Prevention and Toxics
ORD	Office of Research and Development
PCB	Polychlorinated Biphenyl
POC	Proof of Concept
QSAR	Quantitative Structure-Activity Relationship
RARE	Regional Applied Research Effort
RFA	Request for Application
SAB	Science Advisory Board
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan

BACKGROUND

The Chemical Safety for Sustainability (CSS)/Human Health Risk Assessment (HHRA) Subcommittee of the Environmental Protection Agency (EPA) Board of Scientific Counselors (BOSC) conducted its first annual review at the EPA's Research Triangle Park Main Campus in Research Triangle Park, North Carolina on October 6-8, 2015. The following is the list of Subcommittee members who participated in the meeting:

- Ponisseril Somasundaran, Ph.D., Subcommittee Chair, LaVon Duddleson Krumb Professor, Columbia University
- Gina Solomon, M.D., M.P.H., Subcommittee Vice-chair, Deputy Secretary for Science and Health, California Environmental Protection Agency
- Paloma Beamer, Ph.D., Associate Professor, Mel & Enid Zuckerman College of Public Health, University of Arizona
- Dale Johnson, Ph.D., President and CEO, Emiliem Inc. and Elara Bioscience Inc.; Adjunct Professor, University of Michigan and University of California-Berkeley
- Rebecca Klaper, Ph.D., Professor and Director of the Great Lakes Genomics Center, School of Freshwater Sciences, University of Wisconsin-Milwaukee
- Jerzy Leszczynski, Ph.D., Professor, Jackson State University
- Jennifer McPartland, Ph.D., Senior Scientist, Environmental Defense Fund
- James Stevens, Ph.D., Distinguished Research Fellow, Eli Lilly and Company
- Donna Vorhees, Sc.D., Owner, The Science Collaborative; Adjunct Assistant Professor, Boston University School of Public Health
- Katrina Waters, Ph.D., Scientist, Pacific Northwest National Laboratory
- Clifford P. Weisel, Ph.D., Professor, Environmental and Occupational Health Sciences Institute, Rutgers University

EPA's BOSC Executive Committee (EC) was chartered in 2014 to provide advice and recommendations on all aspects (technical and management) of the Office of Research and Development's (ORD) research program. In July 2014, the BOSC EC joined the Science Advisory Board (SAB) to advise the EPA Administrator on EPA's strategic research directions. To arrive at their recommendations, the SAB and BOSC EC reviewed preliminary drafts of ORD's 2016-2019 Strategic Research Action Plans (StRAPs) for each of the six national research programs, and received briefings and additional background materials from ORD's Deputy Assistant Administrator for Science and its National Program Directors (NPDs). This two-day meeting culminated in a report to the EPA Administrator in January of 2015. The programs then revised their StRAPs based upon the report.

As the programs begin to implement the research outlined in the StRAPs, ORD is asking the BOSC to advise its Assistant Administrator as to whether ORD is "doing the science right?" The BOSC EC will address cross cutting issues of interest to ORD broadly while the program-specific BOSC subcommittees will provide targeted advice on accomplishing the program's objectives and the research articulated in their 2016-2019 StRAPs.

The BOSC CSS/HHRA Subcommittee was established to provide program-specific advice to EPA's CSS Research Program, and a portion of EPA's HHRA research program.[3] The vision of the CSS research

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[3] The SAB/BOSC review of the HHRA research program was restricted to its research areas and not its risk assessment products as these are given guidance by other review committees such as the SAB Clean Air Scientific Advisory Committee (CASAC) and the Chemical Assessment Advisory Committee (CAAC).

program is to lead development of innovative science to support safe, sustainable use of chemicals and materials required to promote ecological wellbeing, including human and environmental health, as well as to protect vulnerable species and populations. The HHRA research program supports risk-based decisions by EPA, State/local/tribal agencies, and the public to protect public health and the environment, which are based on reliable, transparent, and high-quality risk assessment methods, models, and data. The CSS and HHRA research programs plan to engage the Subcommittee over the next several years to provide advice on the programs' portfolios and to assess progress in addressing EPA's needs.

The Subcommittee was tasked with addressing a set of charge questions common to all of the BOSC subcommittee efforts this year related to program design, problem formulation, and responsiveness to partners' (customers') needs (General Charge Questions 1, 2, and 3). In addition, the Subcommittee was tasked with two questions specific to the CSS research program related to the scope and implementation of certain CSS research topic areas, and fit-for-purpose translation and knowledge delivery (CSS-Specific Charge Questions 4 and 5), and one question specific to the HHRA research program related to the characterization of new data and computational methods for risk assessment (HHRA-Specific Charge Question 6).

These questions were designed to provide useful, high-level recommendations on relatively big-picture aspects of the programs' design and operation, allowing the nascent Subcommittee to establish familiarity with the research programs, while at the same time, preparing the Subcommittee for future charges that will require a deeper understanding of the programs.

CHARGE QUESTIONS AND CONTEXT

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

The StRAPs are designed to clearly convey the vision and objectives of the research program, and to describe, at a high level, the research topics, and major outputs planned for 2016-2019. Upon receiving recommendations from the SAB and the BOSC EC, as well as from EPA partners and others, ORD has further developed the StRAPs, including refining the objectives and topics, and providing more clarity. At an operational level, each research program is aiming to accomplish its objectives through research spanning physical, biological and social sciences and through numerous ORD laboratories, centers, and Science to Achieve Results (STAR) grantees all across the country. In addition, ORD has heeded the advice of the SAB and BOSC in past years to do more to integrate research across the six programs, across EPA and with other Federal partners. Given these complexities, we recognize there are likely several reasonable approaches for organizing the research to best accomplish the objectives.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

ORD works with EPA partners to design the research programs to meet Agency priorities. The first step in this process is problem formulation which provides the foundation of the research. Although it can be tempting to jump to a list of research priorities, problems that are well defined lead to the most effective research efforts and solutions. The problem formulation stage of research planning lays the groundwork for the StRAPs and is the reference point for any changes in priorities as budgets change and new issues

emerge. Problem formulation occurs at many different levels including the articulation of issues in the EPA Strategic plan; meetings with EPA partners including regular staff-to-staff meetings; workshops and conferences where states, regions, policy and science staff describe the problems they face; and discussions among senior managers at EPA. In addition, each National Program Director reaches out to EPA partners in a variety of targeted ways to agree on problem definition.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

ORD places a very high value on working closely with EPA partners to design the research programs to meet Agency priorities. During the preparation of the StRAPs, the programs were guided by the EPA Strategic Plan and undertook a variety of activities to actively engage partners, both to understand their priorities and to elicit their input on research directions. These include many regular meetings with EPA policy and regional staff, communities of practice for specific scientific disciplines throughout the Agency, annual two day meetings led by the NPDs, annual senior level meetings with EPA Assistant and Regional Administrators, and formal requests from ORD's Deputy Assistant Administrator (DAA) for science to receive comments from across the Agency twice during the year of StRAP development.

In addition to the up-front work with EPA partners to understand their research needs for the upcoming year(s), ORD also needs to be flexible enough to address top priority, unanticipated needs or environmental crises that emerge at any given time. The research program will describe interactions with EPA partners, present examples of recent responsiveness to unexpected events, and explain how they work with EPA partners to accommodate acute needs while resources are limited.

Specific to CSS: Charge Question 4. Please provide input on the scope and implementation for 2016-19 in the following topic areas: Complex System Science, Lifecycle Analytics, Chemical Evaluation

EPA's Chemical Safety for Sustainability Research Program (CSS) is leading the development of innovative science to support safe, sustainable selection, design, and use of chemicals and materials required to promote ecological wellbeing, including human and environmental health, as well as to protect vulnerable species, lifestages, and populations. The ultimate goal is to enable the Agency to address impacts of existing chemicals, anticipate impacts of new chemicals and materials, and evaluate complex interactions of chemical and biological systems to support Agency decisions. Working in conjunction with our partners in the EPA regulatory programs and regions, we have identified priority needs for information and methods to make better-informed, more-timely decisions about chemicals. CSS science is strategically scoped within three integrated Research Topics to support Agency priorities.

Specific to CSS: Charge Question 5. Please provide input on opportunities and approaches for fit-for-purpose translation and knowledge delivery.

CSS is committed to lead the translation and delivery of key research results to our partners through promoting web-based tools, data, and applications to support chemical safety evaluations and related decisions, respond to short-term high priority science needs for CSS partners, and allow for active and strategic engagement of the stakeholder community.

Specific to HHRA: Charge Question 6. Please comment on the research dimensions for the HHRA program and, in particular, the proposed approaches for characterization of new data and computational methods to improve confidence and build capacity for their application in the context of risk assessment.

The HHRA program advances the scientific basis for risk assessment including development of contemporary hazard identification, dose-response assessment and cumulative risk methods, and through application of innovative computational methods and characterization of new data (such as the data developed through the CSS program).

CSS STRAP OBJECTIVES AND PRIORITY RESEARCH TOPICS

The CSS research program StRAP FY 16-19 is aligned around four major research objectives: (1) Build Knowledge Infrastructure; (2) Develop Tools for Chemical Evaluation; (3) Promote Complex Systems Understanding; (4) Translate and Actively Deliver. The research objectives serve as the overarching framework for more focused research topics that guide specific research and development activities. These include:

Chemical Evaluation

Advance cutting-edge methods and provide data for risk-based evaluation of existing chemicals and emerging materials.

Life Cycle Analytics

Address critical gaps and weaknesses in accessible tools and metrics for quantifying risks to human and ecological health across the life cycle of manufactured chemicals, materials, and products. Advance methods to efficiently evaluate alternatives and support more sustainable chemical design and use.

Complex Systems Science

Adopt a systems-based approach to examine complex chemical-biological interactions and predict potential for adverse outcomes resulting from exposures to chemicals.

A fourth research topic focuses on translation and active delivery of CSS research and products, demonstration and application of CSS scientific tools, and knowledge delivery to EPA Partners:

Solutions-based Translation and Knowledge Delivery

(1) Promote Web-based tools, data, and applications focused on tailored solutions to support chemical safety evaluations and related decisions; (2) Respond to short-term high priority science needs for CSS partners; and (3) Allow for active and strategic engagement of the stakeholder community.

HHRA STRAP OBJECTIVES AND PRIORITY RESEARCH TOPICS

The HHRA research program StRAP FY 16-19 is aligned around three major research objectives: (1) Characterize Risks, (2) Advance and Refine Assessment Methods; (3) Enhance and Engage. The research objectives serve as the overarching framework for more focused research topics that guide specific research and development activities. The BOSC CSS/HHRA Subcommittee is tasked with reviewing the portion of the HHRA research program that includes its research areas and not its risk assessment products. The specific HHRA research topics for review by the Subcommittee include:

Community and Site-specific Risk

Significant progress in environmental protection has occurred in the United States over the past decades, but many challenges remain, and some communities are disproportionately impacted. While many environmental problems are global, national and regional in nature, their impacts are experienced most acutely at the community level.

Advancing Analyses and Applications

The HHRA program is multidisciplinary and aimed at incorporating scientific innovations to advance analytic approaches and applications. Projects under this topic are targeted at enhancing hazard characterization, expanding the repertoire of dose-response methods and models, and characterizing the utility of emerging data and new computational tools as applied to risk assessment. Another project enhances and maintains databases and software support to ensure transparency, and facilitate understanding and translation to Agency partners and external stakeholders. These projects are critical to keeping assessment activities contemporary with emerging concepts in exposure sciences, advances in biotechnology, and the evolution of computational approaches and systems biology for understanding disease processes and ecosystem impacts. Refinements to current approaches are expected to improve the accuracy, efficiency, flexibility, and utility of applications across the large landscape of assessment activities served by the HHRA program and position it to be both more agile and better support characterization of wellness and sustainability.

RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

The Subcommittee was favorably impressed by the breadth and depth of the Chemical Safety for Sustainability (CSS) and Human Health Risk Assessment (HHRA) programs, and by their accomplishments to date. The research programs articulate a clear vision of their overall mission and their plan to reach their objectives. Their cross cutting goals and projects contain novel solutions for addressing important data gaps. The research objectives articulated in the StRAPs are ambitious, especially in the case of the CSS, and they will be challenging to accomplish in the 2016-2019 time frame. Nonetheless, based on the Subcommittee's review, specific topics and project areas are on-track to make important progress toward those goals by 2019. The CSS Program has the potential to be truly transformative of the work of EPA and of entire fields of science; the HHRA program provides a service that is cross-cutting and fundamental to

informing decisions both within and outside the Agency. Together, the two programs are demonstrating responsiveness to the relevant recommendations of the National Research Council on toxicity testing (2007), exposure science (2012), and risk assessment (2008). The programs are demonstrating the potential to deliver the scientific foundation needed to address important knowledge gaps and thereby to enhance protection of human health and the environment while reducing uncertainty.

Areas for Improvement

The Subcommittee has identified information technology (IT) as a critical factor related to the overall success of the CSS and HHRA programs. There is an immediate need to evaluate the sufficiency of the IT resources and infrastructure available to support: (1) the research programs; and, (2) the necessary transfer and deployment of data and analytical tools to EPA partners (i.e., EPA program and regional offices) and the public. There is also a need to address public-facing website accessibility and functionality on a continual basis. The programs in CSS and HHRA are highly IT-intensive and will continue to be at an increased rate as new data, tools, and technologies are developed and established. The timely ability of CSS to release data and tools in fully interactive web-based interfaces is urgent. The IT challenges include multiple hurdles that relate to resources, hiring, contracting, purchasing, and Agency website rules. One example is the need to comply with directives requiring data transparency without sufficient support and 'IT space' to deposit new tools and techniques in the public domain.

EPA has multiple audiences and must remember that these audiences include technical experts as well as the general public. The Agency is required to present information to the public in plain English, which is important so that a non-technical audience understands EPA's scientific work. However, scientific data and tools often cannot be fully explained in simple language, and these data and tools must also be made publicly available. The Subcommittee recommends that different EPA communications should be tailored to the needs of different user communities, and that technical and scientific information should be presented in language appropriate to the target audience. The Subcommittee applauds both programs for their ongoing efforts to make data and tools publicly available and believes that addressing the IT and science communication issues is critical to the ability of both programs to achieve their objectives in the 2016-2019 time frame.

The research programs include a portfolio of methods, tools, and information that will grow and evolve in upcoming years. Case studies have been an integral part of the design and development of many scientific methods, and serve well here to explain and demonstrate the proposed approaches. The CSS research and product portfolio serves to address the paucity of data for a majority of chemicals that exist now. Some of these chemicals will eventually enter the environment, sometimes through unexpected means. As with any effort of this type, technological advances and new data will likely change the focus of scientific inquiry over time, causing some methods to become obsolete while others may be enhanced. Scientific portfolios can never remain static and must be continually evaluated and upgraded. We noted examples of such evolution already in the CSS Program (e.g., around development of screening tools for thyroid activity), as well as other areas where additional evolution is needed (e.g., around incorporating metabolism into various test platforms and models).

The CSS Program could benefit from a well-defined "proof of concept" (POC) evaluation where actual outcomes can be measured against the expected outcomes within a specified timeframe. This evaluation would occur after the tools have been developed and introduced. In a 3-year timeframe, there should be several POCs, which could serve to reprioritize the portfolio, thereby possibly eliminating some tools or assays and bring in new methodologies within a defined budget. These types of POC evaluations will also

incentivize researchers toward creating highly reproducible tools and methods and will engender more confidence from the outside community.

Given the very ambitious nature of the CSS program, it is important to manage the complex interdependencies and trade-offs to make sure the overall program will make tangible progress toward the longer term goal of changing, advancing and ultimately improving the way chemical evaluation is done. It is important to balance aspirational goals to change the state-of-the science and the real task of delivering, in a timely fashion, solutions to key questions. The enthusiasm of the CSS program is laudable, but there are real, significant, and critical interdependencies in, for example, the Adverse Outcome Pathway (AOP) definitions and the move toward systems approaches. Another example is the desire to integrate Virtual Tissue work into the AOP focus for risk assessment, but it is not yet clear how close the tissue models or next-generation culture systems are to realizing achievable, meaningful, and useful results. POC evaluations may also be helpful in this area.

Summaries and timelines could help those external to the programs better understand what the programs are doing and where they are going. This exercise could be useful in operationalizing the StRAPs by summarizing all the deliverables and timelines in one place. Summaries and schematics could also be useful to show how the database tools interrelate and how they can be used individually and together.

Fundamentally, both the CSS and the HHRA research programs are seeking to catalyze organizational change within the government and in the broader scientific community. Organizational change is extremely difficult, and it requires specific attention. It is clear that the science must be the top priority because it will be impossible to earn the confidence of the other EPA program offices, the regional offices, and the broader stakeholder communities if the science is not exceptionally strong and relevant. But even strong and relevant science will encounter resistance if it is too far ahead of the user community. For these reasons, the Subcommittee suggests that the CSS program consider working with experts in organizational change as it continues efforts to engage partners within and outside the Agency.

The programs in CSS and HHRA are—without question—some of the premier entities of the EPA. They present an opportunity to be a showcase of Agency innovation and guardianship of human and environmental health and sustainability.

Recommendations

1. There is an immediate need to evaluate the sufficiency of the IT resources and infrastructure available to support: (1) the research programs; and, (2) the necessary transfer and deployment of data and analytical tools to EPA partners and the public.
2. Different EPA communications should be tailored to the needs of different key communities; technical and scientific information should be presented in language appropriate to the target audience.
3. The CSS Program could benefit from a well-defined "proof of concept" (POC) evaluation where actual outcomes can be measured against expected outcomes within a specified timeframe.
4. Summaries, schematics, and timelines could help those external to the programs better understand what the programs are doing and where they are going.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

Based on positive testimonies from EPA partners, it appears that CSS and HHRA are effectively involving EPA partners (i.e., EPA program and regional offices) in the problem formulation stage of research planning and that there has been much improvement in facilitation of two-way communication with partners. CSS's Connectome and HHRA's Risky Business as well as monthly calls, webinars, and face-to-face interactions on-site with the partners have been successful in engaging EPA partners in planning StRAPs and generating excitement for research being performed by CSS and HHRA.

Meeting with and sharing draft StRAPs with partners and explicitly and formally soliciting their feedback seems to be an effective means of involvement. This was further evident from specific examples provided by partners. For example, an internal workshop with the Office of Policy directly led to formation of many of the goals of Project 7 within HHRA. A representative from Region 3 reported that their region was able to provide input and contribute to the writing of STAR Requests for Applications (RFAs).

In the HHRA program, tools are being developed to fulfill needs expressed for risk assessment. HERO is a great example to help with transparency. Clearly, there has been obvious effort to improve communication, and despite lack of funding for travel and IT support, there have been obvious efforts to develop virtual methods to connect with EPA partners. The program directors are commended for their efforts to transform the culture, and they are encouraged to continue to work with their management and executive council peers to maintain the energy in these efforts.

Areas for Improvement

It is difficult to assess the effectiveness of CSS and HHRA approaches of engaging the EPA partners when there are no formal evaluation metrics provided. We heard great reviews from EPA partners that were included in the StRAP development process, but it is not clear how representative they are of EPA partners or how effective the process is at reaching EPA partners. In the future, the process of engaging with partners could benefit from a more formal program evaluation. Program evaluation is a systematic method and research discipline in itself that can be used to assess the effectiveness and efficiency of a process and determine if it is meeting its goals. By formalizing the program evaluation, CSS and HHRA would be completing a more holistic needs assessment and could identify additional barriers to receiving input on problem formulation from partners.

Another challenge in engaging EPA partners in the formulation stage, especially the regional offices, is that many of these employees are already strapped for time and resources. However, since early stage user involvement enhances the quality and success of tool and information deployment at the user level, CSS and HHRA should formalize a program to ensure this happens as a routine part of research formulation. There was a clear desire communicated by the EPA partners (particularly from the regions) for more face-to-face interactions. CSS and HHRA could look for more capabilities for travel or virtual interactions with their partners, or encourage more cross-office details. This would allow CSS and HHRA research staff to become more familiar with the day-to-day work of their partners and the problems they encounter that could most directly benefit from the research capabilities at CSS and HHRA. These efforts would definitely benefit from enhanced IT capabilities. HHRA Superfund technical support centers could engage NIEHS-funded Superfund Research Program investigators in responding to regulatory needs for regional partners, and developing case studies to evaluate HHRA tools and research products.

Recommendations

1. CSS and HHRA should establish a process to ensure that early stage user involvement happens as a routine part of research formulation.
2. The process of engaging with partners could benefit from a more formal program evaluation. By formalizing the program evaluation, CSS and HHRA would complete a more holistic needs assessment and could identify additional barriers to receiving input on problem formulation from partners.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

According to the charge document, this question pertains to how well the CSS and HHRA research programs (1) work with their partners (i.e., EPA program and regional offices) to design research programs that meet Agency priorities, and (2) maintain flexibility in addressing "top priority unanticipated needs or environmental crises that emerge at any given time." The BOSC Subcommittee heard presentations from representatives of several EPA regional and program offices describing CSS and HHRA efforts to achieve these two objectives. Presenters described largely successful efforts, but also noted some important opportunities for improvement.

CSS research programs have provided important support to the work of the Office of Chemical Safety and Pollution Prevention. CSS research holds the promise of helping with evaluations of chemicals for which there is little if any exposure or toxicological information. The challenge associated with new chemicals and nanomaterials, illustrates the need and tremendous potential value of the high throughput and related technology being developed by CSS. Some EPA partners expressed great enthusiasm for the CSS product RapidTox, and others noted the use of CSS's ToxCast for emergency response.

EPA regional partners at times must make risk-based decisions for addressing chemicals with inadequate or nonexistent hazard and exposure data. They reported that the Regional Applied Research Effort (RARE) program is among the best available ways to meet these and other high-priority, near-term research needs of regional offices. HHRA research programs play a critical role in protecting public health by supplying research that informs regional decision-making and policy. HHRA provides regular individual technical support to regions that frequently goes undocumented. Archived webinars are very helpful. HHRA also has been critically important in emergency response actions, such as the spill that contaminated drinking water with 4-methylcyclohexanemethanol (MCHM) in West Virginia and the Gold

King mine spill in Colorado, as well as with preparation of guidance to help regional offices respond to specific exposure situations, such as polychlorinated biphenyls (PCBs) in schools. The development of acute toxicity values was highlighted as an important need by several EPA partners, and the Subcommittee believes this area needs greater emphasis in the HHRA program.

Areas for Improvement

Success of EPA partners depends on the successful transfer of science and technology to support prompt response to rapidly developing issues. Some regional staff report difficulty identifying the appropriate HHRA or CSS staff person to approach with a question, and that ORD does not always understand regional responsibilities. The successful transfer of science and technology requires effective connections between ORD staff and EPA partners and a mutual understanding of roles and responsibilities. This transfer of knowledge could be encouraged by dedicating a new budget line item to its implementation (e.g., EPA Partner Collaboration) with appropriate oversight. Planning and budgeting for collaboration will enhance the participation of EPA partners in problem formulation, the design of research and the successful use of research results at the regional and program levels. For example, it is important to explain how some of the CSS modeling programs demonstrated during the genius bar can be used to address EPA partner responsibilities and to plan for the time and continual training needed to ensure their successful application. The Subcommittee understands that the CSS program is hiring two new outreach people, and believes that dedicated staff will be an excellent investment in this area. Similar positions might also be helpful in the HHRA program.

Regional and program offices are ideal "incubators" for pilot testing some ORD tools. CSS and HHRA should continue to engage partners in the development of new case studies that mimic realistic field scenarios and demonstrate the utility of CSS tools and methods with an explicit review process. Case studies described in the StRAPs were chosen in consultation with EPA partners over time via meetings, webinars, and other means. The case studies defined to date, such as application to the Endocrine Disruptor Screening Program, seem appropriate and useful. What remains unclear is exactly how case study success will be evaluated and how the proposed research will directly or indirectly support each of EPA's various regulatory programs. How will EPA judge whether case studies achieve pre-specified goals? Formal goals and measures of success should be defined now to help guide the research program toward useful applications. EPA needs to look forward to possible uses of its research, such as risk-based decision-making, and to possible challenges or "roadblocks." With this information, EPA should define its measures, or criteria, for success. EPA cannot make specific predictions about the utility of new tools and methods before it tests them. Measures of success could change over time as more experience and knowledge is gained.

Recommendations

1. CSS and HHRA should continue to engage partners in the development of new case studies that mimic realistic field scenarios and demonstrate the impact of their methods to influence informed decisions for chemicals that lack sufficient data.
2. Formal goals and measures of success should be defined to help guide the research program toward useful applications.
3. The transfer of knowledge to EPA partners could be encouraged by dedicating a new budget line item to its implementation to enhance participation in problem formulation, the design of research and the successful use of research results at the regional and program levels.

Specific to CSS: Charge Question 4. Please provide input on the scope and implementation for 2016-19 in the following topic areas: Complex System Science, Lifecycle Analytics, Chemical Evaluation

Complex Systems Science

The CSS Research Program is uniquely positioned to help the Agency to advance the science on predictive exposure and toxicology to support a more systems-based approach to risk assessment in the future. Complex Systems Science has the potential to transform the field by translating in *vivo/in vitro* measurements and *in silico* predictions of molecular initiating events (MIEs) to modeled measures of adverse response that are reflective of apical endpoints using AOPs.

Areas for Improvement

There are several steps that need to occur to demonstrate the utility of this approach and create a strong framework for using these data in ecological and human health risk assessment. These steps include:

1. Making the connection between data obtained from high throughput (developed from off-the-shelf technologies that are not completely representative of anticipated mechanisms of action) to data and assays indicative of defined AOPs (i.e., those that are supported by quantitative and qualitative information that links the data to apical endpoints) used in risk assessment. The current programs anticipate the need for both qualitative and quantitative modeling approaches. Qualitative models are based on known network connectivity without kinetic/abundance data; whereas quantitative models predict internal exposure and time-course with quantitative biological values. The CSS program scientists fully understand that when a model increases in complexity the amount of "real" data needed obviously increases, which is shown by the number of new technologies under development for evaluation. Translation of AOPs from qualitative frameworks to quantitative predictions could more effectively integrate high-throughput toxicity testing (HTT) and medium throughput testing with risk assessment. Along the same lines, transitioning from a knowledge base to a quantitative framework will require a concerted effort to generate dynamic data (both concentration and time) and enable prediction of hazard or even risk with integration of dosimetry and exposure assessment. While the computational complexity of truly simulating biological system behavior from an AOP and complex systems data is probably beyond the 2019 timeframe, a proof-of-concept through a case study that would demonstrate the viability of such an approach could be completed within that timeframe. Also, the continued integration between CSS and HHRA to work backwards from apical endpoints to molecular initiating events (MIEs) and incorporate dosimetry/exposure at the site of action will ensure greater confidence in the approach long-term.

2. Expanding data beyond models of human toxicology (and pharmacology) to include organisms and systems that can help make predictions for the environment as a whole. The Subcommittee recognizes that CSS is expending some effort on ecosystem health in parallel with human AOPs (such as estrogen agonism) however it's not clear that similar cross-species extrapolations for other relevant endpoints are in progress. ToxCast efforts and cross species extrapolations using molecular similarities need to be verified with experimental data from environmentally relevant species to determine how well predictions match endpoint data in a real world setting. For example, SeqAPASS appears to be a very interesting first step towards making predictions across species for potential interactions of a chemical with AOPs. However, experimental data is necessary to verify the predictions as more than a theoretical exercise. For example, more genomic and proteomic data on organisms that are representative of species used in environmental risk assessments would provide more accurate estimations for these tools. It will ultimately also be important to determine the combined effects of chemicals in mixed systems as real life systems are composed of multiple chemicals with additive, synergistic or antagonistic interactions. Over time as CSS and HHRA programs mature and science and technology evolve, it will be essential to include interactions among multiple factors in the evaluation of risks from exposures to chemicals. Added to the complexity is the fact that in many systems conditions such as pH, dissolved solids and temperature can be changing continuously, step-wise or suddenly. With hundreds of thousands of chemicals in the environment, computational chemistry capability has to be developed to handle such complexity.
3. Creating and supporting the IT infrastructure needed to make the best use of the data from EPA and external researchers to support the AOP/Complex Systems framework. The CSS AOP wiki concept provides a unique opportunity to leverage the collective wisdom of the environmental health, toxicology and risk assessment communities. One challenge is to build an ontology or lexicon with sufficient IT structure, similar to Reactome, so that the database is searchable and the terminology is standardized. CSS should consider working with other public database efforts to see if they can leverage capabilities and define a community standard similar to Reactome. For example, the structure provided on the wiki for the "androgen receptor agonism leads to reproductive dysfunction" AOP is a good example of an AOP formatted to allow the multi-scale, multi-dimensional framework necessary for applying systems approaches for prediction. At this early stage of development, this is an opportunity for CSS to define a standard for the community. This type of research is based on both the impacts of chemicals (CSS) as well as Sustainability of Communities and should be in coordination with this other research focus area to provide strength.

The goal of the Virtual Tissues models is very important for predicting biological responses from physiological activity in relevant species and thus demonstrate the translation of *in vitro* measurements to a biological system response. In this way, the virtual tissue models are a complement to the HTS assay data and may be one possible mechanism to successfully predict the likelihood of adverse response for a chemical with only *in vitro* data and to identify gaps in biological space that require new assay development. If successful, virtual tissue models could eventually be used to formulate and parameterize AOPs in the most appropriate species beyond the 2019 time period. However in the absence of a contribution back to chemical evaluation or AOP framework or a conclusive demonstration that they have the capability to link to actual apical outcomes, they could be perceived as a theoretical exercise. The Subcommittee recommends that in the 2016-2019 timeframe, CSS develop a proof-of-concept case study that would demonstrate for an untested chemical that the biological activity defined in ToxCast translates to biological properties at the virtual tissue level leading to apical endpoints for physiological response *in vivo*.

Lifecycle Analytics

A robust lifecycle analytics program is important to ensure the safe application of chemicals in their design, use, and disposal. CSS has an ambitious plan involving lifecycle analytics, although the plan is only in the early phases of implementation. This plan will be accomplished by the combination of four research project areas: Sustainable Chemistry, Emerging Materials, Life Cycle and Human Exposure Modeling, and Ecological Modeling. The CSS program proposes a combination of experimental approaches, development of new computational tools, and application of such tools to various aspects of chemicals. Lifecycle analytics are a crucial area for the 2016-2019 CSS research program design, and though it is an ambitious program, the previous accomplishments of various CSS components provide an indication that it could be successfully executed as proposed.

Some of the strengths of the proposed approach include the fact that it applies various methods and techniques, such as high-throughput screening, mechanistic toxicology, cheminformatics, and computational chemistry, to the life cycle evaluations of chemicals. It also includes the development of important computational tools such as the Chemical Transformation Simulator. The program involves the academic community, through the STAR program, in development of the basis for understanding the impact of chemicals during their life cycle. Finally, the Subcommittee noted the collaboration among the labs and programs on ecological modeling linking molecular properties to ecosystem characteristics.

Some challenges identified to date include the need for information on a large pool of compounds. Evaluation of new materials, such as nanomaterials, may require development of new, specific approaches since their properties depend not only on their chemical formula but also on their size, shape, and surface properties including chemical heterogeneity. Thus it is vital to recognize that the application of traditional methodologies used for non-nanoscale materials to nanomaterials can not only yield inaccurate results but even misleading information. IT challenges exist here also, since the software developed will require constant updates and improvements.

Areas for Improvement

The already impressive CSS computational chemistry program could be further strengthened and focused on building reliable, quantum chemistry tools for predictions of toxicity and exposure of selected pools of chemicals and nanomaterials. A more robust computational chemistry program will assist CSS in preserving its leading role in application of computational tools to environmental problems and provide reliable, tested approaches. Other recommendations relate to how the program is communicated and on outreach about the lifecycle analytics work. For example, this program is very closely linked to the sustainability goals of the Agency, yet the specific links have not been made as clearly as they could be. Enhanced interactions with the public, including knowledge transfer about these useful tools and approaches, will be important as multiple entities undertake their own efforts at lifecycle analyses. There may also be opportunities to reach out across the Agency to involve Program offices in the effort, in order to enhance the uptake of the information as it is developed.

Chemical Evaluation

The Subcommittee commends the ToxCast programs for the advances they have made in *in-vitro* and *in-silico* molecular biological approaches for evaluating of toxicity of chemicals. CSS has established a large database of biological and biochemical activity data for chemicals, including those with unknown effects, which is an invaluable resource for the scientific community around the world. As pointed out under responses to questions 2 and 3, CSS has in fact applied that information to real public health and environmental health issues in the field. Other programs at EPA are starting to use information from

ToxCast to help inform risk decisions and provide solutions and monitoring methods for regional needs and rapid response to environmental events. These are clear demonstrations of impact to both program and regional needs. As the CSS program expands to incorporate a broader array of approaches, including medium-throughput assays, and exposure science tools, new opportunities will appear.

Areas for Improvement

The Subcommittee identified several challenges that need to be addressed as CSS efforts move forward.

1. Moving from concentration-based, single time biochemical data to also include more dynamic, exposure-based predictions of altered biological activity over multiple time points. It is well known that toxicity is a dynamic event which results in a perturbation of dynamic biological systems, and where reaction fluxes constantly are altered in response to changing chemical and stress environments. Systems toxicology models must be developed that incorporate both fast and slow components, such as enzyme reactions, and transcription, translation and signaling. This will be extremely important when the difficult modeling of multiple simultaneous chemical exposures takes place. An example of collecting more dynamic data would be the continuous collection of data over a 72 hour period for certain assays (e.g. zebrafish, neurite outgrowth) rather than at specified time points. Such an approach could help identify sensitive periods, mechanisms, and information on cumulative effects. Furthermore, each compound may display a difference in the flux of events leading to a toxic endpoint.
2. Incorporation of metabolism and/or metabolites into the various screening programs is an important challenge to address, since for many compounds metabolites are the putative toxic entity. Predictive models are being used, and an effort should be made to evaluate whether certain important metabolites could be added to the ToxCast pool of chemicals. Appropriate metabolizing additions (e.g., S9 liver fraction) are also being evaluated for new *in vitro* assays under development, and should continue to be pursued. The current scientific staff is well aware of the challenges regarding metabolism and has started to incorporate the issue into future programs which will be critical for new work in progress. The desire for stronger integration with quantitative structure-activity relationship (QSAR) modeling for read-across and prediction of metabolism has resulted in several new hires to address that gap. This will also require some thought into the actual chemical space represented by the ToxCast chemicals, and whether this has to be expanded.
3. Integration of internal dosimetry with target tissue(s), and margins of exposure in relation to toxicity events, are key to the translation from hazard to risk. Maintaining that focus and appropriately resourcing the efforts will be essential for success. Selection of new ToxCast compounds should consider specific needs both for enhanced modeling as well as the needs of the risk assessors. As mentioned earlier, multiple chemicals per AOP, as defined by relevant co-occurring mixtures, will represent a large challenge and will potentially add an increased level of uncertainty to AOP modeling, which highlights the importance of including HTS screening of important mixtures. It will be important that real world data on chemical exposures be used to define new chemical space and/or mixtures that can be added to the HTT program. The CSS program has a number of important ongoing efforts focused on exposure science, including ExpoCast, other exposure modeling, and extramural funding focused on exposure. The Subcommittee supports the use of program resources to develop and improve exposure models, as well as to develop and deploy other approaches to measure exposure. The Subcommittee would welcome the opportunity to review the exposure science aspects of the CSS program in more detail in the future.
4. Although ToxCast has provided a plethora of data, the assays that were used for this enormous investment were largely created for evaluation of pharmaceuticals and alternative targets for medicine. The scientists in CSS recognize that this is a weakness of ToxCast. Adding knowledge from

Complex Systems research and defining new assays that will be necessary for the results to be actually predictive for risk assessment, such as the assays developed for thyroid dysregulation and neurotoxicity, can provide a stronger basis for HTS modeling and predictive capabilities, effectively closing the iterative loop of internal integration across the CSS program. In addition, in order to understand the complex systems beyond human, mouse, and rat to other organisms that are important in the environment, there needs to be inclusion in HTS as well as molecular target assay development that includes species that provide a broader representation of organisms used in laboratory and environmental risk assessments. Translation across species is a key tool for risk assessment. SeqAPASS, as demonstrated, appears to be a good tool for translating sequence across species for assay targets in ToxCast. The BOSC Subcommittee would like to know how this can be better used or augmented to predict structure and ultimately activity necessary for risk assessment. For example, are there structural biology approaches that could be used to improve prediction of function (and potential outcomes) across species that can then be used for assay development that can provide improved predictive capability?

When the ToxCast Program was launched, HTT technologies and computational chemistry in pharmaceutical research were already mainstream. Yet, they still had to make important shifts along the way to move from predicting biological activity for pharmaceuticals to using it for prioritizing chemicals for tier 2 testing. The microphysiological systems and computational biology approaches being employed in the Complex Systems program are an order of magnitude more complicated and are rapidly emerging disciplines. What can be learned from the history of the Chemical Evaluation Program to ensure the success of the Complex Systems Program?

Recommendations

1. ToxCast efforts and cross species extrapolations using computational approaches should be verified with experimental data from environmentally relevant species to determine how well predictions match endpoint data in a real world setting. Molecular target assay development should also include species that provide a broader representation of organisms used in laboratory and environmental risk assessments.
2. CSS evaluations should include metabolism, as well as interactions among multiple chemicals. HTS screening of important mixtures of chemicals and of metabolites will help to address uncertainties and serve the needs of AOP modeling of mixtures.
3. CSS should develop a proof-of-concept case study that would demonstrate for an untested chemical that the biological activity defined in ToxCast translates to biological properties at the virtual tissue level that lead to apical endpoints for physiological response *in vivo*.
4. CSS should consider dynamic analysis over multiple time points and/or continuous data collection for specified time intervals in some assays to replicate the actual dynamic events that occur in vivo. This will be extremely important as chemical mixtures are added to screening efforts.
5. CSS should select assays for inclusion in ToxCast and additional chemicals for screening based on evidence of actual exposure and the needs of exposure and dose modeling and risk assessment.

Specific to CSS: Charge Question 5. Please provide input on opportunities and approaches for fit-for-purpose translation and knowledge delivery.

The Subcommittee is encouraged by steps taken and planned for the translation and delivery of CSS products to Agency partners and key external stakeholders (e.g., non-governmental organization (NGO) community, industry, and academia). In particular, the Subcommittee is pleased that *Solutions-Based*

Translation and Knowledge Delivery[4] represents one of the four core CSS integrated research topics[5] within its *Strategic Research Action Plan* (StRAP). Ultimate success of CSS fit-for-purpose translation and knowledge delivery will require that CCS continue to prioritize this component of the StRAP in parallel with progress made in the other core research topics.

CSS highlighted a handful of ongoing collaborative efforts with EPA program and regional offices intended to demonstrate how CSS products can be used to support programmatic and regional activities and simultaneously support further refinement and development of such products. Examples include EPA's Endocrine Disruptor Screening Program (EDSP) where the Agency has recently taken public comment on the integration of a CSS product, the Estrogen Receptor Expert Model, into the EDSP Tier 1 testing battery; and collaborative ecology-focused AOP development work with Regions 5 and 8. Several program and regional offices expressed enthusiasm for RapidTox as a preliminary screen for data poor chemicals. Additionally, the Subcommittee learned about past and future conferences and events where CSS products, such as the iCSS dashboard, have been or will be demonstrated (e.g., during genius bar sessions). The Subcommittee also learned about CSS stakeholder outreach efforts including the ToxCast data summits and the EPA-NIEHS-EDF meeting focused on applications of CSS and related federal tools in environmental health research related to neurological disorders and disease.

Areas for Improvement

While the Subcommittee commends CSS for its efforts to ensure that its research products are accessible (knowledge delivery) and can be applied to meet specific purposes of its various stakeholders (fit-for-purpose translation), the Subcommittee shares CSS's sentiment that there is a need to increase the scientific literacy of partners on CSS data and tools. Presentations from regional and program partners were positive with nearly unanimous agreement on the potential value and utility of CSS products for various regional and programmatic activities. These EPA partners did signal, however, that more experience, training, and demonstration will be needed to realize this potential. For example, representatives from the Office of Pollution Prevention and Toxics (OPPT) mentioned that carving out time to bring ORD researchers to meet with OPPT scientists has been a challenge to successful science knowledge transfer of CSS research products to potential OPPT applications. Region 8 indicated that better ways are needed to connect ORD staff scientists with regional scientists and that additional mechanisms beyond RARE are needed to facilitate collaborations between these scientists.

With regard to external engagement, CSS highlighted the joint EPA-NIEHS-EDF meeting as a valuable opportunity for understanding the interest and needs of academics, such as molecular epidemiologists, to utilize CSS products. More opportunities for CSS to connect with key external partners and stakeholders would greatly aid uptake of CSS research products (knowledge transfer) and identification of how fit-for-purpose tools can be developed for various audiences with different interests in the application of CSS products. Success in fit-for-purpose knowledge delivery will require action at multiple levels.

CSS needs to be equipped with an IT infrastructure that matches the caliber and volume of research products it produces. The Subcommittee learned that existing IT infrastructure can be a significant

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[4] The *Strategic Research Action Plan (StRAP) for EPA's Chemical Safety for Sustainability (CSS) Research Program* defines Solutions-Based Translation and Knowledge Delivery as, "Promote Web-based tools, data, and applications to support chemical safety evaluations and related decisions, respond to short-term high priority science needs for CSS partners, and allow for active and strategic engagement of the stakeholder community."

[5] The four CSS StRAP integrated research topics are Chemical Evaluation, Life Cycle Analytics, Complex Systems Science, and CSS Translation and Delivery.

hindrance to achieving CSS goals around science-based translation and knowledge delivery. In addition, CSS research products are continuously updated online with new and refined data and tools, sometimes resulting in significant changes in how results for individual chemicals or tests are interpreted. Those updates are not always clearly communicated to partners and stakeholders.

The Subcommittee recognizes the significant time that information-sharing and training requires as well as the budgetary realities of supporting the ideal scope of internal and external partner outreach and engagement. Nevertheless, successful knowledge transfer, development and evaluation of fit-for-purpose tools requires ongoing interaction with key partners.

CSS clearly views translation of its research products as central to the success of the program and has made significant strides in this regard. The Subcommittee looks forward to reviewing future progress in the uptake and use of emerging CSS data and tools by internal and external partners.

Recommendations

1. The Subcommittee strongly recommends that CSS systematically identify IT needs and communicate these needs to those within the Agency who can enable and deliver the appropriate IT infrastructure to the program.
2. The Subcommittee recommends that CSS implement a system to clearly communicate when additions and modifications to partner-facing research products are made—noting not only when products have been updated but also the nature of such updates.
3. The Subcommittee recommends that CSS outline what opportunities there may be for more formalized interaction, training, and feedback with key partners and then determine what incremental steps can be taken in the near-term. In doing so, CSS should consider the EPA Sustainable Futures Program as a possible model for training.

Specific to HHRA: Charge Question 6. Please comment on the research dimensions for the HHRA program and, in particular, the proposed approaches for characterization of new data and computational methods to improve confidence and build capacity for their application in the context of risk assessment.

The HHRA research program is adapting and propagating an open and transparent approach to efficient use of technology tools for conducting and reviewing risk analysis.

- Bringing in information scientists to develop Health and Environmental Research Online (HERO) is a laudable approach that should help to integrate necessary literature reviews and increase transparency for work products.
- ExpoBox houses many tools from the simplest to the more complex and has multiple different search capabilities with the potential for characterizing site specific exposures.
- BMDS provides an on-line framework for risk estimation that provides a comparison for different approaches including those used internationally.

The HHRA research program is appropriately beginning to use information from CSS to obtain rapid toxicological information for novel and emerging chemicals, especially in emergency response situations and where traditional data are not available.

The Subcommittee commends the HHRA research program for examining the application of genetic and epigenetic data to inform the understanding of susceptibility and variability in cumulative risk assessment methods. Developing a framework for the incorporation of this information into risk assessment and transmitting those approaches across the Agency will be a challenge but if successful could significantly improve chemical risk assessment.

The Subcommittee also commends the HHRA research program for continuing to work on developing approaches to cumulative risk assessment. Including non-chemical stressors as one of the components of cumulative risk assessment is particularly difficult but is scientifically important and should continue to be pursued. Cumulative impacts may also be useful to consider in the future as part of a benefits analysis. The Subcommittee particularly encourages continued efforts to incorporate factors such as poverty, stress, noise, and local community concerns in cumulative risk assessments, as relevant to each decision context.

The HHRA research program is using systems tools to obtain new data and identify resources and expertise to develop risk evaluation for emergency response to poorly-studied chemicals in collaboration with and to meet the needs of regional and program office partners. This reflects a broad commitment on the part of the HHRA research program to meet the needs of program partners.

Areas for Improvement

This program is heavily dependent upon IT and personnel resources to conduct literature reviews, populate and maintain HERO, and incorporate newer data into risk assessments. In particular, compiling older hard copy literature into the HERO database is time consuming and may need additional human and IT resources.

Exposure evaluation using real-time sensor data is both an opportunity and challenge. Sensors can provide improved rapid response capabilities, tools that can be used by a broad range of users including people with less technical knowledge, and generation of a wider range of data on spatial and temporal concentrations. However, sensor data may require additional levels of quality assurance in the field and generate large amounts of data requiring higher levels of expertise to interpret. The HHRA program should endeavor to anticipate and respond to the likely increase in these data, whether collected by the program and its partners or entities outside of EPA.

Improving the confidence that program and regional partners have with preliminary or predictive risk assessments based on computational methods though the combined effort of CSS and HHRA will continue to be important in the future. This will necessitate an ongoing commitment to training and collaboration. Achieving this will require continuing and expanding efforts to have face-to-face meetings with the program offices and regional scientists and may require tailored approaches based on needs.

Overall, the Subcommittee is very impressed with the HHRA research program. HHRA should continue its current efforts to explore, employ, and strengthen different approaches for risk assessment using informatics and other methods to help tailor its approaches to the specific decision-making needs of its partners. New data streams may become part of screening evaluations, evaluations of public health concerns, informing regulatory and technological decisions, prioritizing research needs and funding, and even developing approaches for cost-benefit analyses.

Recommendations

1. HHRA should develop acute or non-lifetime reference doses/reference concentrations when data are available and as warranted by the decision context. These non-lifetime approaches may be well suited to new data streams and have been requested by regional offices and other program offices within EPA.
2. HHRA should continue its commendable efforts to connect with scientists in the regional offices, program offices, and NIEHS Superfund Centers to leverage the new scientific tools in risk assessment to be relevant to site specific exposures and for transmission of risk information to the public.
3. HHRA should explore the feasibility of using the CSS rapid toxicological and exposure tools to develop preliminary risk-based screening levels for data-poor chemicals. One area to explore might be to focus on data-poor chemicals or even on tentatively identified compounds ("TICs") identified at cleanup sites or in surface water samples in the regions. Such chemicals are currently unregulated and they may deserve some scrutiny for potential risks.
4. The various online tools, especially ExpoBox, could benefit from an overarching guidance document or navigation guide that considers the different levels of expertise of the intended users. Two examples of potential improvements are: (1) searches that bring up lists of links could also provide some insight on the capabilities of each tool and the inputs needed for deploying them; and (2) providing more curation of the outputs would be helpful to facilitate comparison and selection of a tool appropriate to specific applications.

SUMMARY LIST OF RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

- **Recommendation 1.1**: There is an immediate need to evaluate the sufficiency of the IT resources and infrastructure available to support: (1) the research programs; and, (2) the necessary transfer and deployment of data and analytical tools to EPA partners and the public.
- **Recommendation 1.2**: Different EPA communications should be tailored to the needs of different key communities; technical and scientific information should be presented in language appropriate to the target audience.
- **Recommendation 1.3**: The CSS Program could benefit from a well-defined "proof of concept" (POC) evaluation where actual outcomes can be measured against expected outcomes within a specified timeframe.
- **Recommendation 1.4**: Summaries, schematics, and timelines could help those external to the programs better understand what the programs are doing and where they are going.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

- **Recommendation 2.1**: CSS and HHRA should establish a process to ensure that early stage user involvement happens as a routine part of research formulation.

- **Recommendation 2.2**: The process of engaging with partners could benefit from a more formal program evaluation. By formalizing the program evaluation, CSS and HHRA would complete a more holistic needs assessment and could identify additional barriers to receiving input on problem formulation from partners.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

- **Recommendation 3.1**: CSS and HHRA should continue to engage partners in the development of new case studies that mimic realistic field scenarios and demonstrate the impact of their methods to influence informed decisions for chemicals that lack sufficient data.
- **Recommendation 3.2**: Formal goals and measures of success should be defined to help guide the research program toward useful applications.
- **Recommendation 3.3**: The transfer of knowledge to EPA partners could be encouraged by dedicating a new budget line item to its implementation to enhance participation in problem formulation, the design of research and the successful use of research results at the regional and program levels.

Specific to CSS: Charge Question 4. Please provide input on the scope and implementation for 2016-19 in the following topic areas: Complex System Science, Lifecycle Analytics, Chemical Evaluation

- **Recommendation 4.1**: ToxCast efforts and cross species extrapolations using computational approaches should be verified with experimental data from environmentally relevant species to determine how well predictions match endpoint data in a real world setting. Molecular target assay development should also include species that provide a broader representation of organisms used in laboratory and environmental risk assessments.
- **Recommendation 4.2**: CSS evaluations should include metabolism, as well as interactions among multiple chemicals. HTS screening of important mixtures of chemicals and of metabolites will help to address uncertainties and serve the needs of AOP modeling of mixtures.
- **Recommendation 4.3**: CSS should develop a proof-of-concept case study that would demonstrate for an untested chemical that the biological activity defined in ToxCast translates to biological properties at the virtual tissue level that lead to apical endpoints for physiological response *in vivo*.
- **Recommendation 4.4**: CSS should consider dynamic analysis over multiple time points and/or continuous data collection for specified time intervals in some assays to replicate the actual dynamic events that occur in vivo. This will be extremely important as chemical mixtures are added to screening efforts.
- **Recommendation 4.5**: CSS should select assays for inclusion in ToxCast and additional chemicals for screening based on evidence of actual exposure and the needs of exposure and dose modeling and risk assessment.

Specific to CSS: Charge Question 5. Please provide input on opportunities and approaches for fit-for-purpose translation and knowledge delivery.

- **Recommendation 5.1**: The Subcommittee strongly recommends that CSS systematically identify IT needs and communicate these needs to those within the Agency who can enable and deliver the appropriate IT infrastructure to the program.

- **Recommendation 5.2**: The Subcommittee recommends that CSS implement a system to clearly communicate when additions and modifications to partner-facing research products are made—noting not only when products have been updated but also the nature of such updates.
- **Recommendation 5.3**: The Subcommittee recommends that CSS outline what opportunities there may be for more formalized interaction, training, and feedback with key partners and then determine what incremental steps can be taken in the near-term. In doing so, CSS should consider the EPA Sustainable Futures Program as a possible model for training.

Specific to HHRA: Charge Question 6. Please provide input on opportunities and approaches for fit-for-purpose translation and knowledge delivery.

- **Recommendation 6.1**: HHRA should develop acute or non-lifetime reference doses/reference concentrations when data are available and as warranted by the decision context. These non-lifetime approaches may be well suited to new data streams and have been requested by regional offices and other program offices within EPA.
- **Recommendation 6.2**: HHRA should continue its commendable efforts to connect with scientists in the regional offices, program offices, and NIEHS Superfund Centers to leverage the new scientific tools in risk assessment to be relevant to site specific exposures and for transmission of risk information to the public.
- **Recommendation 6.3**: HHRA should explore the feasibility of using the CSS rapid toxicological and exposure tools to develop preliminary risk-based screening levels for data-poor chemicals. One area to explore might be to focus on data-poor chemicals or even on tentatively identified compounds ("TICs") identified at cleanup sites or in surface water samples in the regions. Such chemicals are currently unregulated and they may deserve some scrutiny for potential risks.
- **Recommendation 6.4**: The various online tools, especially ExpoBox, could benefit from an overarching guidance document or navigation guide that considers the different levels of expertise of the intended users. Two examples of potential improvements are: (1) searches that bring up lists of links could also provide some insight on the capabilities of each tool and the inputs needed for deploying them; and (2) providing more curation of the outputs would be helpful to facilitate comparison and selection of a tool appropriate to specific applications.

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

Appendix C: BOSC Homeland Security (HS) Subcommittee

Paula Olsiewski, Ph.D. (Chair) *Alfred P. Sloan Foundation*	Edward Hackney *United Water*	Edwin A. Roehl, Jr. *Advanced Data Mining International, LLC*
Tammy P. Taylor, Ph.D. (Vice Chair) *Pacific Northwest National Laboratory*	Janis E. Hulla, Ph.D. *U.S. Army Corps of Engineers*	Monica L. Schoch-Spana, Ph.D. *University of Pittsburgh Medical Center*
Andrew DeGraca *San Francisco Public Utilities*	Debra R. Reinhart, Ph.D. *University of Central Florida*	

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February 11, 2016

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

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LIST OF ACRONYMS

BOSC	Board of Scientific Counselors
BOTE	Bio-Response Operational Testing and Evaluation
CBR	chemical, biological, and radiological
CBRN	chemical, biological, radiological, and nuclear
CIS	Customer Information Systems
DAA	Deputy Assistant Administrator
DeconST	Decontamination Selection Tool
EC	Executive Committee
EPA	U.S. Environmental Protection Agency
ERLN	Environmental Response Laboratory Network
FACA	Federal Advisory Committee Act
GIS	Geographic Information System
HSRP	Homeland Security Research Program
ICS	Industrial Control Systems
IWASTE	Incident Waste Decision Support Tools
NAS	National Academies of Sciences
NPD	National Program Director
ORD	Office of Research and Development
OSTP	Office of Science and Technology Policy
RSMS	Riverine Spill Modeling System
SAB	Science Advisory Board
SAM	Selected Analytical Methods
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan
TEVA-SPOT	Threat Ensemble Vulnerability Assessment – Sensor Placement Optimization Tool
WEST	Waste Estimation Support Tool
WLA	Water Laboratory Alliance
WST	Water Security Toolkit

BACKGROUND

The Homeland Security Subcommittee of the Environmental Protection Agency (EPA) Board of Scientific Counselors (BOSC) conducted its first annual review at the EPA Cincinnati Headquarters in Cincinnati, OH on August 25, 26, and 27, 2015. The following is the list of Subcommittee members and all members were present for the entire meeting:

- Paula J. Olsiewski, PhD, Subcommittee Chair, Program Director, Alfred P. Sloan Foundation
- Tammy P. Taylor, PhD, Subcommittee Vice-chair, Chief Operating Officer, National Security Directorate, Pacific Northwest National Laboratory
- Andrew DeGraca, Water Quality Division Director, San Francisco Public Utilities
- Edward Hackney, Director of Revenue Management, United Water
- Janis E. Hulla, PhD, DABT, ERT, ATS Senior Toxicologist, US Army Corps of Engineers, Environmental Engineering Branch, Sacramento District
- Debra R. Reinhart, PhD, Assistant Vice President for Research, Office of Research and Commercialization, University of Central Florida
- Edwin A. Roehl, Jr., Chief Technical Officer, Advanced Data Mining International, LLC
- Monica L. Schoch-Spana, PhD, Senior Associate, Center for Health Security, University of Pittsburgh Medical Center

EPA's BOSC Executive Committee (EC) was chartered in 2014 to provide advice and recommendations on all aspects (technical and management) of the Office of Research and Development's (ORD) research program. In July 2014, the BOSC EC joined the Science Advisory Board (SAB) to advise the EPA Administrator on EPA's strategic research directions. To arrive at their recommendations, the SAB and BOSC EC reviewed preliminary drafts of ORD's 2016-2019 Strategic Research Action Plans (StRAPs) for each of the six national research programs, and received briefings and additional background materials from ORD's Deputy Assistant Administrator for Science and its National Program Directors. This two-day meeting culminated in a report to the EPA Administrator in January of 2015. The programs then revised their StRAPs based upon the report.

As the programs begin to implement the research outlined in the StRAPs, ORD is asking the BOSC to advise its Assistant Administrator as to whether ORD is "doing the science right?" The BOSC EC will address cross cutting issues of interest to ORD broadly while the program-specific BOSC subcommittees will provide targeted advice on accomplishing the program's objectives and the research articulated in their 2016-2019 StRAPs.

The BOSC Homeland Security Subcommittee was established to provide program-specific advice to EPA's Homeland Security Research Program (HSRP). The mission of the HSRP is to conduct research and deliver products that improve the capability of EPA to carry out its homeland security responsibilities. The Program conducts applied, relevant research and aims to deliver useful products to the end users of this work. HSRP plans to engage the Subcommittee over the next several years to provide advice on the Program's portfolio and to assess progress in addressing EPA's needs.

The Subcommittee was tasked with addressing a set of questions common to all of the BOSC subcommittee efforts this year and are related to program design, problem formulation, and responsiveness to partners' (customers') needs (Questions 1, 2, and 3). In addition, the Subcommittee was charged with several questions developed by the HSRP regarding including transition of results to end users (Question 4) and how the Program might effectively incorporate social science into its research efforts (Question 5).

These questions were designed to provide useful, high-level recommendations on relatively big-picture aspects of the Program's design and operation, allowing the nascent Subcommittee to establish familiarity with the entire Program, while at the same time, preparing the Subcommittee for future charges that will require a deeper understanding of the Program.

CHARGE QUESTIONS AND CONTEXT

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

The StRAPs are designed to clearly convey the vision and objectives of the research program, and to describe, at a high level, the research topics, and major outputs planned for 2016-2019. Upon receiving recommendations from the SAB and the BOSC EC, as well as from EPA partners and others, ORD has further developed the StRAPs, including refining the objectives and topics, and providing more clarity. At an operational level, each research program is aiming to accomplish its objectives through research spanning physical, biological and social sciences and through numerous ORD laboratories, centers, and Science to Achieve Results (STAR) grantees all across the country. In addition, ORD has heeded the advice of the SAB and BOSC in past years to do more to integrate research across the six programs, across EPA and with other Federal partners. Given these complexities, we recognize there are likely several reasonable approaches for organizing the research to best accomplish the objectives.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

ORD works with EPA partners to design the research programs to meet Agency priorities. The first step in this process is problem formulation which provides the foundation of the research. Although it can be tempting to jump to a list of research priorities, problems that are well defined lead to the most effective research efforts and solutions. The problem formulation stage of research planning lays the groundwork for the StRAPs and is the reference point for any changes in priorities as budgets change and new issues emerge. Problem formulation occurs at many different levels including the articulation of issues in the EPA Strategic plan; meetings with EPA partners including regular staff-to-staff meetings; workshops and conferences where states, regions, policy and science staff describe the problems they face; and discussions among senior managers at EPA. In addition, each National Program Director reaches out to EPA partners in a variety of targeted ways to agree on problem definition.

Charge Question 3. How well does the Program respond to the needs of EPA partners?

ORD places a very high value on working closely with EPA partners to design the research programs to meet Agency priorities. During the preparation of the StRAPs, the programs were guided by the EPA Strategic Plan and undertook a variety of activities to actively engage partners, both to understand their priorities and to elicit their input on research directions. These include many regular meetings with EPA policy and regional staff, communities of practice for specific scientific disciplines throughout the Agency, annual two day meetings led by the National Program Directors (NPDs), annual senior level meetings with EPA Assistant and Regional Administrators, and formal requests from ORD's Deputy Assistant Administrator (DAA) for science to receive comments from across the Agency twice during the year of StRAP development.

In addition to the up-front work with EPA partners to understand their research needs for the upcoming year(s), ORD also needs to be flexible enough to address top priority, unanticipated needs or environmental crises that emerge at any given time. The research program will describe interactions with EPA partners, present examples of recent responsiveness to unexpected events, and explain how they work with EPA partners to accommodate acute needs while resources are limited.

Specific to HS: Charge Question 4. How well has the Program transitioned research to the end-user? How can we improve our ability to transition research to the end-user in the future?

Conducing high-quality research responsive to partner needs is not successful unless the resulting scientific products are transitioned successfully to the partners who will use them. However, this transition is not a trivial endeavor because it requires that products are formulated and delivered to maximize usefulness to the partners. Transition is successful when end-users use the products.

Specific to HS: Charge Question 5: How can we infuse social science into the development of our research products to improve their usability?

Over the last several years, the National Academies of Sciences (NAS), EPA Science Advisory Board, and BOSC have recommended that EPA research account for the social science aspects of decision making, including decisions made during disaster response. The NAS and the Office of Science and Technology Policy (OSTP) have highlighted key social factors in building community resilience to disasters. Given limited resources, HSRP seeks the advice from the Subcommittee on how best might targeted social science research help achieve the Program's objectives.

STRAP OBJECTIVES AND PRIORITY RESEARCH TOPICS

The HSRP StRAP FY16-19 is aligned around two major research objectives as were described briefly above: (1) improve water utilities'[6] abilities to prepare for and respond to incidents that threaten public health; and (2) advance EPA's capabilities to respond to wide area contamination incidents.

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[6] The Subcommittee defined water to include source water, drinking water and wastewater.

The Research Objectives described above serve as the overarching framework for more focused research *topics* that guide specific research and development activities. The research topics are:

Characterizing Contamination and Assessing Exposure

Develop sample collection and analysis methods that increase the capability and capacity of the Agency's Environmental Response Laboratory Network (ERLN) [which includes the Water Laboratory Alliance (WLA)][7] to respond to both water-related and wide area contaminations. Provide the science needed to establish sampling strategies for indoor and outdoor areas that provide the maximum amount of information regarding the extent of contamination while minimizing the sampling and laboratory resources required. Develop methods to assess exposure pathways and utilize exposure modeling for chemical, biological, radiological, and nuclear (CBRN) contaminants to support risk assessment.

Water System Security and Resilience

Develop water systems models that enable utilities to design and operate their water systems so that they are more resilient to intentional attacks or natural disasters including understanding the implications of various operational and design decisions on the overall resilience of the system. Develop approaches for detecting and responding to a water system contamination event or other system disruptions. Develop methods to decontaminate drinking and waste water systems and treat contaminated water.

Remediating Wide Areas

Fill critical gaps in science and technology to inform selection and implementation of contamination mitigation and cleanup technologies, remediation monitoring approaches, treatment and disposal tactics for contaminated wastes, and strategies for confirmation of successful cleanup.

PROCESS

The agenda prepared by HSRP leadership was designed to provide the Subcommittee a high-level, big-picture overview of the Program's structure, operation, and staffing expertise to initiate the Subcommittee's familiarity with the Program. The Subcommittee's view is that the agenda prepared was extremely helpful in establishing this baseline understanding to prepare the Subcommittee for future charges that will result in a deeper understanding of the Program. The three day agenda brought the Subcommittee together with the entire HSRP leadership team and staff who execute individual projects that comprise the Program. The leadership team presented the overview of the Program described in the StRAP 2016-2019. This was followed by an overview of partner engagements that lead to the prioritized research lifecycle. The HSRP leadership provided the following definitions for common terms:

1. **Partner** – Our primary customers; the end-users of our work from whom we performed it; the groups from which we solicit needs, invite to work with us on the research, and work closely with on formulation and delivery of the outputs. Since HSRP's mission is to improve the capability of EPA to carry out its homeland security responsibilities, our Partners are the operational offices at EPA. Since EPA's Office of Water works very closely with utilities, we consider utilities as partners as well and the EPA offices.

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[7] A nationwide laboratory network with the capability and capacity to analyze for CBRN agents during routine monitoring and in response to terrorist attacks and other disasters. The WLA includes water utility laboratories.

Examples: Office of Emergency Management's Office of Emergency Response and Office of Resource Conservation and Recovery (and divisions and branches below), Office of Water's Office of Groundwater and Drinking Water (Water Security Division), Regions, and water utilities.

2. **Stakeholder** – External entities that benefit from our research. Although these entities may use EPA Homeland Security research products or outputs, they are not the primary end-users of the research.
   Examples: Department of Homeland Security, Department of Health and Human Services (includes Centers for Disease Control), Department of Defense, state laboratories, etc.
3. **Product** - A deliverable produced by the research program designed to be scientific ingredients that are synthesized into Outputs (see below).
   Examples: Journal articles, detailed reports, and conference proceedings.
4. **Output –** A deliverable produced by the research program developed to be directly usable by our Partners.
   Example: Decision support tools and software, sampling and analysis methods, and data syntheses.
5. **Partner need** – A capability gap identified and prioritized with Homeland Security Research partners. Needs are used to plan Outputs.
   Example: Self-help decontamination and risk reduction measures for anthrax.

Appropriately cleared Subcommittee members then received a classified briefing on homeland security threats to better understand the prioritization of research needs with threats. Two poster sessions allowed Subcommittee members direct engagement with HSRP researchers to witness first-hand the project details that are aligned with the StRAP and prioritized research projects. A video presentation of a field exercise called, "Bio-Response Operational Testing and Evaluation," (BOTE, used below) was shown to demonstrate the applied nature of the research program and the strong collaboration among partners and stakeholders. A "Tools Café" was a two hour session that allowed the Subcommittee to get further acquainted with HSRP staff while simultaneously participating in demonstrations of software tools developed and maintained by HSRP. Finally, the Subcommittee heard a panel discussion by members of the partner community, including the EPA Office of Solid Waste and Emergency Response's Office of Emergency Management, Office of Water's Water Security Division, Office of Solid Waste and Emergency Response's Office of Resource Conservation and Recovery, Region 4 On-Scene Coordinator, Office of Solid Waste and Emergency Response's Office of Emergency Management, and the Greater Cincinnati Waterworks.

RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

The HSRP StRAP clearly defines strategic goals and objectives over the next few years. However, as has been evident in recent times (the Ebola outbreak, cyber-attacks, the Elk River chemical spill, etc.), unforeseen hazards and disasters occur and must be responded to in a timely and efficient manner. It is difficult to plan for resource use during these emergencies, however without doing so, the ability to make progress on all objectives is threatened.

Because of the severity of the threat of cyber-attacks, the research schedule should be modified to prioritize cyber security research ahead of other areas to counter the continuous and ever-increasingly

sophistication of cyber-attacks that plague utilities. As utilities interconnect formally disconnected systems to increase efficiencies, they create an ever expanding attack surface – often without understanding the impact and risks. As very few utilities have staff prepared to deal single-handedly with chemical or biological attack remediation, knowledge of cyber security is limited in the utility space; consequently research and guidance is needed from HSRP.

StRAP Cyber security research and guidance should include focus on operational technologies such as:

- SCADA / ICS (Industrial Control Systems),
- Smart Metering / Revenue Stream,
- CIS (Customer Information Systems, Online Bill and Data Presentment),
- GIS (Geographic Information System),
- Physical Security Systems (card access, camera & DVR), and
- Conventional IT Systems (GL/AP/AR/File Shares/Email).

This reordering of priorities does not diminish the importance of other chemical or biological research as those directly impact human safety. Adding cyber capabilities is an appropriate response to the reality that at any given point in time, thousands of utility firewalls are under direct attack from outsiders, systematically probing for any vulnerability – a logic controller at a well with easy-to-find default security credentials, the online bill payment site with customer information stored in clear text, a GIS file inadvertently shared publically providing great details about critical infrastructure, a SCADA control system with remote access enabled for external support being commandeered, an entire neighborhood of 'smart valves' at a customers' houses being hacked, to name a some very real use-cases. These could all be prevented with the right architectures, security models, and guidance. In consideration of these observations, HRSP should consider the following two recommendations to Charge Question 1.

Recommendations

1. Cyber security needs to move to the beginning of the time line.
2. Develop a process and strategy that allows responses to, and prioritization of, unforeseen and emerging needs while ensuring that good progress can be made on StRAP research objectives. For example, consider incorporating into the project prioritization process a weighing of the costs versus the benefits of implementing research products from the perspectives of end users.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

To understand the intent of Charge Question 2 it is necessary to understand the meaning of the term "partner" as used by ORD and HSRP. The BOSC-HS Subcommittee was provided with the following definition for "partner", "*Our (ORD's) primary customers; the end-users of our work from whom we performed it; the groups from which we solicit needs, invite to work with us on the research, and work closely with on formulation and delivery of the outputs.*" Since HSRP's mission is to improve the capability of EPA to carry out its homeland security responsibilities, our Partners are the operational offices at EPA. Since EPA's Office of Water works very closely with utilities, we consider utilities as partners as well and the EPA offices." Other examples of partners given were Office of Emergency Management's Office of Emergency Response and Office of Resource Conservation and Recovery (and divisions and branches below), Office of Water's Office of Groundwater and Drinking Water (Water Security Division), and Regions.

For comparison, "stakeholder" was also defined as "*External entities that benefit from our research. Although these entities may use EPA Homeland Security research products or outputs, they are not the primary end-users of the research.*" Given examples of stakeholders were Department of Homeland Security, Department of Health and Human Services (includes Centers for Disease Control), Department of Defense, state laboratories, etc.

A meeting of the Subcommittee with HSRP held August 2015 included a Partner Panel Discussion, whose participants represented four intra-Agency organizations and one utility, the Greater Cincinnati Water Works. With enthusiasm, all of the participants gave examples of collaboration with the HSRP staff, citing several successful projects and engagements. Involvement in developing and planning projects was also described.

One of the EPA's homeland security responsibilities is supporting water systems to prepare for and recover from attacks and other disasters by leading efforts to provide states and water utilities with guidance, tools and strategies. One of two research objectives in the StRAP for 2016-2019 is to improve water utilities' abilities to prepare for and respond to incidents that threaten public health; and all three of HSRP's current research topics are relevant to water and other types of utilities. However, HSRP's direct interaction with utilities is limited. The primary means of ascertaining the needs of utilities is through the Office of Water and its participation on committees in umbrella organizations such as the American Water Works Association and the Water Research Foundation. More direct involvement of a broader range of utilities in the formulation, planning, and review of projects could expand the knowledge base of HSRP and utilities alike, and lead to better, more widely used research products. Utilities, as well as first responders, will be much more likely to test and use tools they help develop. Increased interactions could also leverage EPA's and utilities' limited research budgets to get more value out of them.

Intra-Agency partners may not have the breadth of expertise with respect to the full suite of chemicals, biologics and radionuclides that are included within "all hazards". Risk would arise from not anticipating a potential threat and formulating an effective response. Similarly, sub-optimal selection or over-reaching technology limits of programmed methods when developing a decision support tool could cause the tool to fall short of need. Therefore, HSRP is encouraged to reach out to external experts and authoritative bodies in addition to their intra-Agency partners when formulating research plans. The primary recommendation associated with Charge Question 2 is listed below.

Recommendations

1. While HSRP is doing a good job consulting with internal EPA partners, the breadth and diversity of partners, stakeholders and world class experts to be consulted regarding research needs should be expanded. For example, include first responders, water and solid waste utilities, and professional societies and research entities, such as the US National Academies and the Water Research Foundation.

Charge Question 3. How well does the Program respond to the needs of EPA partners?

As noted in Charge Question 2, HSRP provided a definition of partners: "… the end-users of our work… operational offices at EPA … and utilities…" From an EPA operational office perspective, HSRP does a very good job responding to those needs as was obvious from feedback at the August Subcommittee meeting. For example, HSRP quickly responded to Ebola patient waste handling concerns. HRSP seems to have a

large informal communication network among EPA operational offices although no formal communication plan appears to exist.

It appears that HSRP has had limited interactions with utilities and therefore HSRP has an opportunity to develop and strengthen utility partnerships. Utilities need "dual-use" (both routine operations and emergency response) and "all-hazard" products that address the full range of utility experiences and needs (flooding, earthquake, tornado, fire, dirty bomb, etc.). HSRP has produced some good dual-use products including the EPA-NET hydraulic model that can be used to analyze routine operations or identify a contaminant introduction point. Most products, however, seem to have been developed with an initial hazard in mind. For example, the I-Waste model was reportedly developed for a dirty bomb scenario and later expanded to help respond to Hurricane Katrina. HSRP has also done some good work on distribution system pipe decontamination yet, the actual testing was only with one type of pipe when utilities use many types. Utilities need a range of pipe materials tested to have confidence in using HRSP research to address real world emergencies. In a related vein, because utilities need products that have the best cost-benefits, products that have relatively low cost benefits should generally not be developed.

An expanded list of partners would improve and institutionalize communications and provide critical input at key points of the research cycle (StRAP development, project development, and project delivery) or when unexpected events occur (i.e., Ebola). Improved communication will support HSRP research planning, priority setting, and keeping up with evolving partner needs, especially end users at water and solid waste utilities.

Recommendations

1. Develop, maintain, and institutionalize channels of communication needed to support HSRP research planning, setting priorities, and keeping up with the evolving needs of partners, especially end users at the water and solid waste utilities. For example, communications channels need to be maintained when staff members retire or change positions.

Specific to HS: Charge Question 4. How well has the Program transitioned research to the end-user? How can we improve our ability to transition research to the end-user in the future?

The BOSC-HS Subcommittee identified these strengths related to research transition to the end-users:

1. Validation tiers for chemical sampling and chemical analytical processes,
2. Tracking of visits to tools websites to assess popularity and,
3. Collection of Selected Analytical Methods (SAM) appears to be widely used.

Some of the opportunities for improvement that are not captured in the recommendations that follow include:

1. Adding cost-benefit analysis and uncertainty analysis to facilitate the end-users' decision-making with regard to the usefulness of the HSRP's tools,
2. Making the research products applicable to as many CBR hazards as possible through, for example, improvements in modular design,
3. Communicating up-front how security and software updates will be addressed,
4. HSRP has developed or is developing software tools for use by partners and stakeholders. A number of them are aimed at water distribution system security: Water Security Toolkit (WST) modeling tool

for identifying possible contaminant injection locations, hydrants for flushing, and locations for decontamination; EPANET-RTX fate and transport modeling tool; CANARY contamination detection tool; and TEVA-SPOT (Threat Ensemble Vulnerability Assessment - Sensor Placement Optimization Tool). Other tools support contaminated site remediation: RSMS (Ohio Riverine Spill Modeling System) for emergency river spill response and planning; Incident Waste Decision Support Tools (IWASTE) for all hazards incidents; DeconST (Decontamination Selection Tool) that integrates scenario-specific sampling, decontamination and waste management; and WEST (Waste Estimation Support Tool) for wide area radiological incidents.

5. Some of the tools have been developed to a commercial or near-commercial grade for use by a large number of users, for example, EPANET-RTX and CANARY. Other tools are expected to have a limited number of users and have been developed to a lesser grade, for example, RSMS and WEST. The tools use a variety of platforms, including C, Java™, MATLAB™, and Microsoft Excel™, and interoperability is limited. This can increase the costs of adding capabilities through extensions and/or integration to meet 'all hazards" and new needs; increase long-term maintenance and support costs; and raise the tools' collective complexity and training requirements. HSRP understands these are important issues and is considering transitioning responsibility for the tools to experts in software migration and version control after the intellectual capital has been established.

The first recommendation relative to Charge Question 4 is that the HRSP should **develop tools that have capabilities for routine operation and maintenance as well as 'all hazards' emergency response and multiple-use capabilities. For example, with regard to Water Quality Surveillance & Response Systems, develop a plan for supporting tools with future updates, and minimize the number of platforms during tool development to improve interoperability, broaden functionality, and reduce the amount of training required by users.**

A second recommendation relative to Charge Question 4 is connected to Recommendation 2.1. "One of the EPA's homeland security responsibilities is supporting water systems to prepare for and recover from attacks and other disasters by leading efforts to provide states and water utilities with guidance, tools and strategies. One of two research objectives in the StRAP for 2016-2019 is to improve water utilities' abilities to prepare for and respond to incidents that threaten public health; all three of HSRP's current research topics are relevant to water and other types of utilities. However, HSRP's direct interaction with utilities is limited. The primary means of ascertaining the needs of utilities is through the Office of Water and its participation on committees in umbrella organizations such as the American Water Works Association and the Water Research Foundation. More direct involvement of a broader range of utilities in the formulation, planning, and review of projects could expand the knowledge base of HSRP and utilities alike, and lead to better, more widely used research products. Increased interactions would leverage EPA's and utilities' limited research budgets to get more value out of them."

Therefore, the second recommendation to Charge Question 4 is for HSRP to **broaden outreach, engagement, and the participation in projects to a wider spectrum of utilities. For example, develop more systematic and coordinated approaches to get input and feedback from water utilities, use plain language, and consider knowledgebase of end users.**

Technologists who develop new technology for use by others understand that their products carry inherent uncertainty and risk when put to use; however, without guidance, end-users might take information that has significant uncertainty at face value, and act without considering alternatives.

HSRP stated there can be a large amount of uncertainty about analyzing most of the agents they work on. For example, *B. anthracis* has been the topic of research for a long time, yet the detection limit remains

unclear. HSRP currently does not always have a good answer for how to calculate or estimate uncertainty, but recognizes their responsibility to identify uncertainties and variability in samples and populations, be transparent about what is known and unknown, and provide a best estimate. In some cases, an estimate will be qualitative because an uncertainty analysis is not possible.

The software tools developed by HSRP in Microsoft Excel™ can be coupled with an add-in like the Crystal Ball™ risk analysis tool to perform Monte Carlo simulations with uncertainty parameters. The stated accuracy of the waste management tools is an order of magnitude estimate for planning purposes. With regard to remediation of wide area incidents, a big source of uncertainty is that there is almost no data with which to ground truth models, the Fukushima incident being an exception. If one of these tools is used for a real incident, the information provided by the tool would eventually be supplanted by actual data to inform decisions.

The physics-based modeling tools for water flow and water quality in distribution systems have a lot of uncertainty, as does the tool for contaminant detection in distribution systems. HSRP is trying to understand the sources of uncertainty using Monte Carlo analysis and to quantify those uncertainties when these tools are applied, the goal being to provide end-users with some information about the uncertainty.

The Subcommittee agrees that end-users need to know if a technology is ready for serious use and what an appropriate level of confidence should be. An approach that uses validation levels might be the most understandable to a broad range of end-users, for example, the Technology Readiness Levels used by Department of Defense and NASA.

The third recommendation to Charge Question 4 is therefore for HSRP to **develop validation and/or readiness measures that will develop confidence among end-users in HSRP's analytical tools, decontamination response methods, and software tools. Example measures are the Technology Readiness Levels used by the Department of Defense and NASA. Consider adding a measure of uncertainty to better inform the end users' selection of the clean-up options being developed by the Remediation Wide Areas topic.**

The EPA's homeland security responsibilities include cleaning up building and outdoor areas impacted by a terrorist attack or other disaster by leading efforts to establish clearance goals and clean up. Large numbers of assays are an essential need, and to facilitate obtaining them, the EPA is also charged with developing a nationwide laboratory network with the capability and capacity to analyze for chemical, biological and radiological (CBR) agents for routine monitoring and in response to a terrorist attacks — the Environmental Response Laboratory Network. One of two research objectives in the StRAP for 2016-2019 is to advance the EPA's capabilities to respond to wide area contamination incidents, and one of three of HSRP's current research topics, Characterizing Contamination and Assessing Exposure, has a time-critical aspect during the early phase of an of an incident (first 72 hours) that involves mostly local responders, and a cost-versus-benefits aspect at all times. The restoration of service is also time critical for a contaminated water system. Another research topic, Remediating Wide Areas, is perhaps less time critical, but includes Characterizing Contamination and Assessing Exposure and many other problems to be addressed. Remediating Wide Areas can ultimately involve collecting data from a spatially distributed sensor network that generates massive volumes of data.

An important question to consider during sampling is "how do you know if you are really collecting the representative sample?", and a series of sampling events may be needed to see if the contamination is spreading and/or persisting. Additionally, ongoing efficacious decision making by responders, agencies,

and stakeholders requires that data of sufficient quality be generated, converted into usable information, and distributed quickly to maintain relevancy. This collection of issues can be investigated by assessing state-of-the-art in methods for on-site screening and analysis, and automated data QA, reduction, and display. Based on this, the HSRP should consider a fourth and final recommendation in relation to Charge Question 4 to **develop a strategy for incorporating real-time analyses, for example, transitioning from a laboratory-based approach to a graphical online-based approach that can identify and quantify CBRN threats using emerging technologies such as mobile, GIS-coupled, real-time chemical sensors/monitors.**

Recommendations

1. Develop tools that can be routinely operated and maintained, and have 'multi-use' or 'all hazards emergency response' capabilities where appropriate. For example, with regard to Water Quality Surveillance & Response Systems, develop a plan for supporting deployed tools with future updates, and minimize the number of development platforms to improve interoperability and functionality. Currently, important programs are written in different languages, for example, Decon is in Microsoft Excel™ and TEVA-SPOT is in Java™.
2. Broaden outreach, engagement, and the participation in projects to a wider spectrum of utilities. For example, develop more systematic and coordinated approaches to obtaining input and feedback from water utilities, use plain language in communications, and consider the knowledgebase of end users.
3. Develop validation and/or readiness measures to establish awareness and manage expectations among end users of the expected performance of the analytical tools, decontamination response methods, and software tools produced by HSRP. For example, consider the Technology Readiness Levels used by DOD and NASA, and adding measures of uncertainty to better inform end users about the clean-up options being developed for the Remediation Wide Areas topic.
4. HSRP should develop a strategy for incorporating real-time analyses into their project portfolio, for example, transitioning from a laboratory-based approach to a graphical online approach that can identify and quantify CBRN threats, and apply emerging technologies to develop mobile, GIS-coupled, real-time chemical sensors/monitors.

Specific to HS: Charge Question 5. How can we infuse social science into the development of our research products to improve their usability?

Over the course of the workshop, the Subcommittee discerned among HSRP personnel and partners in attendance a strong appetite for infusing more social science into product development. To date, however, certain factors have inhibited the broad integration of social, behavioral, and decision sciences within HSRP: the Agency as a whole is mostly populated with physical scientists doing environmental work. As a result, social science has had limited influence on ORD's everyday work, and little understanding exists about the diverse "branches" within social science. Scarce organizational resources have also made it difficult to stretch beyond "core" familiar physical science. Indeed, the limited work done by HSRP in risk communication was recently curtailed for financial reasons.

Despite HSRP's organizational culture and financial limitations, many signs suggest that fertile ground exists for greater inclusion of social science. HSRP staff are self-aware that more can and should be done in this arena. A cultural anthropologist who currently serves as a supporting researcher can, along with others, champion needed change. HSRP partners such as the On-Scene Coordinators, given their operational perspective, appreciate the complex social and political dimensions to contamination incident response, and have an intuitive sense that more could be understood about the role of social media. Risk

communication aspects (e.g., contamination and clean-up of water reservoirs) have been pursued by HSRP in the past. The Agency, more broadly, understands the importance of addressing community values when accomplishing its environmental mission and HSRP can tap experienced personnel such as Community Involvement Coordinators.

The Subcommittee recommends some initial steps to deepen the social science footprint within HSRP. First, HSRP should, in collaboration with its partners, convene periodic professional development events to refine the largely inchoate understanding of how social science can help improve water utility preparedness and response and enhance EPA response capabilities for wide-area contamination incidents. A workshop on social science applications in homeland security, for example, could spark deeper understanding and new ideas within HSRP. Second, HSRP should build capitalize on existing projects such as the Bio-Response Operational Testing and Evaluation (BOTE) to gain short-term returns from the application of social science. A natural BOTE follow-on project might be message testing, held in multiple communities, around different decontamination approaches. Third, HSRP should at the outset of project planning involve an expanded pool of partners in considering the potential application and added value of social science. The following two specific recommendations emerged for HSRP leadership's consideration.

Recommendations

1. Develop a process that involves partners for considering the employment of social science in projects during problem formulation as well as throughout the research process.
2. Develop social science training activities, such as workshops and expert lectures, to orient the staff to potential applications of psychological, sociological, and anthropological elements, and to make social science an integral part of current and future projects. HSRP should capitalize on existing assets, for example, the Community Involvement Coordinators and other partner organizations, and existing initiatives, such as the Bio-Response Operational Testing and Evaluation.

SUMMARY LIST OF RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

- **Recommendation 1.1**: Cyber security needs to move to the beginning of the time line.
- **Recommendation 1.2**: Develop a process and strategy that allows responses to, and prioritization of, unforeseen and emerging needs while ensuring that good progress can be made on StRAP research objectives. For example, consider incorporating into the project prioritization process a weighing of the costs versus the benefits of implementing research products from the perspectives of end users.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

- **Recommendation 2.1**: While HSRP is doing a good job consulting with internal EPA partners, the breadth and diversity of partners, stakeholders and world class experts to be consulted regarding

research needs should be expanded. For example, include first responders, water and solid waste utilities, and professional societies and research entities, such as the US National Academies and the Water Research Foundation.

Charge Question 3. How well does the Program respond to the needs of EPA partners?

- **Recommendation 3.1**: Develop, maintain, and institutionalize channels of communication needed to support HSRP research planning, setting priorities, and keeping up with the evolving needs of partners, especially end users at the water and solid waste utilities. For example, communications channels need to be maintained when staff members retire or change positions.

Specific to HS: Charge Question 4. How well has the Program transitioned research to the end-user? How can we improve our ability to transition research to the end-user in the future?

- **Recommendation 4.1**: Develop tools that can be routinely operated and maintained, and have 'multi-use' or 'all hazards emergency response' capabilities where appropriate. For example, with regard to Water Quality Surveillance & Response Systems, develop a plan for supporting deployed tools with future updates, and minimize the number of development platforms to improve interoperability and functionality. Currently, important programs are written in different languages, for example, Decon is in Microsoft Excel™ and TEVA-SPOT is in Java™.
- **Recommendation 4.2**: Broaden outreach, engagement, and the participation in projects to a wider spectrum of utilities. For example, develop more systematic and coordinated approaches to obtaining input and feedback from water utilities, use plain language in communications, and consider the knowledgebase of end users.
- **Recommendation 4.3**: Develop validation and/or readiness measures to establish awareness and manage expectations among end users of the expected performance of the analytical tools, decontamination response methods, and software tools produced by HSRP. For example, consider the Technology Readiness Levels used by DOD and NASA, and adding measures of uncertainty to better inform end users about the clean-up options being developed for the Remediation Wide Areas topic.
- **Recommendation 4.4**: HSRP should develop a strategy for incorporating real-time analyses into their project portfolio, for example, transitioning from a laboratory-based approach to a graphical online approach that can identify and quantify CBRN threats, and apply emerging technologies to develop mobile, GIS-coupled, real-time chemical sensors/monitors.

Specific to HS: Charge Question 5. How can we infuse social science into the development of our research products to improve their usability?

- **Recommendation 5.1**: Develop a process that involves partners for considering the employment of social science in projects during problem formulation as well as throughout the research process.
- **Recommendation 5.2**: Develop social science training activities, such as workshops and expert lectures, to orient the staff to potential applications of psychological, sociological, and anthropological elements, and to make social science an integral part of current and future projects. HSRP should capitalize on existing assets, for example, the Community Involvement Coordinators

and other partner organizations, and existing initiatives, such as the Bio-Response Operational Testing and Evaluation.

SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

The Subcommittee found that the HSRP StRAP clearly defines strategic goals and objectives over the next few years. The topics and project areas are well planned and organized. However, the Homeland Security Research Program often is called to respond in a timely and efficient manner to unforeseen hazards and disasters, such as the Ebola outbreak, cyberattacks on water utilities, and the Elk River chemical spill. It is difficult to plan for resource use during these emergencies, however without doing so, the ability to make progress on all objectives is threatened. The Subcommittee recommends that the Program develop a process and strategy that allows responses to, and prioritization of, unforeseen and emerging needs while ensuring that good progress can be made on StRAP research objectives.

In addition, because of the severity of the threat of cyber-attacks, the Subcommittee recommends that the Program's research schedule should be modified to prioritize cyber security research ahead of other areas to counter the continuous and ever-increasingly sophistication of cyber-attacks that plague utilities. As utilities interconnect formally disconnected systems to increase efficiencies, they create an ever expanding attack surface – often without understanding the impact and risks. As very few utilities have staff prepared to deal single-handedly with chemical or biological attack remediation, knowledge of cyber security is limited in the utility space; consequently research and guidance is needed from HSRP.

The Program has done a good job transitioning research to the end user, particularly through the development of validation tiers for chemical sampling and chemical analytical processes, tracking visits to tools websites to assess popularity, and the collection of Selected Analytical Methods appears to be widely used. The Subcommittee recommends that the Program develop tools for end users that can be routinely operated and maintained, and have 'multi-use' or 'all hazards emergency response' capabilities where appropriate. For example, with regard to Water Quality Surveillance & Response Systems, develop a plan for supporting deployed tools with future updates, and minimize the number of development platforms to improve interoperability and functionality. In addition, the Subcommittee recommends that HSRP develop validation and/or readiness measures to establish awareness and manage expectations among end users of the expected performance of the analytical tools, decontamination response methods, and software tools produced by HSRP.

In conclusion, the Subcommittee recognizes that the activities of the HSRP are well aligned with the mission of the Program and that HSRP staff members have shown considerable progress toward the objectives of conducting research and delivering products that improve the capability of EPA to carry out its homeland security responsibilities.

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

Appendix D: BOSC Sustainable and Healthy Communities (SHC) Subcommittee

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November 17, 2015

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LIST OF ACRONYMS

BOSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
C-FERST	Community-Focused Exposure and Risk Screening Tool
DAA	Deputy Assistant Administrator
DASEES	Decision Analysis for a Sustainable Environment, Economy, and Society
EC	Executive Committee
EPA	Environmental Protection Agency
EQI	Environmental Quality Index
FACA	Federal Advisory Committee Act
FEGS	Final Ecosystem Goods and Services
FY	Fiscal Year
GPRA	Government Performance and Results Act
HWBI	Human Wellbeing Index
NCEE	National Center for Environmental Economics
NIEHS	National Institute of Environmental Health Sciences
OECD	Organisation for Economic Co-operation and Development
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
RARE	Regional Applied Research Effort
RESES	Regional Sustainability and Environmental Research Program
ROE	Report on the Environment
SAB	Science Advisory Board
SHC	Sustainable and Healthy Communities
SHCRP	Sustainable and Healthy Communities Research Program
StRAP	Strategic Research Action Plan
TSC	Technical Support Center
Tribal-FERST	Tribal-Focused Environmental Risk and Sustainability Tool

BACKGROUND

The Board of Scientific Counselors (BOSC) is a Federal advisory committee that provides advice and recommendations to EPA's Office of Research and Development (ORD) on technical and management issues related to its research programs. The Science Advisory Board (SAB) advises the Environmental Protection Agency (EPA) Administrator on strategic research directions and reviews the quality and relevance of the scientific and technical information being used by the EPA. To arrive at their recommendations, the SAB and BOSC EC reviewed preliminary drafts of ORD's Strategic Research Action Plans (StRAPs), and received briefings and additional background materials from ORD's Deputy Assistant Administrator for Science and its National Program Directors for the six research programs. The SAB and BOSC EC then held a two-day meeting in July 2014 with ORD officials to discuss the materials and develop recommendations, culminating in a report to the EPA Administrator in January 2015 on research directions for 2016-2019. The research programs then revised their StRAPs based upon the report.

EPA's BOSC Executive Committee (EC) was rechartered in 2014 to provide advice and recommendations on all aspects (technical and management) of ORD's research program. The role of the BOSC is to advise the ORD Assistant Administrator at an operational level. Five subcommittees have been established to provide targeted advice to ORD's research programs on accomplishing the objectives and producing high-quality research outputs, as articulated in the six StRAPs. The general charge questions below were designed to address the research processes that ORD administers. However, as subcommittee reviews of these research programs are just commencing, it is important to acknowledge that there are many equally important issues that will need to be addressed through additional BOSC subcommittee efforts over the coming years.

The BOSC Sustainable and Healthy Communities (SHC) Subcommittee was established to provide program-specific advice to EPA's Sustainable and Healthy Communities Research Program (SHCRP). The mission of the SCHRP is to conduct research and deliver products that improve the capability of EPA to carry out its responsibilities, including cleaning up communities, making a visible difference in communities, and working toward a sustainable future. SHCRP conducts applied, relevant research and aims to provide the knowledge, data, and tools needed to meet today's needs without compromising the ability of future generations to meet their needs in ways that are economically viable, beneficial to human health and wellbeing, and socially just, while supporting local communities seeking to become more sustainable. SHCRP plans to engage the Subcommittee over the next several years to provide advice on the Program's portfolio and to assess progress in addressing EPA's needs.

CHARGE QUESTIONS AND CONTEXT

This Subcommittee was tasked with addressing a set of charge questions common to all of the BOSC subcommittee efforts this year and are related to program design and problem formulation (Questions 1, 2 and 3). The general charge questions below are designed to address some of the front-end research processes ORD undertakes, fully understanding that there are many equally important issues that will have to be addressed through additional BOSC subcommittee efforts over the coming years.

The Subcommittee was also charged with several questions developed by the SHCRP (Questions 4, 5, and 6). These questions are designed to provide useful, high-level recommendations on aspects of the SHCRP's design and operation, allowing the newly formed Subcommittee to establish familiarity with the entire program, while at the same time, preparing the Subcommittee for future charges that will require a deeper understanding of the SHCRP.

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

The StRAPs are designed to clearly convey the vision and objectives of the research program, and to describe, at a high level, the research topics, and major outputs planned for 2016-2019. Upon receiving recommendations from the SAB and the BOSC EC, as well as from EPA partners and others, ORD has further developed the StRAPs, including refining the objectives and topics, and providing more clarity. At an operational level, each research program is aiming to accomplish its objectives through research spanning physical, biological and social sciences and through numerous ORD laboratories, centers, and STAR grantees all across the country. In addition, ORD has heeded the advice of the SAB and BOSC in past years to do more to integrate research across the six programs, across EPA and with other Federal partners. Given these complexities, we recognize there are likely several reasonable approaches for organizing the research to best accomplish the objectives.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

ORD works with EPA partners to design the research programs to meet Agency priorities. The first step in this process is problem formulation which provides the foundation of the research. Although it can be tempting to jump to a list of research priorities, problems that are well defined lead to the most effective research efforts and solutions. The problem formulation stage of research planning lays the groundwork for the StRAPs and is the reference point for any changes in priorities as budgets change and new issues emerge. Problem formulation occurs at many different levels including the articulation of issues in the EPA Strategic plan; meetings with EPA partners including regular staff-to-staff meetings; workshops and conferences where states, regions, policy and science staff describe the problems they face; and discussions among senior managers at EPA. In addition, each National Program Director reaches out to EPA partners in a variety of targeted ways to agree on problem definition.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

ORD places a very high value on working closely with EPA partners to design the research programs to meet Agency priorities. During the preparation of the StRAPs, the programs were guided by the EPA Strategic Plan and undertook a variety of activities to actively engage partners, both to understand their priorities and to elicit their input on research directions. These include many regular meetings with EPA policy and regional staff, communities of practice for specific scientific disciplines throughout the Agency, annual two day meetings led by the NPDs, annual senior level meetings with EPA Assistant and Regional Administrators, and formal requests from ORD's Deputy Assistant Administrator (DAA) for science to receive comments from across the Agency twice during the year of StRAP development.

In addition to the up-front work with EPA partners to understand their research needs for the upcoming year(s), ORD also needs to be flexible enough to address top priority, unanticipated needs or environmental crises that emerge at any given time. The research program will describe interactions with EPA partners, present examples of recent responsiveness to unexpected events, and explain how they work with EPA partners to accommodate acute needs while resources are limited.

Specific to SHC: Charge Question 4. SHC has committed to integrating ecological and human health to better address issues of human and community wellbeing. Does the research program contain the elements necessary to integrate these two critical elements of EPA's mission?

SHC's StRAP defines sustainability as the long-term wellbeing that emerges from a resilient economy existing within a healthy society dependent on an intact, functional environment. At the community and regional scales, high environmental quality and access to ecosystem service benefits are hypothesized to have critical impacts on the promotion of health and wellbeing. Conversely, a degraded natural (and social) environment has adverse effects on health and wellbeing. Therefore, SHC strives to integrate ecological and human health in our research to better address issues of human and community wellbeing.

Specific to SHC: Charge Question 5. SHC's portfolio includes both hypothesis-driven research and the development of decision-support tools to aid Agency, state, and community stakeholders. Is the balance of research and tool development appropriate for this program?

SHC is committed to developing actionable science and technology to enable community stakeholders inside and outside of the Agency to make decisions that support long-term wellbeing. It also provides science and tools for cleaning up contaminated sites, dealing with oil spills and leaking underground storage tanks, and managing materials. This requires building tools that provide easier access to scientific information and easier application of that science to decision making. At the same time, SHC is responsible for producing high quality science that makes the causal links or engineering applications needed to populate those tools.

Specific to SHC: Charge Question 6. SHC has a mission to address the short-term needs of EPA's Office of Solid Waste and Emergency Response (OSWER) for research on contaminated sites, oil and fuel spills, and sustainable materials management. How can SHC best leverage these short-term research goals with longer-term community sustainability and environmental justice goals?

SHC provides EPA's Office of Solid Waste and Emergency Response (OSWER) with research and technical support to address long-term, pressing issues that require immediate resolution. For instance, SHC provides support on remediating or monitoring individual contaminated sites. SHC scientists also provide research or technical support for individual decisions such as those on coal combustion residues or leachates from re-used materials. These are near term needs but not short-term issues. SHC also works with OSWER and communities with Superfund or Brownfield sites who face decisions on managing materials. In addition to supporting OSWER's needs, SHC considers longer-term questions about restoration of the natural and built environment as well as community revitalization that underlies community wellbeing and environmental equity.

STRAP OBJECTIVES AND PRIORITY RESEARCH TOPICS

The SHC Strategic Research Action Plan (StRAP) outlines the ORD's role in achieving EPA's objectives for cleaning up communities, making a visible difference in communities, and working toward a sustainable future. It was developed with considerable input and support from partners within EPA program and regional offices, as well as from outside stakeholders such as community leaders, other Federal agencies, nonprofit organizations, and colleagues across the scientific community. It includes research and development to generate and provide access to environmental science on health, wellbeing, and the environment, and to place that science in the context of the critical decisions facing communities. This plan also contains research and development focused on some of our nation's most pressing issues – contaminated sites, oil spills, and waste management.

The Sustainable and Healthy Communities research program is designed to develop research and tools that offer solutions to community-based decision makers, inside and outside EPA. SHC is committed to providing high quality information in user-friendly formats to help optimize community decisions across the three dimensions of sustainability—economics, society, and environment. The four program objectives are:

1. Develop the data, models, and tools to expand community stakeholders' capabilities to consider the social, economic, and environmental impacts of decision alternatives on community wellbeing, and support the next generation of environmental scientists.
2. Develop the causal relationships between human wellbeing and environmental conditions and the tools and metrics that allow assessment and tracking of progress.
3. Provide research and technical support for cleaning up communities, ground water, and oil spills; restoring habitats and revitalizing communities; and advancing sustainable waste and materials management.
4. Develop a Sustainability Assessment and Management Toolbox to help the Agency and others build sustainability into day-to-day operations.

These objectives flow from EPA's Strategic Plan, consultation with EPA program and regional partners, and ORD scientists' understanding of pressing science needs.

Each of the objectives identified above corresponds with one of SHC's research topics that guide specific research and development activities for addressing the objective-specific "Science Challenges" as set forth in the SHC StRAP. The research topics are:

Topic 1: Decision Support and Innovation

Under this topic, SHC will develop the data, models, and tools to expand community stakeholders' capabilities to consider the social, economic, and environmental impacts of decision alternatives on community wellbeing. For example, tools will incorporate decision science techniques, spatial analysis, and sustainability assessment to help users frame decisions, increase community-engagement, understand implications of decisions, and identify potential solutions that promote a more sustainable future.

Topic 2: Community Wellbeing: Public Health and Ecosystem Goods and Services

Topic 2 strives to develop the causal relationship between human wellbeing and environmental conditions as well as the tools and metrics that allow assessment and tracking of progress. For example, SHC research will provide the science that informs the quantification, valuation, and classification of ecosystem services, improve the understanding of chemical and non-chemical determinants of public health and wellbeing, and allow assessment and tracking of changes over time. SHC will explore the dynamics of integrated human-ecological systems and identify implications of changes in both the built and natural environment on human wellbeing, paying special attention to vulnerable groups and lifestages.

Topic 3: Sustainable Approaches for Contaminated Sites and Materials Management

This topic provides research and technical support for cleaning up communities, ground water, and oil spills, restoring habitats and revitalizing communities, and advancing sustainable waste and materials management. Specifically, this work will help partners and stakeholders improve the efficiency and effectiveness of addressing contaminated sediments, land, and ground water and resultant vapor intrusion. SHC research will also provide and evaluate standards, products, data, and approaches to prevent, characterize, and cleanup environmental releases of petroleum and other fuel products. SHC methods, models, tools, and data will enhance sustainable materials management.

Topic 4: Integrated Solutions for Sustainable Communities

The goal of Topic 4 is to help the Agency build sustainability into its day-to-day operations. SHC will provide community stakeholders with a suite of simple to complex tools that used together provide a systems approach to help them optimize actions that are based on a full accounting of the costs, benefits, tradeoffs, and synergies among social (including public health), economic, and environmental outcomes of alternative decisions. Specifically, SHC aims to develop a Sustainability Assessment and Management Toolbox for use by community stakeholders.

PROCESS

Review of Materials

The SHC provided a suite of materials for the BOSC SHC Subcommittee in September 2015. These materials included the following:

- SAB/BOSC General Findings and Overarching Recommendations from 2014 and EPA Responses
- Slides on SHC's Vision & Priorities
- SHC Strategic Research Action Plan FY 2016-2019
- Recent Accomplishments in SHC Research
- Project Descriptions, Outputs, and Posters
- Index of Completed Journal Articles
- Additional Supplemental Materials

Subcommittee members reviewed these documents prior to the face-to-face meeting.

Subcommittee Meeting

The Subcommittee held a meeting to prepare the review of the SHCRP at the EPA Research Triangle Park campus in North Carolina on September 24-25, 2015. The agenda is attached as an appendix to this report. Essentially, the first day focused on presentations from the SHCRP to the Subcommittee, including poster sessions and a presentation of online tools. The second day focused on Subcommittee deliberations toward responses to the charge questions. The Subcommittee worked in full group and breakout groups to discuss and address the charge questions and associated recommendations. Interaction between SHC staff and the Subcommittee throughout the meeting allowed for clarifications and are captured in the minutes from the meeting.

Post-Meeting Response to Charge Questions

Members continued to collaborate in breakout groups to finalize the responses to the charge questions in the weeks after the face-to-face meeting. These responses were incorporated into this report in October 2015, in advance of the Subcommittee's teleconference on November 4 wherein full Subcommittee perspectives were incorporated into the report.

RECOMMENDATIONS

Responses to charge questions are organized by (i) general observations, (ii) particular strengths, (iii) opportunities for improvement, (iv) challenges, and (v) recommendations.

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

General Observations

The StRAPs are designed to clearly convey the vision and objectives of the research program, and to describe, at a high level, the research topics, and major outputs planned for 2016-2019. The Subcommittee generally found the vision and objectives to be clearly conveyed and the topics and project areas to be planned and organized appropriately. Nevertheless, greater specificity, such as via second order objectives, was seen as desirable to include in the next StRAP as well as a more systematic process to document progress.

Particular Strengths

The Subcommittee wishes to recognize and applaud the strong and consistent focus on sustainability and systems orientation of the programs within the SHCRP. Sustainability is critical to our collective future, and EPA is the appropriate organization to tackle this thorny problem. A focus on sustainability by EPA can help shift the national conversation to this important topic to allow for focus on emerging challenges and global and national scale issues and drivers such as climate change, immigration, shrinking cities, economic change, geopolitics, changing demographics, increasing income inequality and persistent poverty. The SHCRP, along with sustainability science in general, articulates sustainability as an inextricably intertwined, nested, and interactive pursuit.

Based on EPA's overarching strategic priorities of making visible differences in communities, cleaning up communities and advancing sustainable development, and working toward a sustainable future, the SHCRP clearly plays a leading and umbrella role for the entire EPA ORD program in addition to their own program development objectives and products. It is the Subcommittee's general observation that SHC's integrating and leading role should be recognized and further prioritized within EPA ORD. The SHC program has succeeded in developing knowledge, solutions, and strategies—characterized as tools in a toolbox—that are available, accessible and ready to address the changing challenges and needs of today and tomorrow in demographic, technological, and ecosystem dynamics including climate change, values, and changing social priorities as well as other emerging issues.

The Subcommittee also noted considerable progress in drawing on other ORD programs in the design of projects and tools, and improvements in interoperability as indicated by the potential of the Interoperability Workshop held October 19–22, 2015 at the EPA's Research Triangle Park campus.

Opportunities for Improvement

SHC is still a relatively new program at EPA, and it is perhaps unsurprising that the new structure only partially integrates various older programs with an array of newer efforts. However, this very newness also presents an opportunity to bring together an overarching framework that can help support integration across various aspects of sustainability.

Challenges

The Subcommittee recognizes the SHC confronts considerable challenges posed by the breadth of sustainability, constraints from limitations of budget and the scope of responsibilities of other agencies. There are numerous potential elements that could stand in the way of sustainability efforts: organizational structures, disparate locations, parochialism, funding models, and leadership challenges. We encourage EPA and SHC to be vigilant about problems that could occur in each of these areas. Within these constraints, the Subcommittee concluded that sustainability in general, and indices and metrics developed by SHC specifically, are appropriate aspects of the Agency's research trajectory to meet the needs of the nation.

Regarding Charge Question 1, the Subcommittee offers the following recommendations.

Recommendations

1. The Subcommittee encourages greater integration across projects and topics to achieve goals of holism and inclusion. Consistent with the cross-cutting nature of sustainability, topic areas and project areas should not be advanced in isolation. Instead systematic mechanisms to coordinate and integrate should be applied. One of these mechanisms could be expanded use of shared staff appointments across research topics.
2. The Subcommittee recommends greater integration across scales in the programs, products and tools produced by SHC. The clients or users of product and tools produced by SHC include individuals, community groups, local agencies, regional planning authorities, regulators and many others. Greater attention could be given to making these products customizable and scalable. Also differences in technical skills and capacity of various user populations can be more fully addressed. Furthermore, the Subcommittee recommends that SHC also address the need to scale up and down to capture key interactions influencing community experiences and decision making. Communities do not always control their own destinies and they are often quite internally heterogeneous.
3. The Subcommittee recommends SHC develop more systematic and transparent processes for selection of communities and projects to include in analysis and data collection. The Subcommittee noted a lack of transparency in how communities were selected to participate in programs or to be included in data gathering efforts. One case in point is the seemingly ad hoc process for selecting the 50 cities to include in the EnviroAtlas. Development of a meta-analytic framework could be valuable in addressing the integration described in the aforementioned recommendations.
4. The Subcommittee recommends a greater focus and emphasis on outcomes. While it is important to assess both outputs and outcomes, the Subcommittee sees benefit from greater emphasis on outcomes than is currently in place. Outcomes can be tracked across partners and communities. Efforts such as the Human Wellbeing Index (HWBI) and Environmental Quality Index (EQI) provide useful metrics by which broad-scale outcomes could be measured.
5. The Subcommittee recommends a specific effort be undertaken to document gaps in current knowledge, with the goal of enabling other researchers, including current researchers outside EPA as well as future researchers at EPA, to pursue those areas. Identifying such knowledge gaps provides opportunities to SHC research to advance knowledge and provide the most valuable sustainability services and information to communities.
6. The Subcommittee recommends developing projects under Topic 4 (“integrated solutions”) that are more closely related to the topic area. The Subcommittee was struck by the fact that under this topic were not integrated solutions but instead an array of fairly specific research activities (e.g.,

"Carbon stable isotopes as indicators of coastal eutrophication", "Nutrient enrichment and precipitation changes do not enhance resiliency of salt marshes to sea level rise in the Northeastern U.S."). While this research appears to be useful in its own right, it seems only indirectly related to the goal of "integrated solutions." Alternately, a more explicit connection between the outputs and the overarching goal should be made.

7. The Subcommittee recommends that efforts be taken to more fully develop the conceptualization of sustainable and healthy communities. Given that EPA in general, and SHC specifically, have the opportunity to be global leaders in sustainability, presenting an integrated framework for how to think about sustainability and health could be transformative both for the U.S. and for communities around the world. Further, the Subcommittee recommends that SHC provide national leadership in defining core principles of wellbeing, community, resiliency, and sustainability. This not only involves synthesizing definitions, but continued work on matching units and levels of analysis to research questions and improving data availability at multiple scales. This requires continuous effort to avoid committing the ecological fallacy of applying observations made at larger scales to the individual scale.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

General Observations

While it is likely the EPA approach is moderately effective given the comments provided directly to the Subcommittee from a non-representative sample of EPA partners, limited evidence was provided to the Subcommittee for a conclusive finding. However, based on the evidence provided as well as discussions with EPA program offices and regions, we can note positive improvements from SHC's past partner engagement activities.

In this Charge Question as well as the following one, the Subcommittee distinguishes between the formal EPA "partners" as defined by ORD practice and the vast number of other research stakeholders. Stakeholder groups include university-based scholars, other Federal research offices, advocacy groups and non-profit research organizations, and the specific communities (city and regional governments and general citizenry) that are sites of SHC research or implicated by research findings because of common environmental traits. The evidence regarding formally defined partners' involvement is incomplete, and for other stakeholder groups is essentially unavailable.

There are effectively two research planning activities occurring in parallel: one involving research projects that are directly requested by EPA partners, and the other for SHC staff-directed research which includes formal topic identification, agenda-setting, and problem formulation like the StRAP. For the former, the involvement of EPA partners is obvious and the primary concerns involve SHC capacity and prioritization of the partners' requests. For the latter, the activity has become more formal and—as noted above—apparently more thoughtful and robust than earlier EPA efforts.

Particular Strengths

Partners can and have included many constituencies and stakeholders for SHC. Formally, this includes EPA partners (regional and program offices), all of which have some level of official involvement in the StRAP and other planning processes. SHC staff has dramatically improved the formal engagement strategies with the EPA partners compared to previous efforts, as noted by the EPA partners' testimonials and project documentation. The informal engagement with partners and the broader stakeholder groups has also

expanded, and there has been opportunity granted to scholars to be more engaged with other stakeholders.

Opportunities for Improvement

The involvement of other EPA offices is either unclear, given the evidence presented, or not documented, such as the Office of Sustainable Communities. Other stakeholders are engaged in planning as mediated through the Regional Offices. These may include: state/local/tribal authorities, citizenry and neighborhood-level stakeholders, other Federal research offices (including EPA ones like the National Center for Environmental Economics, or NCEE), topical networks/knowledge, research organizations, scholars, or other funders (e.g., philanthropic organizations). It would be helpful to understand whether EPA sees cities as partners—either individually or collectively by coordinating with one or more of the city associations (e.g., the ICLEI network of Local Governments for Sustainability, Urban Sustainability Directors Network, National League of Cities, International City/County Management Association). Many of these groups are involved informally and, in some cases, serendipitously.

The question about opportunities for improvement will be easier to answer when EPA defines the process for involving EPA partners (both within and outside the Agency) and develops measures of its effectiveness. In the future, the Subcommittee would like to review a defined process and documentation of the actual engagement in the preceding year. It may be useful to organize future meetings of SHC and the Subcommittee in a way that provides opportunities for meeting with centers and labs as well as partnering regions and communities. This could aid in enhancing understanding of the implementation of tools and their effectiveness in diverse situations.

Further, the extent to which the StRAP is actually implemented, becomes a benchmark against which project execution is measured, and is revised, is unclear. Questions remain regarding the relevance and utility of research plans (as embodied in the StRAP): How do projects and their tasks come directly out of the StRAP? Are both the StRAP and projects concurrent products of SHC? Is the StRAP frequently revisited and updated with partner involvement, and are projects mapped against it? These questions may exist only because there are gaps in the information presented to the Subcommittee.

Challenges

Partner involvement in research planning is subject to administrative and organizational changes beyond SHC's control (such as ORD reorganizing, Administrator prerogative, and Congressional mandate). As such, involvement is a work in progress and will continue to be constrained despite attempts to expand and document.

Regarding Charge Question 2, the Subcommittee offers the following recommendations.

Recommendations

1. The Subcommittee recommends that the SHCRP formalize the engagement process without overly complicating the engagement. EPA's approach appears to be moderately effective. The Subcommittee defines "moderately effective," however, as having discovered no specific shortcomings in the evidence provided. The Subcommittee was unable to determine if the process is as effective as it could be or consistent across the broad range of partners who could inform problem formulation. The Subcommittee believes that SHC can develop a process to provide more

transparent and clear evidence of partner (and stakeholder) stakeholder engagement and priorities in problem formulation.

2. The Subcommittee recommends that the SHC explicitly define "partners" and their appropriate roles in research planning. It is appropriate to note that certain stakeholders should or should not have a role in research planning, but this should be a conscious and documented decision. Opportunities for casual and informal engagement with stakeholders should be fostered through reallocation of resources for attendance at research conferences and outreach to other Federal researchers—essentially, formally allowing the informal activity to occur.
3. The Subcommittee recommends that the SHCRP develop measures and criteria to assess the effectiveness of stakeholder involvement. While each project and individual tasks may have different involvement requirements, there should be a conscious set of criteria against which effectiveness can be assessed during and after project completion. Some SHC grant programs (like the Regional Sustainability and Environmental Research Program, or RESES) require explicit "success measures" that include partner involvement, for example. The same strategy could apply to research planning efforts, and might be applicable to reporting under the Government Performance and Results Act (GPRA) (for example, through a "partner satisfaction" metric).
4. The Subcommittee recommends improvements in the documentation of the activities themselves. One opportunity for documentation is to use web-based tools to document and track actual partner input and identify priorities. It would also be useful to document changes in prioritization by SHC as a part of this tracking effort. Current topic "charters" and "abstracts" describe this information, but there is inconsistency in reporting across projects leading to a failure to account for informal input provided by partners, and it is not analyzed for any patterns or gaps. Consistent documentation of partner involvement activities, outputs, priorities as well as changes and feedback will aid in transparent involvement. Documentation of these efforts will also make external assessment of partner involvement possible. Again, though, efforts to document engagement and decision processes should not be implemented in such a way as to preclude the serendipitous projects which leverage existing research that arise from informal connections within EPA, across other Federal agencies, and among external researchers. However those instances should be noted in a way that recognizes the contributions of those opportunities in the final outputs of the SHCRP.
5. The Subcommittee recommends linking the partner engagement at the research planning stage to the engagement during the longer-term period of research execution. Include explicit plans for how partners will continue to be engaged with the specific project or tasks within the research plan itself. Partner involvement in research methods, data collection, testing, and dissemination are currently done through many communication conduits, but these occur after projects have begun. Having an earlier and explicit partnership plan in the research content plan that is agreed upon by all partners will mitigate any confusion or missed opportunities later. To the extent possible, specific personnel should be named, along with timelines and roles. Note, however, that not every project or task will require the same level of partnership. The plan should simply note the magnitude of involvement needed.
6. For the Subcommittee to more fully understand the implementation of tools and their effectiveness in diverse situations, we recommend future meetings of SHC and the Subcommittee provide opportunities for greater interaction with staff from centers and labs, as well as stakeholders in partnering regions and communities.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

General Observations

There is an inherent but healthy tension between the mandate to support partner needs and a forward-thinking drive into identifying and pursuing new research topics to more broadly support the intent of the SHCRP. The Subcommittee believes there should be a balance among the research investments driven by partner priorities and those developed within and by SHC staff; one should not preclude the other.

Particular Strengths

Several activities exist to tie partner needs into the SHC activities, from projects like RESES to Technical Support Centers (TSCs) and related mechanisms to fund regional priorities, as well as the very frequent partner update calls, meetings, and sessions that are held.

Partnership engagement is both formal and informal. In some cases, robust and universally appreciated projects have come about from informal engagement. We find that partnership engagement is dependent on partner staff availability, interest, and knowledge of the opportunity to participate in the development of all the projects that may be related to the work of SHC.

Opportunities for Improvement

Like the information regarding research planning, the data regarding research engagement in general that is provided to the Subcommittee is limited. Documentation of all partner and stakeholder engagement channels and their robustness is weak. In many cases, for example, the Subcommittee found that SHC researchers were collaborating with other Federal projects (in other departments or agencies) but the project documentation does not include these.

Engagement with specific state/local/tribal authorities or community groups often appears ad hoc, and is likely not representative of all possible research needs or capacities. However, it should be noted, it is not necessarily SHC's role to be an exhaustive research resource to all stakeholder groups, or to intervene in all the direct engagement plans of EPA's program and regional offices.

Challenges

Resources for conducting pressing research separate from partner-driven research appear to be shrinking. Partners and stakeholders should be enlisted and engaged in understanding and articulating the value of exploratory research for their own long-term needs. A related resource issue involves the capacity for SHC to take on new subject areas, and to spend resources documenting partner needs and engagement that may be limited.

Regarding Charge Question 3, the Subcommittee offers the following recommendations.

Recommendations

1. The Subcommittee recommends that research projects pursued by SHC staff that may not reflect immediate partner needs should continue to be encouraged, but should be evaluated through the presentation of an EPA-mission rationale for the investment and expected timeframe for partner involvement and mapping to partner needs and relevance. Clear articulation of how SHC-driven work can support long-term capabilities of programs and regions could relieve the tension between competing priorities.
2. The Subcommittee recommends that formal assessments of partner needs should be documented in such a way that would facilitate clear decision making around prioritization so that those decisions can be communicated transparently. Both formal and informal engagement processes to solicit needs should also be documented so that clear lines can be drawn between the problem formulation stage and the development of a research or tool development project. In presenting the full scope of current and possible research, SHC can negotiate more effectively with partners on priorities given limited resources. Partner-driven research is still a core function and mission of SHC, and should not be jeopardized.
3. The Subcommittee recommends that a reasonable amount of SHC resources be reallocated to partner-related engagement activities, starting with efforts to define the landscape of potential engagement (which may include potential philanthropic funders and co-funders of SHC projects) and informal engagement with all stakeholder types. In particular, other Federal researchers could be productive and easily justifiable partners. Resources should be reallocated to insure that there are staff motivators for partner engagement (e.g., requirements in performance reviews). While resources are constrained, provision of these cost-effective strategies could ensure a longer-term partner satisfaction as well as help identify the terrain of research needs efficiently.
4. The Subcommittee recommends that SHC coordinate with EPA's Program Evaluation office to conduct an implementation study of SHC's partner engagement approach, and output or outcome evaluations of partner engagement (in addition to other outputs and outcomes of interest as noted by other working groups). SHC should develop a partner usage/utility measure for its outputs as part of its GPRA reporting requirements. Note, again, that stakeholders include members of the scholarly community as much as EPA program and regional offices. Metrics could include, for example, bibliometrics for the former and peer review/satisfaction for the latter.

Specific to SHC: Charge Question 4. SHC has committed to integrating ecological and human health to better address issues of human and community wellbeing. Does the research program contain the elements necessary to integrate these two critical elements of EPA's mission?

General Observations

The statement, "SHC has committed to integrating ecological and human health to better address issues of human and community wellbeing" represents a paradigm shift in focus from the traditional linear model of environmental health, whereby a toxin causes a disturbance to human health and the focus of work is on identifying the cause of the toxin and preventing it from having an effect on human health. The new paradigm looks at an integrated model of the socio-ecological system and the impact of disturbances not only to human health but related to a more complex concept of individual and community wellbeing. The Subcommittee observes a strong commitment to this paradigm shift within the SHCRP.

The question relates to an integration of the sustainability agenda and the environmental health agenda. This paradigm shift depends on a complex—not one-dimensional—conceptualization of the relationship between ecological conditions and human health, with mediating socio-economic factors. There are still ways to examine causal flows from environmental conditions to human health, but this paradigm shift requires stepping back at times from traditional causal thinking and into more systems thinking. Health and disease are rendered more complex by the notion of wellbeing. Wellbeing is more than health; it is a state of existence that encompasses a satisfactory or satisfied emotional state that, in turn, presupposes a level of security from physical, economic and social perspectives. The notion of community is integral to EPA's strategic priorities and represents an appreciation of the scale of lived experience and decision making for people sharing common ties and interests in a shared place. Individual, community, economic, and ecological wellbeing are integrally connected.

Having expanded the conceptualization of a simple cause and effect to a multifaceted, complex, dynamic and interactive model, the goal of "integrating ecological and human health to better address issues of human and community wellbeing" relates to EPA's overarching pursuit of sustainability.

While it will take further development of the relationship between SHC and the Subcommittee in the coming years to fully address these issues, from this vantage point it appears that SHCRP contains the elements necessary to integrate ecological and human health to better address issues of human and community wellbeing, but significant additional developments and modifications to existing systems are needed.

Particular Strengths

SHC tools developed to date or in development address many of the challenges faced by communities from urban to rural, from built environments to more natural, from dense to sparse populations as well as the needs of underserved communities in the context of environmental justice.

Particularly impressive are the integrated and interactive tools developed to assess ecosystem goods and services exemplified by the EnviroAtlas, which uses advanced information technology including GIS, landscape-scale science, remotely sensed data, as well as qualitative and quantitative spatial information to enable communities to incorporate consideration of environmental, social, and economic data into decision making with a user-friendly and interactive web-based interface. Stated attention to development of new layers of information at multiple scales is a valuable ongoing enterprise. The national level Report on the Environment (ROE) provides useful macro-scale national information and provides valuable contextual information for the more locally sensitive EnviroAtlas.

Other promising efforts include the EQI and HWBI that aim to gather and collate information from communities to provide valuable insights into the relationship between the ecological environment and human health and community wellbeing in selected areas. These related projects appear to be in early stages and dependent on gathering information from focused populations, but the information opportunities are intriguing. Obviously, more research is needed to move beyond county-level data and to reach a broader set of communities that will make the information more valuable and more widely available, but these appear to be on the right track.

Another set of promising projects and tools are those that address vulnerable communities and issues of environmental justice. The Community-Focused Exposure and Risk Screening Tool (C-FERST) and Tribal-Focused Environmental Risk and Sustainability Tool (Tribal-FERST) are particularly encouraging. In allowing for tribal ownership of the Tribal-FERST tools and extending the ability to manage integration

with their own data, this project shows great sensitivity, wisdom and inclusion of environmental justice principles.

The SHC project on Assessing Environmental Health Disparities in Vulnerable Groups offers the promise of developing new information that would be helpful to communities struggling with the social and economic factors that adversely affect health, the environment and ultimately wellbeing of individuals and communities. This project appears to contain appropriate focus on environmental stressors specifically encountered in child-specific environments through cooperation between EPA and the National Institute of Environmental Health Sciences (NIEHS) (for more information see https://www.niehs.nih.gov/research/supported/dert/programs/prevention/). The Subcommittee sees this focus on children's environmental health as critically important. We note that there are animal models that are also exploring this important area of environmental health and vulnerable populations.

Opportunities for Improvement

Regarding indicator-based tools, such as EnviroAtlas, EQI, and HWBI, it will be important to continue to incorporate the dynamic nature of ecological and socio-economic conditions. Capturing a cross-sectional snapshot of conditions at a given period of time for a particular spatially delineated area is useful, but may not capture important trends or abrupt changes over time. We recognize that capturing temporal dynamics is a function of data availability, but we believe capturing changing conditions over time is an opportunity for improvement in SHC tools.

SHC's conceptualization and measurement of ecological conditions is focused in the project on Final Ecosystem Goods and Services (FEGS). Difficulty may arise when certain ecosystem goods and services are difficult to measure quantitatively (e.g., cultural benefits). This often leads to them being left out, leading to specification error in subsequent modeling efforts. Additionally, the decision to quantify or monetize ecosystem goods and services may not always be appropriate or culturally sensitive, thus presenting a conundrum for researchers and potential crowding out of certain stakeholders. The FEGS project articulates the goal of including "community-specific research elements" in case studies to address "site-specific issues" and that "case study sites will be based on objective criteria" and community typologies, but it is unclear how this local sensitivity will be balanced with a priori determination of FEGS and associated metrics.

Further, when FEGS are broken down by the role they play in an ecosystem and determined a priori, this may miss multiple or confounded or conflicting views. In other words, not all FEGSs are perceived or interpreted in the same way by multiple stakeholders. Thus, who is defining the benefit of the service is very important. There is also conceptual confusion in the notion of "final" ecosystem goods and services. What might be considered a direct benefit at one point may actually be intermediate in the context of a more broadly conceptualized system. In conclusion, an opportunity for improvement lies in a deeper engagement in articulation of ecosystem goods and services, including wrestling with challenges associated with the ecosystem services concepts and measures being discussed in the wider research community.

Challenges

The Subcommittee recognizes that this paradigm shift toward a more systems-oriented approach to understanding the relationships between ecological conditions and human health is a process that takes time. It is easier to focus on shorter-term goals than longer-term research agendas, though these longer horizons are critically important. We appreciate the challenge of creating tools to fit different situations and to fully understand how decision makers in different contexts use SHC tools. The biggest challenge

SHC faces currently is transitioning from tool creation and implementation to evaluation and adaptive development, which is a critical element in moving forward. Effective evaluation processes are complicated by Federal bureaucratic barriers to obtaining feedback from stakeholders, particularly in terms of human subjects review and Paperwork Reduction Act processes.

Another set of challenges is found in how to conceptualize health, wellbeing, community, resiliency, and sustainability. Myriad conceptual and operational definitions exist in the research community and while there are loosely consensual themes, there are wide discrepancies to navigate. The SHCRP faces considerable challenge in putting forth an authoritative conceptualization of core concepts and their measures.

Regarding Charge Question 4, the Subcommittee offers the following recommendations.

Recommendations

1. The Subcommittee recommends expanding SHC's conceptualization of relationships between ecological and human health away from linear, unidirectional articulations toward more complex systems thinking and multi-directional relationships, including the mediating role of socio-economic factors. This may involve reconsidering the nesting hierarchy of sustainability elements and integrating more logic models, causal and feedback loops, and system dynamics models, including assessments of the economic implications of ecological and human health relationships. Such models could depict the relationships among program objectives and activities in the SHC portfolio, and the linkages between environmental quality and human wellbeing that are the foundation of the program and the StRAP.
2. In the further development of tools, the Subcommittee recommends being highly mindful of tools and data available from external partners, particularly other Federal agencies, so as to avoid duplication of effort. Regarding existing resources across governmental, non-governmental, and scholarly research communities, we highlight a few examples. On wellbeing, the Organisation for Economic Co-operation and Development (OECD) has Guidelines on Measuring Subjective Wellbeing and the Centers for Disease Control and Prevention (CDC) emphasizes living conditions as part of wellbeing (http://www.cdc.gov/hrqol/wellbeing.htm). On health, the CDC has a National Environmental Health Tracking System (http://ephtracking.cdc.gov/showHome.action) and a suite of county-level indicators (http://www.countyhealthrankings.org/) and the American Academy of Pediatrics has information on children's health and environment (https://www.aap.org/en-us/about-the-aap/Committees-Councils-Sections/Council-on-Environmental-Health/Pages/default.aspx). The One Health Initiative offers insights on human and animal health connections http://www.onehealthinitiative.com/index.php. On ecological conditions, various entities including the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and the Consortium of Universities for the Advancement of Hydrologic Science, have tools for interoperability with other systems and databases. The SHC's web-based services and tools such as EnviroAtlas are exceptional and will be only more impactful if they connect well with other data sources and systems.
3. The Subcommittee recommends prioritizing efforts in and on vulnerable communities and with vulnerable populations that may have increased likelihood of exposure as well as increased susceptibility to adverse effects of stress and environmental agents (e.g., children and environmental justice communities). At the same time, attention to emergent trends across communities may identify nascent vulnerabilities in communities initially deemed to be more resilient.

4. The Subcommittee recommends that the SHCRP expand the time horizon for investigating the interactions of ecological and human health and community wellbeing. While we recognize the mandate for relatively short planning windows of 5 years or less, we recommend attention be given to longer-term strategies (e.g., 20 years or more) to allow for focus on emerging challenges and global and national scale issues and drivers such as climate change, immigration, shrinking cities, economic change, geopolitics, changing demographics, increasing income inequality and persistent poverty. The Subcommittee advocates for attention to maintaining relevance and being proactive, rather than reactionary, to ensure robust consideration of connections between ecological and human health.
5. While we recognize budgetary constraints, the Subcommittee recommends adding staff in the areas of expertise needed to address this new paradigm, particularly with regard to the social and economic sciences, and with those who understand complex socio-ecological and psycho-physiological systems. It may also be increasingly necessary to tap into external expertise through more extensive partnering. Either way, focusing on workforce development to allow for ongoing attention to the critical domains of the SHCRP is deserving of resources.

Specific to SHC: Charge Question 5. SHC's portfolio includes both hypothesis-driven research and the development of decision-support tools to aid Agency, state, and community stakeholders. Is the balance of research and tool development appropriate for this program?

General Observations

In addressing this charge question, the Subcommittee recognizes the importance of both hypothesis-driven research and the development of tools. SHC is clearly pursuing both of these directions. In addition, though, the Subcommittee believes that research and tools are not separate, but rather intrinsically linked, and that an awareness of the relationship between the two is critical.

The Subcommittee discussed the question of whether the Sustainability Assessment and Management Toolbox provided by SHC (Topic 4) will be flexible enough to address these changes as well as to support the varied nature of community stakeholders who make decisions under different contexts and with differing levels of capacity. There are a host of tools in the toolbox that have been developed to address a host of different situations, very likely more tools than we can imagine, that not only need to be used, but also to be tested in the rapidly changing world. The questions the Subcommittee would ask in turn are:

- For each tool, is there evidence of a needs assessment to document the reason the tool was created?
- Are the tools being used?
- Are they being used appropriately?
- Are they helpful and effective?
- Do they meet the needs of the community?
- Are they appropriately addressing the local, regional, tribal, and global environmental realities and changes?
- Do they need to be modified for general or specific use?
- Are there tools that have not been useful for which no further support should be given?
- Are more tools being developed, requested, or tested?

These questions are offered for consideration by SHC staff as part of the ongoing process of development of decision-support tools.

Particular Strengths

The Subcommittee commends several projects in particular, and each involves decision-support tools. With the growing focus on sustainability (see Charge Question 1), the Subcommittee sees the HWBI and EQI as critical tools to assess the overall state of particular communities. In addition, the Decision Analysis for a Sustainable Environment, Economy, and Society (DASEES) tool, with its ability to support structured decision making (presumably with the ultimate goal of improving along both the HWBI and EQI), was similarly praised in supporting sustainability objectives.

The Subcommittee also applauds EPA's commitment to make all of the Agency's software available via open-source and non-proprietary formats.

Opportunities for Improvement

The Subcommittee notes that, in project descriptions, there is more discussion of tools than of data collection and hypothesis-driven research. Given both the interconnectedness between tools and research, and the challenge of reflecting all aspects of many person-years of work in a single set of documents, the Subcommittee recognizes that this may well be an artifact of the documentation process, rather than an actual imbalance in work being done. It was also noted that this could be due to the stage of the research, where, for example, a "research-heavy" past was now informing a "tool-heavy" present, with the balance between the two being reflected across longer periods of time than a single review cycle.

Challenges

The Subcommittee recognizes a number of challenges faced in the development of tools in particular. For example:

- How can tools be made more useful for policy decisions?
- What kind of obligation does EPA have to keep tools current and interactive with changing needs? (It was said that in the past this was seen as the private sector's role, but are there organizations that will do so with sustainability tools? If not, whose job is it?)
- How can SHC balance two different types of tools: those that respond directly to requests from communities or partners, and those that are developed based on EPA research and then afterwards are disseminated to communities? The Subcommittee recognized that both these development trajectories are potentially viable, but that they serve very different roles in connecting EPA with other organizations (see also Charge Question 3).
- How can SHC assure that tools are accessible to communities with very limited expertise and capacity to use them? (Is there a minimum scale below which the tools become inapplicable or useless, and should this be acknowledged?)

The Subcommittee also acknowledged the fact that some decision-support tools inevitably produce indices that are used to rank communities, and such rankings may sometimes be controversial in their interpretation. The Subcommittee felt that rankings do have value because they can be used to identify areas of critical need or priority for resource allocation. However, rankings need to be clearly defined and bounded, and they may be most useful as a point of entry for further inquiry and dialogue.

Additionally, it was noted that tools that operate on such complex topics as sustainability inevitably include many different variables, and the setting of default values for those variables is challenging.

Regarding Charge Question 5, the Subcommittee offers the following recommendations.

Recommendations

1. The Subcommittee recommends that the SHC compile a catalogue of tools, particularly those related to ecological and community health, and increase effort to integrate tools with attention to interoperability and ability for tools to inform each other and to answer research questions. The catalogue of tools should include information on each tool such as the topic the tool supports, the geographic scale of the tool, and a projection of the period of time the tool will be supported.
2. The Subcommittee recommends continued improvement and innovative development of decision-support tools, particularly drawing on partner and stakeholder engagement to improve dissemination, utility and adaptive improvements of tools. These interactions among tools should be well documented. For example, the EcoHealth Browser might help to guide relationship testing using indicators available through tools such as EnviroAtlas, the EQI or HWBI.
3. While tools for communities and the public are of major importance, tools are also necessary to infuse technology and innovation into regulatory enforcement actions, including air and water quality safeguards, and resource protection responsibilities of the EPA. Therefore, the Subcommittee also recommends development of innovative tools to assist the EPA in its enforcement actions for the purposes of creating sustainable and healthy communities.
4. The Subcommittee recommends raising the profile of basic and applied research in StRAP objectives. The objectives give greater emphasis to decision-support tools, with little mention of how they relate to research. The objectives could be revised to articulate how applied research supports the development of decision-support tools and provides the underlying data and parameters that drive the tools. Tools may also be useful in data collection to help inform research questions, for example through community evaluation of environmental scenarios.
5. The Subcommittee recommends that the StRAP include a description of the scales at which "community" is defined. Human communities exist in a variety of forms that are linked and overlapping, and the SHC portfolio includes tools and products that target different kinds of communities. Enabling the SHC portfolio to reach communities at various scales could broaden its range of impact, and understanding the ways in which communities may overlap or be nested could help foster the spread of SHC-inspired tools.

Specific to SHC: Charge Question 6. SHC has a mission to address the short-term needs of EPA's Office of Solid Waste and Emergency Response (OSWER) for research on contaminated sites, oil and fuel spills, and sustainable materials management. How can SHC best leverage these short-term research goals with longer-term community sustainability and environmental justice goals?

General Observations

OSWER requires timely technical assistance from SHC scientists to develop solutions that reduce environmental damage from contaminated sites and oil and fuel spills to acceptable levels. By all accounts, SHC has been very responsive to the needs of regional offices through the TSCs and has developed excellent products and tools for risk determination and remediation. The development of solutions for

cleaning up or containing environmental toxins is essential to meeting community needs and protecting human health.

However, this research falls short of providing the understanding that is needed to guide communities in achieving longer-term sustainability and environmental justice goals. Consideration of these broader questions requires a scientific understanding and assessment of the impacts of site-specific actions on economic, social and environmental outcomes at neighborhood (i.e., area) and community scales, the social benefits and costs of these site-specific investments over longer periods of time, how these benefits and costs are distributed within and across neighborhoods and communities, and how these changes influence the behavior and decision making of individuals, households, businesses and communities.

Particular Strengths

SHC has done an outstanding job of responding to regional offices and providing technical assistance in a timely manner through the TSCs. As noted by a representative from Region 2 at the Subcommittee meeting, there have been over 150 examples of technical support provided by the SHCRP just this year. Notable examples of technical assistance were shared with the Subcommittee, including work on sediment characterization and vapor intrusion. The knowledge generated through the technical assistance work has benefited the development of useful products and tools for risk determination and remediation.

In addition, SHC has been responsive to regional needs by providing opportunities for collaboration between regional staff and ORD staff, e.g., through the Regional Applied Research Effort (RARE) and RESES programs. A regional representative at the Subcommittee meeting noted that SHC is the only program within ORD's portfolio that has dedicated funding to support this collaboration.

Opportunities for Improvement

The broader goals of the SHCRP to provide the knowledge, data, and tools needed to inform and support sustainable communities provides an opportunity to build on the strong environmental science and technical assistance research that SHC does by framing this work within a broader sustainability science context. Sustainability science is an emerging field that integrates across the natural and social sciences, engineering, and public health to address the problems of human impacts and dependence on ecological systems. The emphasis of this field is on coupling biophysical and social sciences to generate new scientific knowledge and apply it to developing practical solutions that achieve more sustainable and resilient communities. Sustainability science provides a useful framework for linking community responses to short-term events, such as oil or fuel spills, and management of longer-term pollution problems, such as toxic waste sites, with the broader social, economic and environmental processes that influence community-wide sustainability and environmental justice outcomes over the longer run.

Challenges

The challenges of developing a comprehensive framework that can bridge short- and long-term research goals, integrate a diversity of environmental science and social science disciplines, and be applied across multiple spatial and temporal scales are many. Developing such a framework requires a concerted effort over a sustained period of time and raises many questions. OSWER is increasingly focused on areas around contaminated sites and premises using toxic materials, so site-specific response and analysis of SHC tools need to be augmented for a different spatial scale. However, sustainability and environmental justice cannot just be site-specific, but need to also extend beyond site-specific foci to integrate neighborhoods, communities and areas into the scope. Expanding the research scope in this way requires additional

research expertise, e.g., in fostering a better understanding of individual behaviors, community decision making, economic impacts, and the feedbacks between human and environmental systems. The Subcommittee firmly supports this more comprehensive research approach and considers this to be essential to meet the SHC mission, but also recognizes the inevitable tension that arises in terms of resources devoted to short term needs versus the longer-term development of a broader research program. A related challenge is the cost of data collection to analyze individual, neighborhood and community level outcomes and the nonstandardization of data at local scales that can make data integration and consistent program evaluation difficult.

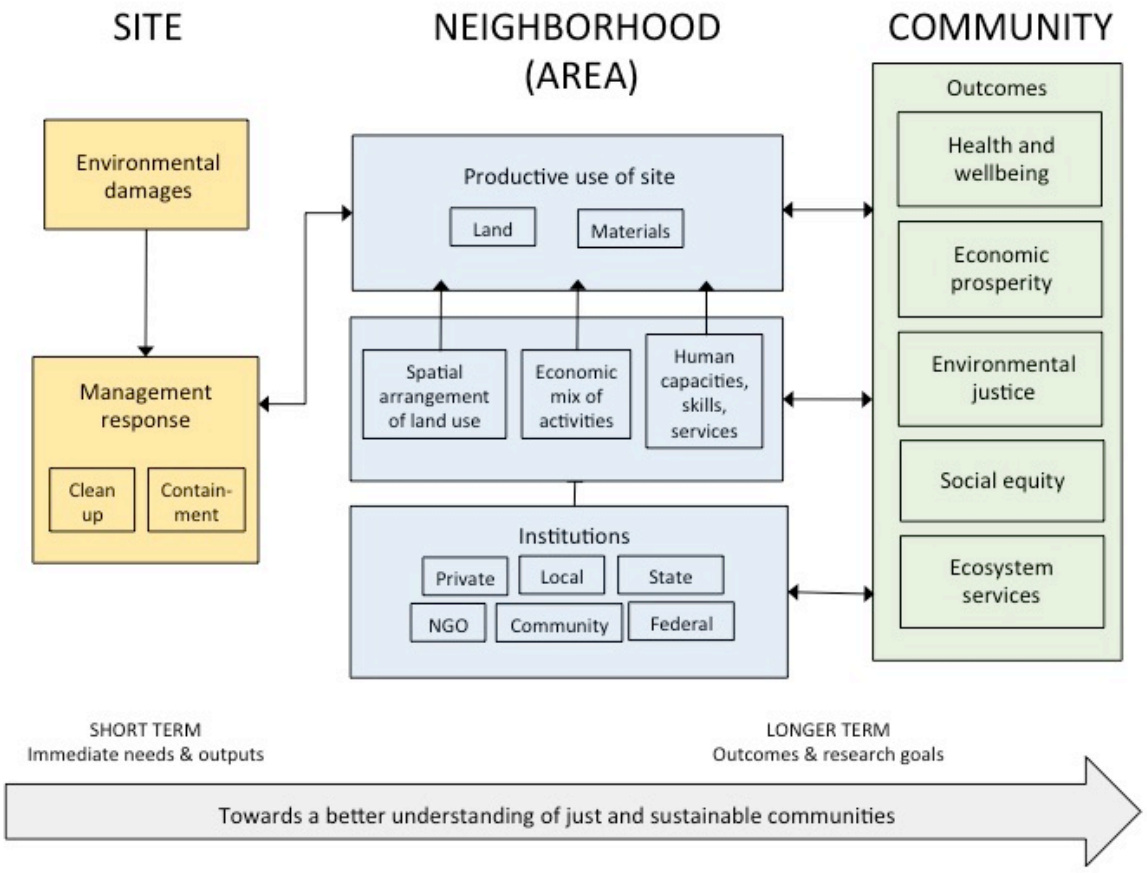
Regarding Charge Question 6, the Subcommittee offers the following recommendations.

Recommendations

1. The Subcommittee recommends expanding focus from site-specific mitigation outputs to area and community level outcomes. The impacts of site-specific cleanup or containment extend beyond a specific location to broader level impacts on neighborhood and community wellbeing. Cleanup of a toxic waste site, for example, may lead to new opportunities for reuse of land and can create opportunities for economic development in neighborhoods, but can also lead to greater inequities if gentrification displaces the poor. Social science research, including integrative studies of the economic, social, and ecological benefits and costs of remediation and redevelopment as well as social mobility and demographic change, is needed to better understand the links between site-specific cleanup and outcomes related to human health, economic prosperity, social equity, ecosystem services, and community well-being.
2. The Subcommittee recommends that the SHCRP collect data and conduct research on local area redevelopment efforts and contaminated sites to better inform decisions on immediate response and longer-term management of those sites. The management responses to toxic and contaminated sites determine the redevelopment opportunities that may be possible in the longer run. Consideration of not only the current, but also future, costs and benefits of various management strategies should be included to identify responses that preserve future redevelopment options and enhance the net benefits of future reuse. Research is also needed to make explicit the benefits and costs of alternative management strategies at neighborhood, community and national scales and how trade-offs vary, and may even conflict, across these scales.
3. The Subcommittee recommends including people-based as well as place-based analytical frames in research and tool development. A holistic approach to assessing the impacts of site-specific actions on area and community level outcomes requires both place-based and people-based data collection and analysis. Individual households and businesses respond to place-specific variables, e.g., households choose residential locations based in large part on neighborhood-level characteristics. Understanding how changes in place-based features influence the actions and wellbeing of people is important for assessing sustainability and environmental justice outcomes.
4. The Subcommittee recommends that the SHCRP adopt a holistic approach to research on the productive uses of land and materials that can be translated into well-being outcomes at neighborhood, community, and national scales. Figure 1 provides a preliminary conceptual framework for linking these shorter and longer-term goals and processes across site, area and community scales. Moving from left to right, optimal site-specific management decisions are influenced by potential redevelopment options for the site, which both depend on and influence the spatial mix of land uses, economic activities, and human skills and services in the area. These activities depend on the institutions and governance networks that influence and constrain them, all of which interact with community-level sustainability and environmental justice outcomes.

5. The Subcommittee recommends that the SHCRP collect data on a broader array of community outcomes to measure wellbeing, including data to quantify indicators of economic prosperity, environmental justice, social equity, and ecosystem services. The factors that influence the longer-term sustainability of a community are multi-dimensional. Sustainable management relies on an understanding of how policies and other governance strategies impact the trade-offs across economic, social and environmental dimensions. Data and modeling to quantify these trade-offs are needed to inform tool development and policy design. Purposeful research designs are needed, including longitudinal studies and quasi-experiments, to improve empirical identification of causal linkages between remediation and outcomes at site, neighborhood and community scales.
6. The Subcommittee recommends that the SHCRP integrate existing research and seek collaboration with partners to build on the accumulated knowledge of sustainability and wellbeing topics. There is a large and growing body of research on sustainability, resilience and community wellbeing on which SHC should build to leverage its own efforts and maximize its impact. SHC should seek to incorporate existing knowledge in developing their research plans, strategies and policy recommendations. In addition, opportunities to collaborate on joint research with internal and external partners may be feasible and should be pursued where possible.

Figure 1: Preliminary conceptual framework for holistic approach to linking site-specific management with broader social, economic and environmental assessment of just and sustainable communities



SUMMARY LIST OF RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

- **Recommendation 1.1**: The Subcommittee encourages greater integration across projects and topics to achieve goals of holism and inclusion. Consistent with the cross-cutting nature of sustainability, topic areas and project areas should not be advanced in isolation. Instead systematic mechanisms to coordinate and integrate should be applied. One of these mechanisms could be expanded use of shared staff appointments across research topics.
- **Recommendation 1.2**: The Subcommittee recommends greater integration across scales in the programs, products and tools produced by SHC. The clients or users of product and tools produced by SHC include individuals, community groups, local agencies, regional planning authorities, regulators and many others. Greater attention could be given to making these products customizable and scalable. Also differences in technical skills and capacity of various user populations can be more fully addressed. Furthermore, the Subcommittee recommends that SHC also address the need to scale up and down to capture key interactions influencing community experiences and decision making. Communities do not always control their own destinies and they are often quite internally heterogeneous.
- **Recommendation 1.3**: The Subcommittee recommends SHC develop more systematic and transparent processes for selection of communities and projects to include in analysis and data collection. The Subcommittee noted a lack of transparency in how communities were selected to participate in programs or to be included in data gathering efforts. One case in point is the seemingly ad hoc process for selecting the 50 cities to include in the EnviroAtlas. Development of a meta-analytic framework could be valuable in addressing the integration described in the aforementioned recommendations.
- **Recommendation 1.4**: The Subcommittee recommends a greater focus and emphasis on outcomes. While it is important to assess both outputs and outcomes, the Subcommittee sees benefit from greater emphasis on outcomes than is currently in place. Outcomes can be tracked across partners and communities. Efforts such as the Human Wellbeing Index (HWBI) and Environmental Quality Index (EQI) provide useful metrics by which broad-scale outcomes could be measured.
- **Recommendation 1.5**: The Subcommittee recommends a specific effort be undertaken to document gaps in current knowledge, with the goal of enabling other researchers, including current researchers outside EPA as well as future researchers at EPA, to pursue those areas. Identifying such knowledge gaps provides opportunities to SHC research to advance knowledge and provide the most valuable sustainability services and information to communities.
- **Recommendation 1.6**: The Subcommittee recommends developing projects under Topic 4 ("integrated solutions") that are more closely related to the topic area. The Subcommittee was struck by the fact that under this topic were not integrated solutions but instead an array of fairly specific research activities (e.g., "Carbon stable isotopes as indicators of coastal eutrophication", "Nutrient enrichment and precipitation changes do not enhance resiliency of salt marshes to sea level rise in the Northeastern U.S."). While this research appears to be useful in its own right, it seems only indirectly related to the goal of "integrated solutions." Alternately, a more explicit connection between the outputs and the overarching goal should be made.
- **Recommendation 1.7**: The Subcommittee recommends that efforts be taken to more fully develop the conceptualization of sustainable and healthy communities. Given that EPA in general, and SHC

specifically, have the opportunity to be global leaders in sustainability, presenting an integrated framework for how to think about sustainability and health could be transformative both for the U.S. and for communities around the world. Further, the Subcommittee recommends that SHC provide national leadership in defining core principles of wellbeing, community, resiliency, and sustainability. This not only involves synthesizing definitions, but continued work on matching units and levels of analysis to research questions and improving data availability at multiple scales. This requires continuous effort to avoid committing the ecological fallacy of applying observations made at larger scales to the individual scale.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

- **Recommendation 2.1**: The Subcommittee recommends that the SHCRP formalize the engagement process without overly complicating the engagement. EPA's approach appears to be moderately effective. The Subcommittee defines "moderately effective," however, as having discovered no specific shortcomings in the evidence provided. The Subcommittee was unable to determine if the process is as effective as it could be or consistent across the broad range of partners who could inform problem formulation. The Subcommittee believes that SHC can develop a process to provide more transparent and clear evidence of partner (and stakeholder) stakeholder engagement and priorities in problem formulation.
- **Recommendation 2.2**: The Subcommittee recommends that the SHC explicitly define "partners" and their appropriate roles in research planning. It is appropriate to note that certain stakeholders should or should not have a role in research planning, but this should be a conscious and documented decision. Opportunities for casual and informal engagement with stakeholders should be fostered through reallocation of resources for attendance at research conferences and outreach to other Federal researchers—essentially, formally allowing the informal activity to occur.
- **Recommendation 2.3**: The Subcommittee recommends that the SHCRP develop measures and criteria to assess the effectiveness of stakeholder involvement. While each project and individual tasks may have different involvement requirements, there should be a conscious set of criteria against which effectiveness can be assessed during and after project completion. Some SHC grant programs (like the Regional Sustainability and Environmental Research Program, or RESES) require explicit "success measures" that include partner involvement, for example. The same strategy could apply to research planning efforts, and might be applicable to reporting under the Government Performance and Results Act (GPRA) (for example, through a "partner satisfaction" metric).
- **Recommendation 2.4**: The Subcommittee recommends improvements in the documentation of the activities themselves. One opportunity for documentation is to use web-based tools to document and track actual partner input and identify priorities. It would also be useful to document changes in prioritization by SHC as a part of this tracking effort. Current topic "charters" and "abstracts" describe this information, but there is inconsistency in reporting across projects leading to a failure to account for informal input provided by partners, and it is not analyzed for any patterns or gaps. Consistent documentation of partner involvement activities, outputs, priorities as well as changes and feedback will aid in transparent involvement. Documentation of these efforts will also make external assessment of partner involvement possible. Again, though, efforts to document engagement and decision processes should not be implemented in such a way as to preclude the serendipitous projects which leverage existing research that arise from informal connections within EPA, across other Federal agencies, and among external researchers. However those instances should be noted in a way that recognizes the contributions of those opportunities in the final outputs of the SHCRP.

- **Recommendation 2.5**: The Subcommittee recommends linking the partner engagement at the research planning stage to the engagement during the longer-term period of research execution. Include explicit plans for how partners will continue to be engaged with the specific project or tasks within the research plan itself. Partner involvement in research methods, data collection, testing, and dissemination are currently done through many communication conduits, but these occur after projects have begun. Having an earlier and explicit partnership plan in the research content plan that is agreed upon by all partners will mitigate any confusion or missed opportunities later. To the extent possible, specific personnel should be named, along with timelines and roles. Note, however, that not every project or task will require the same level of partnership. The plan should simply note the magnitude of involvement needed.
- **Recommendation 2.6**: For the Subcommittee to more fully understand the implementation of tools and their effectiveness in diverse situations, we recommend future meetings of SHC and the Subcommittee provide opportunities for greater interaction with staff from centers and labs, as well as stakeholders in partnering regions and communities.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

- **Recommendation 3.1**: The Subcommittee recommends that research projects pursued by SHC staff that may not reflect immediate partner needs should continue to be encouraged, but should be evaluated through the presentation of an EPA-mission rationale for the investment and expected timeframe for partner involvement and mapping to partner needs and relevance. Clear articulation of how SHC-driven work can support long-term capabilities of programs and regions could relieve the tension between competing priorities.
- **Recommendation 3.2**: The Subcommittee recommends that formal assessments of partner needs should be documented in such a way that would facilitate clear decision making around prioritization so that those decisions can be communicated transparently. Both formal and informal engagement processes to solicit needs should also be documented so that clear lines can be drawn between the problem formulation stage and the development of a research or tool development project. In presenting the full scope of current and possible research, SHC can negotiate more effectively with partners on priorities given limited resources. Partner-driven research is still a core function and mission of SHC, and should not be jeopardized.
- **Recommendation 3.3**: The Subcommittee recommends that a reasonable amount of SHC resources be reallocated to partner-related engagement activities, starting with efforts to define the landscape of potential engagement (which may include potential philanthropic funders and co-funders of SHC projects) and informal engagement with all stakeholder types. In particular, other Federal researchers could be productive and easily justifiable partners. Resources should be reallocated to insure that there are staff motivators for partner engagement (e.g., requirements in performance reviews). While resources are constrained, provision of these cost-effective strategies could ensure a longer-term partner satisfaction as well as help identify the terrain of research needs efficiently.
- **Recommendation 3.4**: The Subcommittee recommends that SHC coordinate with EPA's Program Evaluation office to conduct an implementation study of SHC's partner engagement approach, and output or outcome evaluations of partner engagement (in addition to other outputs and outcomes of interest as noted by other working groups). SHC should develop a partner usage/utility measure for its outputs as part of its GPRA reporting requirements. Note, again, that stakeholders include members of the scholarly community as much as EPA program and regional offices. Metrics could include, for example, bibliometrics for the former and peer review/satisfaction for the latter.

Specific to SHC: Charge Question 4. SHC has committed to integrating ecological and human health to better address issues of human and community wellbeing. Does the research program contain the elements necessary to integrate these two critical elements of EPA's mission?

- **Recommendation 4.1**: The Subcommittee recommends expanding SHC's conceptualization of relationships between ecological and human health away from linear, unidirectional articulations toward more complex systems thinking and multi-directional relationships, including the mediating role of socio-economic factors. This may involve reconsidering the nesting hierarchy of sustainability elements and integrating more logic models, causal and feedback loops, and system dynamics models, including assessments of the economic implications of ecological and human health relationships. Such models could depict the relationships among program objectives and activities in the SHC portfolio, and the linkages between environmental quality and human wellbeing that are the foundation of the program and the StRAP.
- **Recommendation 4.2**: In the further development of tools, the Subcommittee recommends being highly mindful of tools and data available from external partners, particularly other Federal agencies, so as to avoid duplication of effort. Regarding existing resources across governmental, non-governmental, and scholarly research communities, we highlight a few examples. On wellbeing, the Organisation for Economic Co-operation and Development (OECD) has Guidelines on Measuring Subjective Wellbeing and the Centers for Disease Control and Prevention (CDC) emphasizes living conditions as part of wellbeing (http://www.cdc.gov/hrqol/wellbeing.htm). On health, the CDC has a National Environmental Health Tracking System (http://ephtracking.cdc.gov/showHome.action) and a suite of county-level indicators (http://www.countyhealthrankings.org/) and the American Academy of Pediatrics has information on children's health and environment (https://www.aap.org/en-us/about-the-aap/Committees-Councils-Sections/Council-on-Environmental-Health/Pages/default.aspx). The One Health Initiative offers insights on human and animal health connections http://www.onehealthinitiative.com/index.php. On ecological conditions, various entities including the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and the Consortium of Universities for the Advancement of Hydrologic Science, have tools for interoperability with other systems and databases. The SHC's web-based services and tools such as EnviroAtlas are exceptional and will be only more impactful if they connect well with other data sources and systems.
- **Recommendation 4.3**: The Subcommittee recommends prioritizing efforts in and on vulnerable communities and with vulnerable populations that may have increased likelihood of exposure as well as increased susceptibility to adverse effects of stress and environmental agents (e.g., children and environmental justice communities). At the same time, attention to emergent trends across communities may identify nascent vulnerabilities in communities initially deemed to be more resilient.
- **Recommendation 4.4**: The Subcommittee recommends that the SHCRP expand the time horizon for investigating the interactions of ecological and human health and community wellbeing. While we recognize the mandate for relatively short planning windows of 5 years or less, we recommend attention be given to longer-term strategies (e.g., 20 years or more) to allow for focus on emerging challenges and global and national scale issues and drivers such as climate change, immigration, shrinking cities, economic change, geopolitics, changing demographics, increasing income inequality and persistent poverty. The Subcommittee advocates for attention to maintaining relevance and being proactive, rather than reactionary, to ensure robust consideration of connections between ecological and human health.

- **Recommendation 4.5**: While we recognize budgetary constraints, the Subcommittee recommends adding staff in the areas of expertise needed to address this new paradigm, particularly with regard to the social and economic sciences, and with those who understand complex socio-ecological and psycho-physiological systems. It may also be increasingly necessary to tap into external expertise through more extensive partnering. Either way, focusing on workforce development to allow for ongoing attention to the critical domains of the SHCRP is deserving of resources.

Specific to SHC: Charge Question 5. SHC's portfolio includes both hypothesis-driven research and the development of decision-support tools to aid Agency, state, and community stakeholders. Is the balance of research and tool development appropriate for this program?

- **Recommendation 5.1**: The Subcommittee recommends that the SHC compile a catalogue of tools, particularly those related to ecological and community health, and increase effort to integrate tools with attention to interoperability and ability for tools to inform each other and to answer research questions. The catalogue of tools should include information on each tool such as the topic the tool supports, the geographic scale of the tool, and a projection of the period of time the tool will be supported.
- **Recommendation 5.2**: The Subcommittee recommends continued improvement and innovative development of decision-support tools, particularly drawing on partner and stakeholder engagement to improve dissemination, utility and adaptive improvements of tools. These interactions among tools should be well documented. For example, the EcoHealth Browser might help to guide relationship testing using indicators available through tools such as EnviroAtlas, the EQI or HWBI.
- **Recommendation 5.3**: While tools for communities and the public are of major importance, tools are also necessary to infuse technology and innovation into regulatory enforcement actions, including air and water quality safeguards, and resource protection responsibilities of the EPA. Therefore, the Subcommittee also recommends development of innovative tools to assist the EPA in its enforcement actions for the purposes of creating sustainable and healthy communities.
- **Recommendation 5.4**: The Subcommittee recommends raising the profile of basic and applied research in StRAP objectives. The objectives give greater emphasis to decision-support tools, with little mention of how they relate to research. The objectives could be revised to articulate how applied research supports the development of decision-support tools and provides the underlying data and parameters that drive the tools. Tools may also be useful in data collection to help inform research questions, for example through community evaluation of environmental scenarios.
- **Recommendation 5.5**: The Subcommittee recommends that the StRAP include a description of the scales at which "community" is defined. Human communities exist in a variety of forms that are linked and overlapping, and the SHC portfolio includes tools and products that target different kinds of communities. Enabling the SHC portfolio to reach communities at various scales could broaden its range of impact, and understanding the ways in which communities may overlap or be nested could help foster the spread of SHC-inspired tools.

Specific to SHC: Charge Question 6. SHC has a mission to address the short-term needs of EPA's Office of Solid Waste and Emergency Response (OSWER) for research on contaminated sites, oil and fuel spills, and sustainable materials management. How can SHC best leverage these short-term research goals with longer-term community sustainability and environmental justice goals?

- **Recommendation 6.1**: The Subcommittee recommends expanding focus from site-specific mitigation outputs to area and community level outcomes. The impacts of site-specific cleanup or containment extend beyond a specific location to broader level impacts on neighborhood and community wellbeing. Cleanup of a toxic waste site, for example, may lead to new opportunities for reuse of land and can create opportunities for economic development in neighborhoods, but can also lead to greater inequities if gentrification displaces the poor. Social science research, including integrative studies of the economic, social, and ecological benefits and costs of remediation and redevelopment as well as social mobility and demographic change, is needed to better understand the links between site-specific cleanup and outcomes related to human health, economic prosperity, social equity, ecosystem services, and community well-being.
- **Recommendation 6.2**: The Subcommittee recommends that the SHCRP collect data and conduct research on local area redevelopment efforts and contaminated sites to better inform decisions on immediate response and longer-term management of those sites. The management responses to toxic and contaminated sites determine the redevelopment opportunities that may be possible in the longer run. Consideration of not only the current, but also future, costs and benefits of various management strategies should be included to identify responses that preserve future redevelopment options and enhance the net benefits of future reuse. Research is also needed to make explicit the benefits and costs of alternative management strategies at neighborhood, community and national scales and how trade-offs vary, and may even conflict, across these scales.
- **Recommendation 6.3**: The Subcommittee recommends including people-based as well as place-based analytical frames in research and tool development. A holistic approach to assessing the impacts of site-specific actions on area and community level outcomes requires both place-based and people-based data collection and analysis. Individual households and businesses respond to place-specific variables, e.g., households choose residential locations based in large part on neighborhood-level characteristics. Understanding how changes in place-based features influence the actions and wellbeing of people is important for assessing sustainability and environmental justice outcomes.
- **Recommendation 6.4**: The Subcommittee recommends that the SHCRP adopt a holistic approach to research on the productive uses of land and materials that can be translated into well-being outcomes at neighborhood, community, and national scales. Figure 1 provides a preliminary conceptual framework for linking these shorter and longer-term goals and processes across site, area and community scales. Moving from left to right, optimal site-specific management decisions are influenced by potential redevelopment options for the site, which both depend on and influence the spatial mix of land uses, economic activities, and human skills and services in the area. These activities depend on the institutions and governance networks that influence and constrain them, all of which interact with community-level sustainability and environmental justice outcomes.
- **Recommendation 6.5**: The Subcommittee recommends that the SHCRP collect data on a broader array of community outcomes to measure wellbeing, including data to quantify indicators of economic prosperity, environmental justice, social equity, and ecosystem services. The factors that influence the longer-term sustainability of a community are multi-dimensional. Sustainable management relies on an understanding of how policies and other governance strategies impact the trade-offs across

economic, social and environmental dimensions. Data and modeling to quantify these trade-offs are needed to inform tool development and policy design. Purposeful research designs are needed, including longitudinal studies and quasi-experiments, to improve empirical identification of causal linkages between remediation and outcomes at site, neighborhood and community scales.

- **Recommendation 6.6**: The Subcommittee recommends that the SHCRP integrate existing research and seek collaboration with partners to build on the accumulated knowledge of sustainability and wellbeing topics. There is a large and growing body of research on sustainability, resilience and community wellbeing on which SHC should build to leverage its own efforts and maximize its impact. SHC should seek to incorporate existing knowledge in developing their research plans, strategies and policy recommendations. In addition, opportunities to collaborate on joint research with internal and external partners may be feasible and should be pursued where possible.

SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

The Subcommittee generally found the vision and objectives in the StRAP to be clearly conveyed and the topics and project areas to be planned and organized appropriately. As a general conclusion, the Subcommittee acknowledges the consistent focus on sustainability across SHCRP activities, and commends the systems orientation of the programs within the SHCRP. The Subcommittee also recognizes the challenges of the integration across environmental science and social science disciplines, and the application across multiple spatial and temporal scales that sustainability science requires.

The Subcommittee recommends the SHCRP continue to develop its conceptualization of sustainable and healthy communities. EPA in general, and the SHCRP specifically, have an opportunity to be global leaders in sustainability, and in defining core principles of wellbeing, community, and resilience. The development and dissemination of an integrated framework for how to think about sustainable and healthy communities could be nationally and globally transformative.

Furthermore, the Subcommittee recommends expanding SHC's conceptualization of relationships between ecological and human health and wellbeing away from unidirectional articulations toward non-linear, multi-directional relationships. This shift in conceptualization requires the integration of systems thinking into the development of projects and tools, and may involve the integration of causal and feedback loops, scenario building, and system dynamics models. Furthermore, the Subcommittee recommends that the SHCRP expand the time horizon for investigating the interactions of ecological and human health and community wellbeing.

The Subcommittee recommends greater integration across projects, topics, and scales in the outputs, products, and tools produced by the SHCRP. Integration is critical for understanding sustainable and healthy communities, particularly given the scope of the SHCRP. Greater attention could be given to considering the needs, skills, and capacity of the range of users of products and tools produced by the SHCRP, and to ensuring that these products and tools are customizable and scalable to capture key interactions influencing community experiences and decision making.

However, this level of integration represents a kind of paradigm shift in focus from traditional, linear models of community and environmental health. To that end, the Subcommittee recommends that the SHCRP continue to build capacity for greater integration that this paradigm shift requires. In particular, the Subcommittee recommends hiring additional staff with expertise in the social and economic sciences, and in complex socio-ecological systems. The SHCRP could also consider expanding the use of shared staff appointments across research topics.

The Subcommittee recommends that the SHCRP formalize the engagement process with partners and stakeholders, and develop measures and criteria to assess the effectiveness of stakeholder involvement. The Subcommittee also recommends that the SHCRP improve the documentation of partner involvement activities, and better integrate partner involvement from the stages of research planning through execution and evaluation. Finally, in order for the Subcommittee to more fully understand the effectiveness of partner engagement and the implementation of decision-support tools in diverse situations, we recommend future meetings of SHC and the Subcommittee provide opportunities for greater interaction with staff from centers and labs, as well as stakeholders in partnering regions and communities.

The Subcommittee recommends further that the SHCRP compile a catalogue of tools that would include information on each tool such as the topic that the tool supports, the geographic scale of the tool, and a projection of the period of time the tool will be supported. It is further recommended that SHC increase its effort to integrate tools with attention to interoperability and ability for tools to inform each other and to answer research questions. The Subcommittee further recommends continued development of innovative decision-support tools by drawing on partner and stakeholder engagement to improve dissemination, utility, evaluation, and adaptive improvements of tools.

Another important recommendation from the Subcommittee is to systematically and comprehensively evaluate and document feedback from partners and other users of SHC tools in order to examine the effectiveness of decision-support tools. Meta-analytical work to assess efficacy of tools across diverse community types, along with qualitative narrative development of experiences, would be highly useful. Community typological work may be useful in informing selection of cases, rather than ad hoc application of tools for communities most able to engage. It appeared to the Subcommittee in the September 2015 meeting that more has been done in terms of evaluation and adaptive development than was apparent in the documentation provided. It may be that engaging a contractor for this systematic evaluation would be useful.

In conclusion, the Subcommittee believes that the activities of the SHCRP are well aligned with the mission of the Program, and that SHC staff members have demonstrated considerable progress toward the objectives of conducting research and delivering products that improve the capability of EPA to carry out its responsibilities.

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

Appendix E: BOSC Safe and Sustainable Water Resources (SSWR) Subcommittee

Kenneth Reckhow, Ph.D. (Chair) *Duke University*	Bruce Aylward, Ph.D. *Ecosystem Economics LLC*	John Lowenthal *Cardno TEC*
Shahid Chaudhry (Vice Chair) *California Energy Commission*	Lawrence Baker, Ph.D. *University of Minnesota*	Joseph Rodricks, Ph.D. *ENVIRON*
Scott Ahlstrom *Lower Colorado River Authority*	Inez Hua, Ph.D. *Purdue University*	Shane Snyder, Ph.D. *University of Arizona*

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Cindy Roberts, Designated Federal Officer

February 7, 2016

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

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LIST OF ACRONYMS

AWWA	American Water Works Association
BOSC	Board of Scientific Counselors
CCL	Contaminant Candidate List
DAA	Deputy Assistant Administrator
DSDM	Dynamic System Development Method
EPA	Environmental Protection Agency
FACA	Federal Advisory Committee Act
NACWA	National Association of Clean Water Agencies
NDMA	N-nitrosodimethylamine (aka dimethylnitrosamine; DMN)
NGO	Non-governmental Organization
NIH	National Institutes of Health
ORD	Office of Research and Development
OW	Office of Water
PIPs	Pathfinder Innovation Projects
RARE	Regional Applied Research Effort
RD&D	Research, Development, and Demonstration
RRPP	Regional Research Partnership Program (aka R2P2)
RRWR	Resource Recovery and Water Reuse
RSL	Regional Science Liaison
SAB	Science Advisory Board
SBIR	Small Business Innovation Research
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan
TDD	Test Driven Development
UCMR	Unregulated Contaminant Monitoring Rule
WEF	Water Environment Federation
WERF	Water Environment Research Foundation

BACKGROUND

The EPA's BOSC Safe and Sustainable Water Resources (SSWR) Subcommittee[8] met in person August 27–28 and by phone on November 13 to develop responses to EPA Office of Research and Development (ORD) charge questions. The Subcommittee's responses and recommendations are provided in this report.

CHARGE QUESTIONS AND CONTEXT

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

The StRAPs are designed to clearly convey the vision and objectives of the research program, and to describe, at a high level, the research topics, and major outputs planned for 2016-2019. Upon receiving recommendations from the Science Advisory Board (SAB) and the BOSC Executive Committee (EC), as well as from EPA partners and others, ORD has further developed the StRAPs, including refining the objectives and topics, and providing more clarity. At an operational level, each research program is aiming to accomplish its objectives through research spanning physical, biological and social sciences and through numerous ORD laboratories, centers, and STAR grantees all across the country. In addition, ORD has heeded the advice of the SAB and BOSC in past years to do more to integrate research across the six programs, across EPA and with other Federal partners. Given these complexities, we recognize there are likely several reasonable approaches for organizing the research to best accomplish the objectives.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

ORD works with EPA partners to design the research programs to meet Agency priorities. The first step in this process is problem formulation which provides the foundation of the research. Although it can be tempting to jump to a list of research priorities, problems that are well defined lead to the most effective research efforts and solutions. The problem formulation stage of research planning lays the groundwork for the StRAPs and is the reference point for any changes in priorities as budgets change and new issues emerge. Problem formulation occurs at many different levels including the articulation of issues in the EPA Strategic plan; meetings with EPA partners including regular staff-to-staff meetings; workshops and conferences where states, regions, policy and science staff describe the problems they face; and discussions among senior managers at EPA. In addition, each National Program Director reaches out to EPA partners in a variety of targeted ways to agree on problem definition.

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[8] The Subcommittee members serve in their individual capacities and their views and recommendations don't reflect the views of their respective organizations in any way or form.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

ORD places a very high value on working closely with EPA partners to design the research programs to meet Agency priorities. During the preparation of the StRAPs, the programs were guided by the EPA Strategic Plan and undertook a variety of activities to actively engage partners, both to understand their priorities and to elicit their input on research directions. These include many regular meetings with EPA policy and regional staff, communities of practice for specific scientific disciplines throughout the Agency, annual two day meetings led by the NPDs, annual senior level meetings with EPA Assistant and Regional Administrators, and formal requests from ORD's Deputy Assistant Administrator (DAA) for science to receive comments from across the Agency twice during the year of StRAP development.

In addition to the up-front work with EPA partners to understand their research needs for the upcoming year(s), ORD also needs to be flexible enough to address top priority, unanticipated needs or environmental crises that emerge at any given time. The research program will describe interactions with EPA partners, present examples of recent responsiveness to unexpected events, and explain how they work with EPA partners to accommodate acute needs while resources are limited.

Specific to SSWR: Charge Question 4. How can SSWR streamline model and tool development within the program and across other national programs and partners to improve utility, interoperability, and accessibility, and what are some ways we can measure metrics of success?

Specific to SSWR: Charge Question 5: What are the unique aspects of resource recovery and water reuse that SSWR is best able to address? What research products are envisioned to maximize impact?

Specific to SSWR: Charge Question 6. How SSWR can better translate its research products and disseminate such knowledge to a broader community of stakeholders?

RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

Based on the revised Strategic Action Plan (StRAP), ORD briefings, and additional materials provided to the Subcommittee, Table 1 that follows presents the four research program objectives outlined in the StRAP and each proposed research project. The Subcommittee has identified the extent to which it understands how each research program satisfies a specific research objective. The key used is as follows:

- "Meets" means the research program is aligned with the research objective and will help accomplish the objective.
- "Supports" means the research program will likely contribute to the research objective.

- Where the table is blank, there is no or limited connection between the research program and the research objectives. A blank space does not indicate a failure or a problem.

The determination is deliverable oriented based on the information provided. That means if the research plan says it will help translate a research finding into a real-world solution but does not include a deliverable that will actually articulate that objective, then it does not meet the objective. If the deliverable clearly demonstrates alignment with the objective, then it is given a "meets."

Please note that this table simply shows if there are gaps. However, if a research objective does not have a "meets" in its column, then one must wonder if the projects and objectives are properly aligned. Similarly, if a project does not "meet" any objective and only "supports" one or two objectives, it might be a good idea to revisit that project to see if it can be redefined and better aligned.

Overall, it appears reasonable to expect good progress toward the research objectives in the 2016–2019 time frame. However, there does not appear to be a research program that meets the second research objective. Further, there are some research programs that contribute to only one or two research objectives. These weak connections between projects and objectives should be reconsidered. It may be an opportunity to redirect the research or reallocate resources to strengthen other programs.

ORD is to be commended for its efforts to build partnerships with the regions and address needs the regions are experiencing. However, for this effort to be successful, more needs to be done. For example, each region has a point of contact, a Regional Science Liaison (RSL), with whom ORD works. This person's visibility in the region varies significantly from region to region. In addition, their input appears to be ad hoc and based on the specific interest of the person and is not driven by management or job expectations. For example, when one RSL was asked for ideas on how to improve the process, the recommendation was for the request for feedback to be done at a higher level so the process receives more support from management, thus providing responders more time to provide project feedback. The bottom line is that a contact person in the region has been identified, but whether that person has the time to engage given their other job expectations is unclear. We suggest that this engagement of the RSL's in developing ORD research strategies be strengthened over time.

The researchers understand details of the research programs better than the Subcommittee members. The intent of this feedback is to give researchers an outsider's perspective so they can review their plans, if needed, to accomplish the desired objectives.

Ideally it would be great to hear the researchers at the next subcommittee meeting explaining what will be included in their deliverables that meets a research objective.

Table 1

Research Projects	Research Program Objectives			
	Address Current and Long-Term Water Resource Challenges for Complex Chemical and Microbial Pollutants	Transform the Concept of 'Waste' to 'Resource'	Quantify Benefits of Water Quality	Translate Research into Real-World Solutions
Watershed Sustainability				
Project 1: Assess, Map and Predict the Integrity, Resilience and Recovery Potential of the Nation's Water Resources	Supports[9]	Supports		Supports
Project 2: Science to Support New or Revised Water-Quality Criteria to Protect Human Health and Aquatic Life	Supports	Supports		Supports
Project 3: Protecting Water while Developing Energy and Mineral Resources	Meets	Supports		Supports
Project 4: National Water-Quality Benefits	Supports		Meets	
Nutrients				
Project 1: Reducing Impacts of Harmful Algal Blooms	Meets		Supports	Supports
Project 2: Science to Inform the Development of Nutrient Thresholds and Targeting Actions	Supports			Supports
Project 3: Science to Improve Nutrient Management Practices, Metrics of Benefits, Accountability and Communication	Supports	Supports		Supports
Green Infrastructure				
Project 1: Green Infrastructure Models and Tools	Supports	Supports		Supports
Project 2: Support Increased Adoption of Green Infrastructure into Community Stormwater Management Plans and Watershed Sustainability Goals: Information and Guidance through Community Partnerships				Meets
Water Systems				
Project 1: Current Systems and Regulatory Support	Supports	Supports		
Project 2: Next Steps—Technology Advances		Supports		
Project 3: Transformative Approaches and Technologies for Water Systems	Supports	Supports		Supports

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[9] The research program will use tools and techniques that predict impacts with limited understanding of local variables and options to effect improvements. As such, it supports the research objective but does not meet it unless more local information is incorporated into the predictive tools.

Based on information shared during the meeting with the BOSC SSWR Subcommittee, it appears some regional input was limited to review and comment on documents after the fact rather than as part of the development process. We understand there are limited travel dollars in the regions, but one face-to-face meeting per cycle does not seem unreasonable as an approach to more fully engage all the regions and to further build a partnership that will improve the value of research performed.

Recommendations

1. EPA should support the assessment of prediction uncertainty in the application of water quality simulation models.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

It is the opinion of the Subcommittee that there has been effective communication, especially with internal partners, in conducting workshops covering the four focus areas, developing and prioritizing research projects, soliciting review and comments on charters and effectively responding to comments. Communication with outside partners is taking place with organizations such as Global Water Resources Coalition and Water Reuse Association and comments were received from the American Water Works Association (AWWA).

- Tracking this effort, potentially in a spreadsheet and providing to the Subcommittee would help members understanding the communication channels, mechanisms, strategies and their potential effectiveness.
- Subcommittee recommends further partnering with other national and regional organizations such as Water Environment Research Foundation, Association of California Water Agencies, California Association of Sanitation Agencies, etc.

From the provided material, the Subcommittee was not able to identify how progress on the research efforts is measured and identification of metrics, either quantitative or qualitative would be useful.

- The Subcommittee recommends continuing to coordinate research efforts with Science to Achieve Results (STAR) grants to avoid duplication and potentially identify opportunities to build upon or support BOSC research efforts.
- Lastly, the Subcommittee acknowledges some post-secondary outreach with existing college competitions relating to these research charters and recommends that depending on availability of resources, outreaching efforts should be extended to primary, secondary and post-secondary education institutions.

Recommendations

1. Further partnering with additional national and regional organizations such as Water Environment Research Foundation, Association of California Water Agencies, California Association of Sanitation Agencies, etc.
2. Continue to coordinate research efforts with STAR grants to avoid duplication and potentially identify opportunities to build upon or support BOSC research efforts.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

EPA has done an admirable job of aggregating and developing a 2016–2019 StRAP that addresses some of the greatest challenges facing the nation's water resources. EPA ORD provided several examples to demonstrate how the StRAP and the research program in general have engaged with regional offices of EPA. In fact, the program is broad that it raises some concerns regarding the feasibility of addressing so many diverse aspects of sustainability within the confines of human and fiscal resources. The StRAP draft report mentions programs to solicit external collaborators through STAR and Small Business Innovation Research (SBIR) programs and foster internal collaborations through Regional Applied Research Effort (RARE) and Pathfinder Innovation Projects (PIPs).

EPA sought external and internal input for its research program agenda. ORD consulted with the Office of Water (OW), Office of Policy, ORD labs and centers, and regional offices. In 2012–2015, ORD participated in two meetings with the SAB and BOSC and numerous meetings with various EPA offices. These efforts led to development of a prioritized list of research needs for the regional offices and for OW. Appendix B of the StRAP provides a list of partners and stakeholders from federal, state/local agencies, non-governmental organizations (NGOs), and international organizations; however, the depth and breadth of input from these organizations is not specified. It is surprising that AWWA is not listed, as this organization's membership includes water utilities that supply more than 80% of the nation's drinking water. It is also difficult to gauge how EPA ensured they were assessing the priority needs of the nation's water suppliers. These agencies are the first line of defense for safe and sustainable water and must meet or exceed the standards established by the EPA. Therefore, the EPA is highly recommended to find more tangible mechanisms to engage water providers including through formal communications with the AWWA. This apparent weakness with respect to integration of outside partners is reflected by a general weakness of meeting Objective 4 (translation of research).

What is a bit surprising in the draft StRAP document is the lack of discussion on large-scale EPA and other federal agency programs that seem directly related to EPA priority topics. For instance, the StRAP does not mention the EPA's Endocrine Disruptor Screening Program, which seems to be important in discussions of water quality protection from emerging contaminants. The absence of any mention of EPA's efforts on *in silico* and high-throughput *in vitro* toxicology is surprising, especially in light of the ever growing number of discovered emerging contaminants including disinfection byproducts. The StRAP mentioned bioassays, but there was no inclusion of consultation with the National Institutes of Health (NIH) nor mention of EPA's own ToxCast program. While consultations may have occurred, it is important for ORD to explicitly discuss how they interact with these large efforts within EPA and beyond. On the issue of nonpoint source pollution, there could be much closer linkage between the 319 grants program and ORD. At present, research-level analysis of 319 projects is mixed (generally weak) but could be strengthened by collaboration between ORD and 319 staff, either by ORD conducting hands-on research, or by ORD providing coordination and planning support to assist 319 staff in improving the research

elements of their project. The current practices of simply looking for, and broadcasting, "success stories," rather than supporting rigorous analysis of project performance and seeking better science through these projects is unfortunate; developing this synergy could be very fruitful and highly valued by cities which badly need improved science for storm water management.

The research projects provided by EPA cover a gamut of topics that are of national need; however, the prioritization of issues such as decaying infrastructure, disinfection byproducts, and potable water reuse are not entirely transparent. Of particular concern is the lack of transparency as to how the ORD research strategy could potentially address data gaps identified through the Contaminant Candidate List (CCL) process. For instance, in the last round of the Unregulated Contaminant Monitoring Rule (UCMR), N-nitrosodimethylamine (NDMA) was found to be the most widely detected contaminant (EPA 2012) with a mean concentration more than 10-times the calculated 1:1,000,000 cancer risk (EPA 2014). While the EPA's research plans may include addressing the technologies and source water protection activities to protect against substances like NDMA, these are not transparent within the StRAP draft documents provided. The development of analytical methods for emerging contaminants which is explicit in the StRAP draft seems like a topic of lesser priority as compared to addressing those contaminants already known to existing in U.S. drinking waters at elevated concentrations. Other topics of national priority are salt management and distribution system corrosion, both of which seem only tangentially related to ORD's research priorities. The absence of topics that seem paramount to U.S. water utilities is concerning and draws into question whether the EPA has adequately interfaced with the nation's water utilities. Topics such as green infrastructure and resource recovery are clearly on the horizon as major topics for study; however, it is challenging to imagine fully the rationale for the prioritization scheme used by ORD.

Specific to SSWR: Charge Question 4. How can SSWR streamline model and tool development within the program and across other national programs and partners to improve utility, interoperability, and accessibility, and what are some ways we can measure metrics of success?

EPA ORD and OW supported development of a comprehensive set of surface water simulation models that, together with models developed with support from other federal agencies (e.g., U.S. Geological Survey and U.S. Army Corps of Engineers), have been used to assist water management and planning for decades. These models have been constructed and improved over the years, often with a focus on addressing specific water quality and quantity issues and stressing "correct" process description. Little attention has been directed toward assessing model prediction uncertainty for model users.

Yet if we consider what the vast literature on decision analysis recommends for how scientific knowledge should be presented to best inform decision making, knowledge uncertainty is critically important. Using decision analysis as the primary decision support approach for EPA, it is quite clear that EPA needs to provide models that permit uncertainty analysis and provide practical guidance to model users on how to make best use of model prediction error estimates.

Unfortunately, most of the EPA water quality/quantity models are over-parameterized, and as a result parameter errors (variances) and covariance cannot easily be estimated. This means that application of conventional error propagation methods, such as Monte Carlo simulation, may not be meaningful since the essential input of a parameter covariance matrix cannot be determined. Approaches such as regionalized sensitivity analysis, generalized likelihood uncertainty estimation, and Markov chain Monte Carlo analysis should be considered by EPA to partially address this problem. Another option for EPA to consider is to support development of a set of simpler models that facilitate comprehensive error

propagation; with these models, the complex process-oriented model could provide detailed predictions and the simpler model could provide an estimate of prediction uncertainty. Research priorities to improve the utility of water models in ORD SSWR could be determined using sensitivity analysis to identify model processes/parameters for which research might be expected to yield significant reduction in model prediction error, recognizing that any sensitivity analysis is conditional on the model structure and parameters.

Interoperability of models and tools is an important issue for SSWR given EPA's recognition that water management can have major socioeconomic impacts that must be considered in addition to water quality/quantity. One approach to interoperability of models and tools is to build a comprehensive model that includes and links water and socioeconomic simulations. Unfortunately, the resultant comprehensive model can provide major challenges for a comprehensive uncertainty analysis. A suitable alternative is for SSWR to stress, in model development guidance, that models be built with consideration of seamless integration with other models likely to be linked.

Models that are developed under the SSWR research program to inform decision making must be accessible to potential model users. In the past, EPA has supported short courses for model users; this should continue. If the SSWR research program chooses to stress uncertainty analysis in future model development, then accessibility must include guidance on the use of uncertainty analysis and the interpretation of prediction error for informed decision making.

Measures of success can be identified at several levels, such as:

- Number of downloads of each model
- Number of cited applications of each model
- Number of attendees at modeling short courses
- Number of approved Total Maximum Daily Loads based on EPA-supported models

If EPA decides that uncertainty analysis should be a component of water models development in the future, then another measure of success is the number of new models developed with this feature. For existing water models, a corresponding measure of success could be successful retrofit of an uncertainty analysis in these models.

Numerous improvements and new methods related to software development have occurred over the past few years. A web search identified over 14 software development methods, including Agile, DSDM (Dynamic System Development Method), object oriented processes, Scrum, and TDD (Test Driven Development). Rapid development and deployment of new or updated software has become a major focus of highly specialized and qualified staff. We are unaware of EPA's specific software development capabilities but encourage EPA to take advantage of the rapidly developing industry, their methods, and the related collaboration tools.

Going beyond uncertainty analysis, there is a need to reexamine the basic algorithms embedded in many water quality models to determine whether they represent biogeochemical processes well, and where they do not, to improve them. As an example, the problem of understanding "phosphorus legacies" is hampered by the fact that we really don't understand how phosphorus moves through a watershed, accumulates, and leaches to surface waters – and hence can't model long term responses properly. This hampers our efforts to reduce phosphorus loads, especially in agricultural watersheds.

The Subcommittee also note that while complex models are often needed for regional simulation, especially for large water bodies, much simpler models are often needed for local predictions. These types

of models—which might be spreadsheet models—could be invaluable to local watershed managers. ORD might consider developing these types of models for all of their projects. In fact, one of the most widely used water quality models in the world is the simple "Vollenweider-type" model (and its derivatives), a one-equation model that predicts phosphorus concentrations in lakes, and from this, water clarity. The example provided by Alice Gilliland at the BOSC SSWR workshop about a storm water runoff calculator, developed by EPA and geared toward local officials and homeowners, was an excellent example of the type of simple model that could be extremely useful.

Specific to SSWR: Charge Question 5. What are the unique aspects of resource recovery and water reuse that SSWR is best able to address? What research products are envisioned to maximize impact?

Over time, the terminology has evolved from Sewage → Wastewater → Resource Water[10] which is still at an early stage; however, it is a more acceptable terminology to reflect economic benefits for both public and private sector investors. In this context, SSWR can help make a fundamental shift from existing business model of "treating wastewater for disposal" to "treating resource water for reuse and resource recovery." Today's technology can provide solutions to treat the resource water to the various levels of quality (e.g., for irrigation, potable water), but not always at a realistic cost. The need, however, is to educate consumers and public about the true value of resource water (cost effectiveness, cost recovery, life cycle analysis, and tools to assess benefits); this should be done on priority basis where water availability is an issue.

EPA's "2012 Water Reuse Guidelines[11]" report provides a global perspective of issues and challenges being faced in water reuse and resource recovery which by-n-large can be categorized as economic, institutional, public perception, and organizational barriers. Similarly, "Water Resources Utility of the Future...Blueprint for Action[12]" provides an extensive list of interventions to make such facilities cost effective, energy efficient, environmentally friend, and sustainable.

Generally, it has been observed that most of the large facilities have resources and are already practicing in recovering energy, water, and biosolids at their facilities; hence, EPA should focus on small to medium size facilities to reduce dependence on grid electricity through energy efficiency and maximizing digester-gas production (and utilization) by co-digesting sludge and organic waste from local communities and businesses. This will result in improving public perception, reducing greenhouse gas emissions, and offsetting plant's operations and maintenance expenses to bring financial benefits. The Research, Development, and Demonstration (RD&D) focus in such instances should be on developing tools to reduce risks of unplanned reuse considering infrastructure needs, local capacities, matching treatment approach with reuse application, and overall costs and benefits. Resource recovery facilities should be considered as independent business enterprises recovering and marketing water, energy, nutrients (e.g., phosphorous from resource water and humic acids from drinking water production), and biosolids along with other products of interest. As to the specific roles of SSWR, there are several. First, with respect to

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[10] Sometimes reclaimed/reused water is misunderstood as resource water. Resource water (wastewater or sewage in old terminology) is a complex mixture of water and inorganic and organic solids in the form of inert material, ammonium, nitrate, phosphorus, etc. Reclaimed water, on the other hand, is just one of the components of the resource water; other extractables may include biogas, biosolids, nutrients, and heavy metals.

[11] "2012 Water Reuse Guidelines", EPA/600/R-12/618 | September 2012 (http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf)

[12] Water Resources Utility of the Future...Blueprint for Action" by National Association of Clean Water Agencies (NACWA), the Water Environment Research Foundation (WERF), and the Water Environment Federation (WEF)

research on specific technologies, SSWR must consider whether a specific technology is best developed within EPA or within the private sector. In general, government research is best focused on emerging technologies that can require considerable study before moving into private research and development.

SSWR plays a vital role in assessing cumulative human health and environmental impacts of contaminants in treated resource water, biosolids, etc. This type of research is too complicated for states to undertake but is important if we are to avoid unexpected consequences from resource recovery. Similarly, accumulation of contaminants and compounds effects of the contaminants on industrial products, irrigation system storage, and distribution network and piping should be investigated.

SSWR should consider recommending that states to develop risk-based guidelines or regulations for potable and non-potable reuse; preferably EPA should come up with federal suggested standards or reuse regulations to provide a minimum level of protection across the board to increase public confidence. Further, SSWR can also help develop a uniform (risk-based) water reuse guideline framework at national and regional levels.

Sometimes existing legislations become a hurdle. For example, reusing raw materials in the drinking water process is something that is not supported by policies or regulations. Similarly, another critical knowledge gap is absence of a comprehensive technical and economic review of existing and emerging technologies which can produce carbon-based and/or non-nutrient products from wastewater or wastewater byproducts.

Summarizing the above brief discussion, SSWR Subcommittee recommends the following.

Recommendations

1. Replace term “wastewater” with “Resource Water”
2. Work / continue working on researching, developing, and demonstrating scalable Resource Recovery and Water Reuse (RRWR) business models.
3. Determine specific needs for clean water standards – fit-for-purpose – to exploit non-conventional water supply sources.
4. Collaborate with industry to identify and define high-risk, high-reward RD&D needs, and share the outcomes with various stake holders.
5. Assess and mitigate risks from RRWR for public health and the environment.
6. Support public and private entities with innovative approaches for the safe reuse of resource water.
7. Support the professional development of RRWR facilities’ administrators, designers, contractors, operators, and maintenance personnel by offering workshops, seminars and other opportunities to advance their knowledge of all aspects of water reuse and resource recovery operations.

Specific to SSWR: Charge Question 6. How SSWR can better translate its research products and disseminate such knowledge to a broader community of stakeholders?

The Subcommittee acknowledges that SSWR has engaged in a number of workshops, webinars, and other scientific meetings, and has also issued newsletters relating to its scientific programs, all toward the important goals of improving its research planning and ensuring that its programs have a practical effect

on its many stakeholder communities. Further, it's RARE[13] and RRPP[14] programs have been particularly effective in reaching out and providing training opportunities to its regional offices. The SSWR, however, understands that different audiences require different mechanisms for translating scientific information to different audiences and thus seeks advice on ensuring the effectiveness of its translation efforts to other audiences.

The various efforts undertaken by SSWR to convey to stakeholders the results and utility of its research programs can be categorized as efforts in communication about risk and risk management. This categorization is useful because there exists substantial guidance, some of it from EPA itself, on methods of communication on these topics. Efforts of the EPA[15] and other agencies on this topic have been heavily influenced by a seminal 1989 study from the National Research Council called Improving Risk Communication[16]. We believe SSWR can benefit substantially by consulting this report and the others listed below. They offer excellent guidance in the general area of communicating technically complex information, and doing so within specific decision contexts. Specifically, the committee draws from this body of literature and from its own experience to recommend the following general principles and practices.

1. **Risk Communication should always be seen as a dialogue**. Once a decision is made to convey information and possible recommendations regarding its use to potential stakeholders, representatives of those stakeholders should be contacted to gain a solid understanding of their interest in the topic and their expectations. That understanding should play a key role in the communication planning process.
2. **Goal setting and planning**. SSWR should establish specific goals for each communication effort, taking into account the interests and expectations of stakeholders. The purpose and utility of the message, and any constraints on its content, should be explicitly stated and agreed upon within SSWR.
3. **The message**. Preparation of the message should be a joint undertaking of those having the necessary technical understanding and those having experience in communication strategies and techniques. The goal is to develop a message that will be completely clear to the intended stakeholders, according to their understanding of the work and technical skills, without sacrificing scientific quality[17].
4. **The delivery**. It should be ensured that those charged with delivering the message and with engaging with stakeholders in other ways should have appropriate credentials and the best possible communications skills. Whether the delivery is clear and whether those charged with the delivery and stakeholder engagement have adequate understanding should be tested in advance.
5. **The feedback**. It is always important to elicit feedback from stakeholders that addresses questions about the utility, clarity, and effectiveness of the communication effort. A systematic collection and review of such feedback should be used to inform future communication efforts.
6. **Communication under crisis conditions**. SSWR should ensure there is a trained team of communicators ready and able to deliver messages crafted with the extreme care necessary to deal with crisis situations. Guidance and training from professionals in this area should be sought.

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[13] Regional Applied Research Effort (RARE) - a partnership program that unites Agency researchers with colleagues from across the country.

[14] The Regional Research Partnership Program (RRPP aka R2P2) - a program that provides short-term (up to six months) training opportunities for regional technical staff at ORD laboratories or centers and work with ORD scientists on top regional priorities.

[15] Risk Communication in Action: The Risk Communication Workbook. U.S. Environmental Protection Agency, 2007.

[16] Improving Risk Communication. The National Research Council, 1989.

[17] Environmental Decision Under Uncertainty. The Institute of Medicine, 2013.

7. **Training**. When messages are technically complex and potentially controversial, experts in risk communication should be consulted for guidance on all steps of the process. Formal training for selected staff members might also be considered to ensure best practices in communication are adhered to.

The committee recommends that SSWR:

1. Develop a list of all the audiences that should be targets for its communication. Those target audiences should be categorized with specificity such as:
   a. Managers and senior staff or others in regional offices;
   b. Various external groups, such as utilities, state health departments, research organizations including academics, environmental groups, manufacturers and engineering firms;
   c. Affected communities; and
   d. Media.

Briefing credible journalists is often an effective way to spread the word. The Agency should consider wider use of social media as adjuncts to its communication efforts.

1. The committee also strongly recommends that target audiences and communication strategies be identified in the research planning stage. In this way it will become possible to identify resource needs and budgets at an early stage. As SSWR has itself stated, research products have little utility unless their user communities become totally familiar with their value and limitations.

Recommendations

1. Develop a list of all the audiences that should be targets for its communication and categorize these according to their interest and technical abilities. Target audiences and communication strategies should be identified in the research planning stage.
2. Depending on availability of resources, outreaching efforts should be extended to primary, secondary, and post-secondary education institutions.

SUMMARY LIST OF RECOMMENDATIONS

Charge Question 1. Given the research objectives articulated in the StRAP, are the topics and project areas planned and organized appropriately to make good progress on these objectives in the 2016-2019 time frame?

- **Recommendation 1.1**: EPA should support the assessment of prediction uncertainty in the application of water quality simulation models.

Charge Question 2. How effective are the approaches for involving the EPA partners in the problem formulation stage of research planning?

- **Recommendation 2.1**: Further partnering with additional national and regional organizations such as Water Environment Research Foundation, Association of California Water Agencies, California Association of Sanitation Agencies, etc.

- **Recommendation 2.2**: Continue to coordinate research efforts with STAR grants to avoid duplication and potentially identify opportunities to build upon or support BOSC research efforts.

Charge Question 3. How well does the Program respond to the needs of EPA partners (program office and regional)?

- **None**

Specific to SSWR: Charge Question 4. How can SSWR streamline model and tool development within the program and across other national programs and partners to improve utility, interoperability, and accessibility, and what are some ways we can measure metrics of success?

- **None**

Specific to SSWR: Charge Question 5. What are the unique aspects of resource recovery and water reuse that SSWR is best able to address? What research products are envisioned to maximize impact?

- **Recommendation 5.1**: Replace term "wastewater" with "Resource Water."
- **Recommendation 5.2**: Work / continue working on researching, developing, and demonstrating scalable Resource Recovery and Water Reuse (RRWR) business models.
- **Recommendation 5.2**: Determine specific needs for clean water standards – fit-for-purpose – to exploit non-conventional water supply sources.
- **Recommendation 5.3**: Assess and mitigate risks from RRWR for public health and the environment.
- **Recommendation 5.4**: Collaborate with industry to identify and define high-risk, high-reward RD&D needs, and share the outcomes with various stake holders.
- **Recommendation 5.5**: Support public and private entities with innovative approaches for the safe reuse of resource water.
- **Recommendation 5.6**: Support professional development of RRWR facilities' administrators, designers, contractors, operators, and maintenance personnel by offering workshops, seminars and other opportunities to advance their knowledge of all aspects of water reuse and resource recovery operations.

Specific to SSWR: Charge Question 6. What are the unique aspects of resource recovery and water reuse that SSWR is best able to address? What research products are envisioned to maximize impact?

- **Recommendation 6.1**: Develop a list of all the audiences that should be targets for its communication and categorize these according to their interest and technical abilities. Target audiences and communication strategies should be identified in the research planning stage.
- **Recommendation 6.2**: Depending on availability of resources, outreaching efforts should be extended to primary, secondary and post-secondary education institutions.