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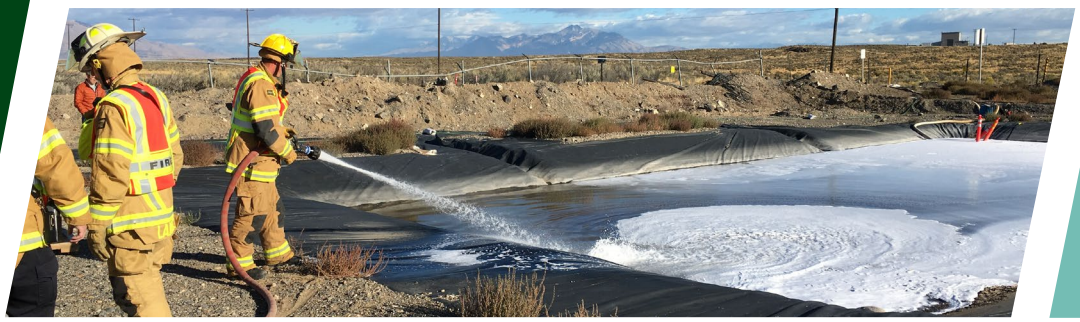
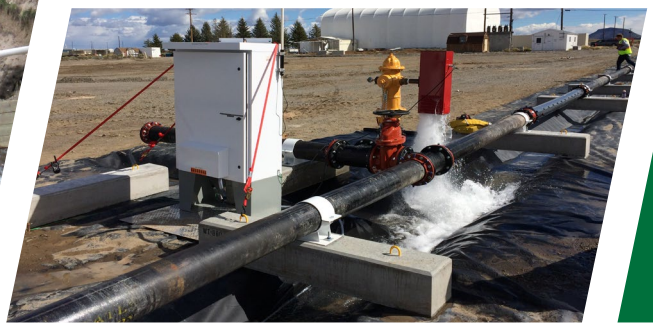


Homeland Security

STRATEGIC RESEARCH ACTION PLAN
FISCAL YEARS 2023-2026





Office of Research and Development
Homeland Security Research Program

Homeland Security (HS)

STRATEGIC RESEARCH ACTION PLAN

Fiscal Years 2023–2026

(Draft as of March 28, 2022)

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List of Acronyms

AHWMPPT	All Hazards Waste Management Pre-Planning Tool
ACE	Air, Climate, and Energy
CEH	Children's Environmental Health
CBRN	Chemical, Biological, Radiological, and Nuclear
CSS	Chemical Safety for Sustainability
DHS	Department of Homeland Security
DWDM	Disaster Waste and Debris Management
EJ	Environmental Justice
EPA	U.S. Environmental Protection Agency
ERB	Equitable Resilience Builder
ERLN	Environmental Response Laboratory Network
FedRAMP	Federal Risk and Authorization Management Program
HERA	Health and Environmental Risk Assessment
HS	Homeland Security Research Program
ICCOPR	Interagency Coordinating Committee for Oil Pollution Research
LC50	Lethal Concentration 50 percent
NCA4	National Climate Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCPPS	NCP includes a Product Schedule
NRP	National Research Program
NRT	National Response Team
OLEM	EPA Office of Land and Emergency Management
ORD	EPA Office of Research and Development
OW	EPA Office of Water
P3	People, Prosperity, and the Planet
PFAS	Per- and Polyfluoroalkyl Substances
PPE	Personal Protective Equipment
PRST	Program, Regional, State and/or Tribal
RA	Research Area

RACT	Research Area Coordination Team
SCADA	Supervisory Control And Data Acquisition
SBIR	Small Business Innovation Research
SDR	Solutions-Driven Research
SHC	Sustainable and Healthy Communities
SLTT	State, Local, Territorial, and Tribal
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan
WMM	Waste and Materials Management
WNTR	Water Network Tool for Resilience

Definitions

Office of Research and Development (ORD): Scientific research arm of EPA that conducts leading-edge research to inform Agency decisions and support partner needs, including state, tribal, and community partners.

National Research Program (NRP): ORD's overall research effort is organized around six highly integrated and transdisciplinary national programs and closely aligned with the Agency's strategic goals and cross-Agency strategies. ORD is a matrixed organization with research direction coming from its six NRPs, each being guided by a Strategic Research Action Plan that identifies the most pressing environmental health research needs with input from many internal and external partners and stakeholders.

Strategic Research Action Plan (StRAP): A description of the overarching direction of ORD's research in a specified timeframe and under a specific research program. Each of ORD's NRPs is guided by a StRAP to structure and coordinate research activities. A StRAP includes a description of identified environmental and public health challenges, research priorities, and ORD's approach to meeting the challenges.

Topic: Overarching research focus under a NRP that encompasses Research Areas, Outputs, and Products.

Research Area: Science area or body of research and expertise assembled to address stakeholder and partner needs in the protection of human health and the environment. It encompasses problem statements, which are delineated through Outputs. Research Areas are nested under Topics and are composed of Outputs, which are composed of Products.

Output: A statement of the results to be achieved in pursuing a Research Area problem statement. It is not tangible deliverable but encompasses Products that are deliverables. They are designed and developed to address specific partner needs that draw on the scientific knowledge and expertise represented in research areas. An Output can be expressed in many ways, such as an intended intermediate outcome, a purpose, aim, goal, or target. Outputs are composed of Products and nested within Research Areas, which are nested within Topics.

Product: A tangible scientific or technical deliverable. It addresses the research needs identified in an Output. Products are nested within Outputs, which are nested within Research Areas, which are nested within Topics.

Partner: An EPA Program Office, EPA Region, representative of a state, or a representative of a Tribe—often referred to as PRST.

Program, Regional, State, and Tribal (PRST) needs: A description of research needs related to human health and the environment as identified by EPA program offices, EPA regional offices, states, and/or Tribes.

Executive Summary

The Homeland Security (HS) Research Program performs applied research that delivers relevant and timely methods, tools, data, technologies, and technical expertise in support of federal, regional, state, and tribal water systems, and promotes local community resilience. The HS Strategic Research Action Plan (StRAP) in FY23-26 will conduct research to address science gaps related to protecting water systems, oil spill response, and cleanup of wide areas contaminated with high-priority Homeland Security Chemical, Biological, Radiological, and Nuclear (CBRN) agents. This includes contamination incidents due to natural disasters, pathogens that cause communicable diseases, covert release of chemicals, and agricultural incidents with animal and crop diseases. The HS will adapt suitable methodologies that have proven their effectiveness and usability in real-world settings via high-quality science with laboratory and field tests, as well as modeling. Research will be performed to understand community needs, develop effective risk communication, and maintain productive stakeholder relationships. The HS's technical and social science research and development in preparation for homeland security incidents will address the Administrator's priorities related to environmental justice and climate change. As such, HS will have a greater focus on community needs and vulnerabilities to promote equitable incident management. A new research area (Research Area 8, Communities, Resilience, and Remediation) will focus on assessing and addressing these research needs and integrating this information with other research areas.

Introduction

To assist the Agency in meeting its goals and objectives, the HS developed this Strategic Research Action Plan (StRAP) for fiscal years 2023–2026 (FY23-26). The HS StRAP is one of six of the following research plans developed for each of the National Research Programs (NRPs) in EPA's Office of Research and Development (ORD):

- Air, Climate, and Energy (ACE)
- Chemical Safety for Sustainability (CSS)
- Health and Environmental Risk Assessment (HERA)
- Homeland Security (HS)
- Safe and Sustainable Water Resources (SSWR)
- Sustainable and Healthy Communities (SHC)

The StRAPs outline four-year research strategies to deliver the research necessary to support EPA's overall mission to protect human health and the environment. The StRAPs are designed to guide an ambitious research portfolio that delivers the science and engineering solutions the Agency needs to meet its goals now and into the future. They also inform our partners and the public of the program's strategic direction over the next four years. The HS StRAP FY23-26 builds upon the previous StRAP FY19-22, and where appropriate, continues research efforts to address longer-term strategic research objectives that can bridge between the four-year research planning cycles.

The strategic directions and Research Areas (RAs) identified in each StRAP serve as planning guides for ORD's research Centers to design specific research products to address the needs of EPA program and regional offices, states, Tribes, and external partners. Partner engagement is an essential part of the StRAP development process to identify research needs to be addressed.

Solutions-Driven Research

ORD is committed to producing research results that address real-world problems, inform implementation of environmental regulations, and help EPA partners make timely decisions based on sound science. This commitment includes exploring ways to improve research processes through the application of a solutions-driven research (SDR) framework. SDR is a specific research approach that emphasizes partner engagement and integration of tasks to develop research that is directly along the path to a solution or decision. Solutions-driven research emphasizes the following:

- Planned partner engagement throughout the research process, starting with problem formulation and informing all elements of research planning, implementation, dissemination, and evaluation.
- A focus on solutions-oriented research Outputs identified in collaboration with partners.
- Coordination, communication, and collaboration both among ORD researchers and between researchers and partners to develop integrated research that multiplies value to partners.
- Cooperation with partners to apply research results to develop solutions that are feasible, appropriate, meaningful, and effective.

ORD is applying principles of solutions-driven research broadly across its six NRPs. ORD will also monitor how we engage with our partners and how we design and conduct our research to ensure that it informs

solutions for our partners' most pressing environmental problems. By doing this, we are engaging in translational science, which will continually improve and increase the value of our research for our partners. Our emphasis on translating science is exemplified by the Outputs listed in this StRAP—they provide solutions to problems identified by our partners.

Program Vision

Through its scientific research, the HS Research Program's vision is that

> (1) federal, state, tribal, and local decision-makers and stakeholders have timely access to information and tools they need to ensure community resilience to catastrophes involving environmental contamination that threaten public health and welfare; and
>
> (2) decision-makers have capabilities to assess and address community needs and vulnerabilities to ensure equitable incident management.

Strategic Direction

Relationship to EPA and ORD Strategic Plans

The FY 2023-2026 EPA Strategic Plan is designed to implement the Administrator's priorities for the next four years. This Strategic Plan identifies four cross-cutting strategies and seven strategic goals with related objectives, describing how the Agency will work toward its mission to protect human health and the environment.

ORD will develop its own strategic plan to respond to and build upon the FY 2023-2026 EPA Strategic Plan. ORD's Strategic Plan will align with the StRAPs for ORD's six research programs, which outline specific research activities that address objectives of the Agency's Strategic Plan.

EPA's HS aligns with all Cross-Agency Strategies, including Strategy 1: Ensure Scientific Integrity and Science-Based Decision Making; Strategy 2: Consider the Health of Children at All Life Stages and Other Vulnerable Populations; Strategy 3: Advance EPA's Organizational Excellence and Workforce Equity; and Strategy 4: Strengthen Tribal, State, and Local Partnerships and Enhance Engagement.

The HS directly supports EPA's Strategic Goals primarily through implementing Goal 6, to safeguard and revitalize communities. HS research also advances the Agency's mission to tackle the climate crisis (Goal 1), take decisive action to advance Environmental Justice (Goal 2), and ensure clean and healthy air (Goal 4) and water (Goal 5) for all communities. The HS StRAP IV outlines the research plan to support the following objectives:

- Accelerate resilience and adaptation to climate change impacts by conducting research to improve capabilities in response and recovery from climate-induced disasters (Objectives 1.2 and 1.3).
- Advance environmental justice during disaster response and recovery by supporting decision-makers to assess and address community needs and vulnerabilities to ensure equitable incident management (Objectives 2.1, 2.2, and 2.3).
- Reduce exposure from radiation emergency (Objective 4.2).

- Ensure safe drinking water and resilient water infrastructure from water systems incidents, including cyberattacks on water distribution systems (Objective 5.1).
- Safeguard and revitalize communities from environmental contamination incidents by improving the Nation's preparedness and response capabilities to environmental emergencies (Objectives 6.1, 6.2 and 6.3).

Changes from FY19-FY22 StRAP

The HS StRAP FY23-26 will have a greater focus on community needs and vulnerabilities to ensure equitable incident management. A new research area (Communities, Resilience, and Remediation) has been created in this StRAP to assess and address community-based needs.

The HS StRAP FY19-22[1] Research Area (RA) 1 on Contaminant Fate, Transport and Exposure will be conducted under multiple research areas in the HS StRAP FY23-26 to provide a foundational basis to inform the specific research needs in sampling, decontamination, and waste management. Hence, there is no RA1 in the HS StRAP FY23-26 with the other RAs maintaining their numbering order for continuity across research planning cycles.

Partner Engagement

Development of ORD's StRAPs has been informed by ongoing and extensive engagement with EPA program and regional offices and external (non-EPA) partners. ORD's partner engagement during strategic research planning ensures a collaborative, transparent, and highly coordinated research portfolio that delivers the data and information that Agency program and regional offices need, and provides resources that help states, Tribes, local communities, and other partners. ORD relies on partner engagement as an essential component throughout the research cycle and especially during problem formulation to identify partner research needs and develop the research Outputs outlined in the StRAPs.

The HS engages partners at different levels and stages throughout the research cycle to identify and discuss their research needs. Building from engagement during StRAP FY19-22 planning and implementation, engagement methods for the HS StRAP FY23-26 included the following:

- Recurring dialogues and meetings with EPA program and regional offices.
- Listening sessions with external partners, including state, tribal, and local partners.
- Workshops with ORD staff and EPA program and regional offices.
- Participation in EPA state and tribal organization meetings (e.g., Environmental Council of the States, Tribal Science Council).

The HS will continue to engage with our EPA partners and state, tribal, and local organizations as we implement the research program outlined in the StRAP, support our research products after they are delivered, and evaluate the usefulness and effectiveness of our research in helping solve environmental and public health problems.

[1] HS's StRAP FY19-22 can be found at epa.gov/research/homeland-security-strategic-research-action-plan-2019-2022.

Research Topics and Research Areas

The HS research portfolio is organized into three interrelated topics: contaminant characterization and risk assessment, environmental cleanup and infrastructure remediation, and community engagement and systems-based tools supporting resilience equity. Within each topic are specific research areas and Outputs. The Outputs serve as planning guides for ORD to design specific research products to address partner needs. The Output descriptions are listed in Appendix 1.

Topic 1: Contaminant Characterization and Risk Assessment

Contaminant characterization provides essential information to plan for effective response actions. The characterization process includes assessing the extent and nature of environmental contamination and informing risks to public health. Information on contaminant characterization, coupled with understanding exposure potential, can be used to inform the potential consequences of contamination episodes on public health and the environment. Contaminant characterization is also supported by understanding the fate and transport of contaminants in the environment. Following a chemical, biological, radiological, and nuclear (CBRN) incident, EPA may support or lead site characterization, remediation, and management of waste in the contaminated environment. Additional characterization of the site may be required during cleanup operations to assess progress, determine waste streams, and inform site re-occupancy and reuse decisions (sometimes referred to as clearance decisions).

Research Area 2: Contaminant Characterization and Risk Assessment

The goal of this research area is to develop reliable and field-usable methodologies and strategies for environmental sampling, sample processing, and analysis by adopting widely accessible and applicable approaches. During a CBRN incident (including incidents associated with climate change related disasters), sampling strategies, sampling plans, and analytical capabilities are needed to inform public health and clean-up decisions. This research area will produce information to predict the movement of contaminants in the environment and develop tools and methods to effectively characterize contamination in affected areas. This research area also assesses exposure to contaminants through understanding the implications of sampling results.

Work under Research Area 2 (RA HS.2) addresses many high-priority EPA program, regional, state, and tribal (PRST) research needs. PRST responders and decision-makers need methods for effective chemical contaminant characterization (sampling and analysis) during response and recovery from CBRN incidents. One Output under RA HS.2 (HS.2.1) will focus research on developing reliable strategies, data management capabilities, and methodologies for sampling, processing, and analysis to address contamination incidents and inform mitigation and remediation decisions. In addition, it is critical to understand how contaminants behave in the environment and have the information needed to address exposure to CBRN contaminants during response and recovery incidents. A second Output under RA HS.2 (HS.2.2) will develop capabilities to address persistence, movement, and related phenomena to understand exposure risk and inform mitigation and remediation decisions. The PRST research needs and associated Outputs are further described in Appendices 1 through 3.

Topic 2: Environmental Cleanup and Infrastructure Remediation

Once the extent of the contamination is understood and its potential impact on public health is assessed, EPA may then be responsible for supporting the cleanup of oil or hazardous contaminants and mitigating the impact of their intentional or accidental releases on human health and the environment. EPA, together with the U.S. Coast Guard, has extensive experience addressing oil spills on land, inland waters (including rivers and lakes), and offshore. Even with this expertise, the need for improved capabilities is widely recognized. EPA also has responsibilities, but less specific experience, in remediating CBRN contamination intentionally released over wide areas—including indoor and outdoor areas and impacting critical infrastructures and water systems. Given the breadth and magnitude of potential scenarios, these releases, including oil spills, pose a significant challenge with long-standing consequences. HS activities on this topic aim to fill the most critical scientific gaps in the capabilities of EPA's response community so that, when needed, EPA can make and support the most informed mitigation and remediation decisions.

Research Area 3: Wide-Area Decontamination

Wide-area contamination from natural disasters, accidents, and intentional incidents requires comprehensive remediation capabilities to help impacted communities recover rapidly. Research Area 3 delivers options that address safety, effectiveness, resource demand, logistics, training, availability, and technology necessary to remediate impacted communities, and to do so equitably. Researchers will continue to develop methods and resources for stakeholders who will be primarily responsible for remediating their properties and facilities during a wide-area incident. Research will be expanded to include pathogens that cause communicable diseases, agricultural incidents involving animal and crop disease, and wide-area contamination incidents due to natural disasters. Communicable pathogens that cause pandemics, such as COVID-19[2], also require an understanding of persistence and effective disinfection technologies for multiple media (e.g., surfaces, aerosols, indoor air handling) to inform decision-making. A large-scale animal or plant agricultural incident would require EPA assistance in the national response to contain, mitigate, and remediate contamination and waste. Researchers, in collaboration with the U.S. Department of Agriculture, will focus on developing and evaluating processes and technologies to treat extremely large volumes of biomass, including crops and animal carcasses. Research will also be expanded to wide-area incidents due to natural disasters related to climate change. These wide-area incidents may have additional impacts on traditional Homeland Security events (e.g., CBRN), as well as creating CBRN contamination incidents themselves. Large-scale urban transport-predictive models for CBRN will continue to be developed and field tested to ensure they are operationally relevant and assist all communities equitably within the impacted area.

PRST responders and decision-makers need methods for containment, mitigation, and decontamination, including self-help following wide-area contamination incidents. The Research Area 3 (RA HS.3) Outputs (HS.3.1, HS.3.2, HS.3.3) will develop reliable strategies, tools, and methodologies for decontamination of wide-area CBRN contamination incidents. The PRST research needs and the associated Outputs are further described in Appendices 1 through 3.

[2] HS's COVID research can be found at epa.gov/covid19-research.

Research Area 4: Water Systems Incident Response Support

Resilient water infrastructure systems can facilitate quick and effective responses during emergency situations, including cyberattacks, to ensure access to adequate water capacity and quality. The priority is to provide tools and methodologies that inform decontamination of water infrastructure, management of the contaminated water, and resumption of operations. Research Area 4 focuses on understanding the movement and persistence of contaminants in water and wastewater systems to inform decisions regarding sampling, decontamination, waste management, and operational countermeasures. Research includes studies to assess full-scale contaminant persistence and decontamination in home plumbing, wastewater, and stormwater systems. The research will also continue to include full-scale decontamination of priority agents in the drinking water distribution system, as determined in conjunction with EPA's Office of Water (OW). In partnership with OW and the Department of Homeland Security, the research program will continue full-scale cybersecurity research. Research on treatment of contaminated water will also continue, with an emphasis on field testing water treatment technologies that could be used by the response community. Wastewater research will continue with a focus on decontamination of critical parts of the treatment plant and collection system. Emphasis will be placed on priority pathogens in wastewater and stormwater systems, with modeling being conducted in addition to pilot and full-scale research. Research will continue, but be scaled down, on online contamination detectors, transitioning to a focus on pilot-scale detection capability and management of sensor data in Federal Risk and Authorization Management Program (FedRAMP) approved clouds. Research will continue on treatment of CBRN contaminated water and delivery of potable water to communities after incidents, focusing on situations where environmental justice is a concern. Water treatment technologies developed and/or field tested in this research area are applicable to supply potable or non-potable water for sanitation in disaster affected areas, including those related to climate change impacts.

PRST responders and decision-makers need tools and methodologies to inform decontamination of water infrastructure, including drinking water, premise plumbing, wastewater, stormwater, source water, reuse, and return to service. Their needs include tools and technologies to inform treatment and management of contaminated water at various scales. Water utilities also need to understand the fate and transport of CBRN contaminants in source water, drinking water, wastewater, and stormwater infrastructure to improve risk management decisions, as well as characterizing potential exposure pathways and consequences of priority contaminants in wastewater and drinking water systems, including premise plumbing. Research Area 4 (RA HS.4), Output HS.4.1, will develop tools and methodologies to inform infrastructure decontamination and management of drinking water, wastewater, and stormwater. RA HS.4, Output HS.4.2, will conduct full-scale testing of cyber vulnerabilities on water system infrastructure and evaluate response and mitigation actions. These actions will demonstrate and document the impact of cybersecurity vulnerabilities on internet-facing, operating-technology, process-control systems used to operate water and wastewater systems, and identify and evaluate response or mitigation actions that could counter the impacts of such a cyber-attack. The PRST research needs and associated Outputs are further described in Appendices 1 through 3.

Research Area 5: Oil Spill Response Support

EPA is responsible for responding to and assessing environmental releases of oil that occur over land, in inland waters, and in the ocean (in conjunction with the U.S. Coast Guard). Oil spills can affect human health and the environment through their impacts on water (including drinking water supplies), air quality, ecosystem health, or through direct exposure to toxic constituents. HS's innovative research approaches help to achieve more efficient and effective management of oil spills with respect to preparedness, emergency response, and fate and transport. This Research Area will continue to (1) refine approaches for spill monitoring and detection technologies for small and large-scale incidents; (2) develop treating agent effectiveness and toxicity protocols for the National Oil and Hazardous Substances Pollution Contingency Plan (NCP)[3] Product Schedule (NCPPS) and to inform regulatory actions; (3) evaluate tradeoffs for spill response mitigation (i.e., conventional booming and skimming, in situ burning, and the application of chemical agents, including but not limited to chemical dispersants, surface washing agents, and chemical herders); and (4) examine ecological issues concerning oil and agent toxicity and biodegradation on aquatic flora and fauna. HS research deliverables help formulate guidance and rulemaking with respect to preparation for, and response to, oil releases. In addition to Agency program offices, this research also informs technical support to the EPA regions, federal agencies, states, and other regulatory authorities. ORD is actively engaged in federal coordination activities, with entities including the National Response Team (NRT) and the Interagency Coordinating Committee for Oil Pollution Research (ICCOPR).

PRST responders and decision-makers have expressed the following needs: toxicity protocols for products submitted to the NCPPS, including bioremediation, solidifier, surface washing, and herding agents, both for agent-only and agent mixed with oil; evaluation of new reference oils testing for dispersant effectiveness, chemical characterization, and toxicity; efficacy test protocols for surface washing agents, solidifiers, and oil herding agents; and determining the effect of long-term shelf life on product efficacy results. These National Contingency Plan Regulatory Support needs will be addressed in the first of two RA HS.5 Outputs (HS.5.1).

Research is also necessary to evaluate new species for toxicity testing, beyond *m. beryllina* and *a. bahia*, for products, oil, and products mixed with oil for development of Species Sensitivity Distributions (SSDs) for potentially affected aquatic communities. More biodegradation experiments on products are needed in support of NCPPS (oil alone, oil plus product, product alone) in salt and fresh water to better assess the fate of products and oil in the environment. The PRST responders need a reference document as an informational guide on subsea blowout numerical models to better inform RRT decision-making and thorough evaluation of submerged oil and floating oil slick detection assets for field usage. Additionally, toxicity and chemistry of in-situ burn (ISB) residues need to be characterized. Behavior, fate, and effects of oil and spill treating agents will be addressed in the second RA HS.5 Output (HS.5.2). Additional PRST research needs and associated Outputs are described in Appendices 1 through 3.

Research Area 6: Waste Management

Waste and materials management present considerable challenges during any large-scale disaster, with wide-area CBRN incidents creating additional complexities. Although different waste and materials

[3] NCP information can be found at epa.gov/emergency-response/national-oil-and-hazardous-substances-pollution-contingency-plan-ncp-overview.

streams are generated in a natural disaster compared to a CBRN incident, HS waste and materials management (WMM) tools developed for CBRN incidents can be leveraged to support natural disaster response. HS will conduct research on methods for managing materials and creating less debris. Building on accomplishments under the HS StRAP FY19-22, treatment technologies for biological and chemical agents will be developed and evaluated, including improved accessibility and usability of the WMM tools. Further exploration of methods for owner/occupant decontamination following a wide-area incident is expected, with a focus on waste management considerations. Finally, research will build social and economic considerations into the waste management tools and associated guidance, practices, and trainings; this will enhance the environmental justice applicability of these tools.

In response to wide-area CBRN contamination incidents, responders and decision-makers need resources that enable efficient, fast, and accurate decision-making—including planning—regarding waste and debris management. Resources should assist in standardization/formalization of disposal units and identification of staging/temporary storage areas based on needed storage capacity, ingress/egress requirements, and site operations. For a wide-area biological incident, effective onsite treatment capacity is needed for treating waste and how waste acceptance criteria are established and measured, including sampling and analytical protocols for waste media that are suitable for Environmental Response Laboratory Network (ERLN) acceptance. Gaps exist in available technologies for solid and aqueous waste treatment for a chemical threat incident, including on-site treatment technologies and containment technologies for waste staging/temporary storage prior to disposal, taking into consideration needed storage capacity, ingress/egress requirements, and site operations. Responders need processes and resources to assist communities in sustainably managing materials under conditions of increasing frequency and magnitude of disasters. The RA HS.6 Output (HS.6.1) will continue advancing approaches and tools for waste and materials management following a wide-area CBRN incident. The PRST research needs and associated Outputs are further described in Appendices 1 through 3.

Topic 3: Community Engagement and Systems-Based Tools Supporting Resilience Equity

Transitioning research into reliable and field-usable capabilities ensures that decision-makers and responders have access to the latest information. Decision-makers and stakeholders need access to tools and information prepared using a systems approach, linking response and recovery activities, and noting their interdependencies. This topic addresses systems-based analysis results and tools by pulling together the connected technical and social elements in response and recovery activities. These linked activities include emergency mitigation, characterization, environmental cleanup, operations management, waste management, and community engagement. Effective technical support and decision-support tools will be developed to ensure that information is readily and easily accessible to decision-makers and stakeholders throughout planning, response, and recovery efforts. These products will empower under-resourced communities, populations of concern, and communities with environmental justice issues.

Research Area 7: Systems-Based Decision Making

This research area will continue to develop a centralized and routinely maintained database for monitoring and surveying the latest findings and methods for emergency mitigation, characterization,

environmental cleanup, operations management, and waste management. Using this centralized database, HS will develop a tool that can simulate the remediation of various response activities to assess the following aspects: impact of various methods on the overall remediation, bottlenecks in the remediation activities, resource availability and demand for remediation, future decision-support-tool feasibility before development, and future methods/technologies before investment. The tool will also allow for assessing the benefit of current or potential capabilities. Research under this area will address data management gaps by developing easy-to-use tools to effectively collect and manage data during all phases of response to contamination incidents.

In response to wide-area contamination events, decision-makers need systems-based response, recovery, and resilience decision support methods and tools, communication tools, contamination extent mapping, and prediction tools and technologies. The first RA HS.7 Output (HS.7.1) will develop tools to support response and recovery decision-making. These tools are also critical to respond to and recover from disasters due to climate change. The second RA HS.7 Output (HS.7.2) will develop models, tools, and information to build equitable community resilience to changing climate-induced disasters. The PRST research needs and associated Outputs are further described in Appendices 1 through 3.

Research Area 8: Communities, Resilience, and Remediation

This research area investigates the intertwined social and environmental variables that affect community resilience and vulnerability to CBRN incidents and other disasters. It focuses on the community scale, while also examining cross-scalar interactions at the watershed, regional, state, or neighborhood scales. The social implications of disaster waste and materials management decisions will be analyzed, and interventions identified to better address environmental justice concerns of communities. Research in this area is based in interdisciplinary social science, primarily drawing from environmental anthropological theories and methods. It uses mixed methods research, such as qualitative and quantitative techniques for data collection, management, and analysis. Specific research methods include interviews, focus groups, surveys, participant observation, and content analysis of documents. These methods allow researchers to elucidate how culture, social dynamics, and other related factors affect decisions and outcomes. This research area uses human-centered design to develop decision-support tools and resources for EPA's state and local partners to use in disaster preparedness, response, and recovery. It generates resources, tools, and trainings for risk communication, outreach, building relationships, and community engagement. These products can be used in remediation and resilience work carried out by EPA and its state and local partners.

Metrics of success and community-social dynamics and decision-making are necessary to facilitate preparation, response, and recovery from disasters. The first RA HS.8 Output (HS.8.1) will conduct social analysis on the need for remediation, removal, and disaster waste and debris management (DWDM) decisions and outcomes. The second RA HS.8 Output (HS.8.2) will develop effective community engagement strategies for building trust, addressing environmental justice concerns, and supporting equitable community resilience to incidents and disasters. A third RA HS.8 Output (HS.8.3) will develop and improve tools and information for social considerations to build community resilience. The PRST research needs and associated Outputs are further described in Appendices 1 through 3.

Implementing the Strategic Research Action Plan

In collaboration with EPA program, regional, state, and tribal partners, ORD scientists and engineers design specific research products responsive to the Outputs outlined in the StRAPs. During the implementation of the previous FY19-22 StRAPs, ORD piloted a successful process in which Research Area Coordination Teams (RACTs), made up of ORD scientists and engineers, EPA program and regional staff, and state members, collaborated to determine the individual research products responding to each Output. ORD is continuing this process for the FY23-26 StRAP.

Each Output in the StRAPs is reviewed by a RACT, which develops goals and objectives for the Output and establishes criteria for the work needed to accomplish it. ORD researchers propose research products, which the RACT reviews and refines to ensure products will meet the goals and objectives of the Output and reflect the timing and specific needs of EPA program and regional, state, and tribal partners. RACT members serve as liaisons to their programs or organizations, which ensures that ORD's partners are able to provide input into the proposed research products. Products developed to address the Outputs may take the form of assessments, reports, tools, methods, journal articles, or other deliverables.

Throughout implementation of the StRAPs, ORD's researchers develop and deliver products. Research to deliver StRAP products is implemented by staff scientists and engineers at research laboratories and facilities in twelve locations across the country, which collectively comprise ORD's four Centers and four Offices. EPA staff are joined in this endeavor by a network of collaborators and partners within and external to EPA. In addition to the extensive intramural research program outlined in the StRAPs, ORD's research portfolio includes extramural research programs that complement or add special focus areas to the overarching program.

Cross-Cutting Research Priorities

For priorities that cut across their programs, ORD's six NRPs will work together to integrate efforts, provide a research portfolio aligned around the Agency's goals, and assist all of EPA's program and regional offices, as well as states and Tribes. Where appropriate, the NRPs will combine efforts to conduct research that advances the science and informs public and ecosystem health decisions and community efforts on the following cross-cutting priorities (Appendix 4):

- Environmental Justice
- Climate Change
- Cumulative Impacts
- Community Resiliency
- Children's Environmental Health
- Contaminants of Immediate and Emerging Concern

EPA program and regional offices and external (non-EPA) partners and stakeholders will also be engaged for these integrated efforts. Long-term, innovative, and multi-disciplinary research is needed to make progress on these complex issues to support a sustainable pathway towards equitable distribution of social, economic, health, and environmental benefits.

Appendix 1: Summary of Proposed Outputs Mapped to Program, Regional, State, and Tribal (PRST) Needs

The following table lists the proposed Homeland Security Research Program Outputs organized by topic and mapped to PRST needs. It should be noted that the Outputs might change as new scientific findings emerge and are also contingent on budget appropriations. See Appendix 2 for more detailed descriptions of the PRST needs and Appendix 3 for detailed descriptions of Outputs.

Research Area[4]	Output	PRST Need(s)
Topic 1: Contaminant Characterization and Risk Assessment		
HS.2 Contaminant Characterization and Risk Assessment	HS.2.1 Developing reliable strategies, data management capabilities, and methodologies for sampling, processing, and analysis to address contamination incidents and inform mitigation and remediation decisions	• Methods for effective chemical contaminant characterization during response and recovery of chemical incidents • Methods for effective biological contaminant characterization during response and recovery of biological incidents • Methods for effective radiochemical/nuclear contaminant characterization during response and recovery of radiochemical/nuclear incidents
	HS.2.2 Develop capabilities to address persistence, movement, and related phenomena to understand exposure risk and inform mitigation and remediation decisions	• Capabilities to determine how contaminants behave in the environment following a CBRN incident • Information to address exposure to CBRN contaminants during response and recovery incidents
Topic 2: Environmental Cleanup and Infrastructure Remediation		
HS.3 Wide-Area Decontamination	HS.3.1 Reliable strategies, tools, and methodologies for decontamination of wide-area radiological contamination incidents	• Containment, mitigation, and decontamination methods including self-help for radiological contamination

[4] There is no StRAP FY23-26 RA1. StRAP FY19-22 RA1 activities have been assigned across subsequent StRAP FY23-26 RAs, with the numerical ordering maintained to provide continuity from StRAP FY19-22 to StRAP FY23-26.

Research Area[4]	Output	PRST Need(s)
Topic 2: Environmental Cleanup and Infrastructure Remediation		
HS.3 Wide-Area Decontamination	HS.3.2 Reliable strategies, tools, and methodologies for decontamination of chemical contamination incidents	• Containment, mitigation, and decontamination methods including self-help for chemical contamination
	HS.3.3 Reliable strategies, tools, and methodologies for decontamination of wide area biological contamination incidents	• Containment, mitigation, and decontamination methods including self-help for biological contamination
HS.4 Water Systems Incident Response Support	HS.4.1 Tools and methodologies to inform infrastructure decontamination and management of drinking water, wastewater, and stormwater	• Develop and evaluate tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), and return to service (Decontamination) • Develop and evaluate tools and technologies to inform treatment and management of contaminated water, including large volumes of water (Water treatment) • Understanding the fate and transport of chemical, biological, and radiological contaminants in source water and drinking water, wastewater, and stormwater infrastructure to improve risk management decisions (Fate and Transport) • Characterizing potential exposure pathways and consequences of priority contaminants in wastewater and drinking water systems, including premise plumbing (Exposure)
	HS.4.2 Full-scale testing of cyber vulnerabilities on water system infrastructure and evaluation of response and mitigation actions	• Demonstrating and documenting the impact of cybersecurity vulnerabilities on internet-facing operating technology process control systems used to operate water and wastewater systems and identifying and evaluating response or mitigation actions that could counter the impacts of a cyber-attack (Cybersecurity)

Research Area[4]	Output	PRST Need(s)
Topic 2: Environmental Cleanup and Infrastructure Remediation		
HS.5 Oil Spill Response Support	HS.5.1 National Contingency Plan Regulatory Support	• Toxicity protocols for products submitted to the NCPPS, including bioremediation, solidifier, surface washing, and herding agents, both for agent-only and agent mixed with oil • Evaluate new reference oils testing for dispersant effectiveness, chemical characterization, and toxicity • Develop efficacy test protocols for surface washing agents, solidifiers, and oil herding agents, and determine the effect of long-term shelf life of products on efficacy results
	HS.5.2 Behavior, Monitoring, Fate and Effects of Oil and Spill Treating Agents	• Evaluate additional new species for toxicity testing beyond m. beryllina and a. bahia for products, oil, and products mixed with oil for development of Species Sensitivity Distributions (SSDs) for potentially affected aquatic communities • Biodegradation experiments on products in support of NCPPS (oil alone, oil plus product, product alone) in salt and fresh water to better assess fate of products and oil in the environment • Develop a reference document as an informational guide on subsea blowout numerical models to better inform RRT decision-making • Evaluation of submerged oil and floating oil slick detection assets • Characterization of toxicity and chemistry of In-situ burn (ISB) residues

Research Area[4]	Output	PRST Need(s)
Topic 2: Environmental Cleanup and Infrastructure Remediation		
HS.6 Waste Management	HS.6.1 Advancing Approaches and Tools for Waste and Materials Management	• Resources that enable efficient, fast, and accurate decision-making, including planning, regarding waste and debris management for all disaster types. Resources should assist in standardization/formalization of disposal units and identification of staging/temporary storage areas based on needed storage capacity, ingress/egress requirements, and site operations. Selection criteria need to include community considerations (e.g., EJ) • For wide-area Bacillus anthracis: Effective onsite treatment capacity for treating waste and improved approaches to how waste acceptance criteria are established and measured, including sampling and analytical protocols for waste media that are suitable for ERLN acceptance • Gap in available technologies for solid and aqueous waste treatment for a chemical threat incident, including on-site treatment technologies • Gap in ability to identify waste staging/temporary storage prior to disposal associated with chemical threat incidents based on needed storage capacity, ingress/egress requirements, and site operations. Selection criteria need to include community considerations and environmental justice • Wide Area Bacillus anthracis: Continued development of self-help guidelines program for bio responses for coordination with internal and external partners • Processes and resources to assist communities in sustainably managing materials under conditions of increasing frequency and magnitude of disasters

Research Area[4]	Output	PRST Need(s)
Topic 3: Community Engagement and Systems-Based Tools Supporting Resilience Equity		
HS.7 Systems-Based Decision Making	HS.7.1 Systems-Based Information and Tools to Support Response and Recovery Decision-Making	• Systems-based response, recovery, and resilience decision support methods and tools • Response and recovery communication tools • Contamination extent mapping and prediction tools and technologies
	HS.7.2 Models, Tools, and Information to Build Equitable Community Resilience to Changing Climate-Induced Disasters	• Climate Change: Systems-based response, recovery, and resilience decision support methods and tools • Climate Change: Response and recovery communication tools • Climate Change: Contamination extent mapping and prediction tools and technologies
HS.8 Communities, Resilience, and Remediation	HS.8.1 Social Analysis of Remediation, Removal, and Disaster Waste and Debris Management (DWDM) Decisions and Outcomes	• Success metrics and community social dynamics related to the social science of decision making
	HS.8.2 Developing Effective Community Engagement Strategies for Building Trust, Addressing Environmental Justice Concerns, and Communicating Risks	• Innovative Strategies for (Enhanced/Incorporating) Environmental Justice, Risk Communication, Building Trust, and Community Engagement during CBRN Incidents
	HS.8.3 Social Considerations for Building Community Resilience	• Identifying vulnerable populations (including those facing compounding disasters), accounting for local priorities, and tool integration, improvement, and/or development

Appendix 2: Descriptions of Program, Regional, State, and Tribal (PRST) Needs

The following describe, in more detail, the PRST needs summarized in the body of the Homeland Security Research Program StRAP for each Research Area and as listed in Appendix 1.

Topic 1: Contaminant Characterization and Risk Assessment

RA HS.2: Contaminant Characterization and Risk Assessment

- **Methods for effective chemical, biological, and radiochemical/nuclear contaminant characterization during response and recovery of chemical incidents:** Effective contaminant characterization, coupled with an understanding of the potential impact on public health, can play an integral role in site remediation and clearance, including but not limited to, the extent of contamination, assessment of decontamination efficacy, determination of waste streams, and to inform re-occupancy and site reuse. Sampling strategies, methodologies, and procedures and analysis capabilities are needed, including real-time detection technologies for homeland security priority agents in various natural and engineered surfaces and media including soil, air, water (including drinking and wastewater system), paved surfaces, building surfaces, etc. These characterization methods, technologies, and strategies need to be field usable and applicable to a wide-area incident.

- **Improved prediction capabilities of how contaminants behave in the environment following a CBRN incident and information to address exposure to CBRN contaminants during response and recovery incidents:** Understanding contaminant fate and transport in the environment including natural and developed areas is important for assessing the risk of exposure during an incident and to inform sampling, decontamination, and waste management strategies. The ability to develop tools and models to assess the persistence and movement of a contaminant in the environment, and potential continuous exposure threat over time, will play a crucial role when informing public health and remediation decisions. Various environmental conditions (e.g., temperature, relative humidity, light) can affect contaminant persistence. Weather conditions (e.g., wind or precipitation) can also impact outdoor contamination, resulting in contamination spread over wide areas that were previously uncontaminated, such as storm sewers and drinking water sources. These effects can complicate remediation efforts and the ability to mitigate contamination, especially during a wide-area incident.

Topic 2: Environmental Cleanup and Infrastructure Remediation

RA HS.3: Wide-Area Decontamination

- **Containment, mitigation, and decontamination methods including self-help for radiological, chemical, and biological contamination:** Wide-area contamination from natural disasters, accidents, and intentional incidents requires comprehensive remediation capabilities to help communities recover rapidly. Responders need these capabilities for safe and timely decontamination, removal, disinfection, inactivation, stabilization, and mitigation for homeland security priority agents from natural and engineered surfaces and media. For wide-area remediation, it is critical that these methods have the following capabilities: they are applicable

to the zones with varied contamination levels, available widely, usable by home or business owners and their contractors, generate minimal waste volume, and have minimal or no impact to applied surfaces and media. In addition, responders and decision makers need strategies and information for how to apply these methods to wide areas having difficulty supplying large numbers of workers, experts, and equipment.

RA HS.4: Water Systems Incident Response Support

- **Tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), and return to service (Decontamination):** If water infrastructure is contaminated with persistent chemical, biological, or radiological agents, it is important to quickly and effectively decontaminate it to ensure access to adequate water capacity and quality. Water utilities and responders need procedures and methodologies to remove contamination from infrastructure surfaces, preferably using pilot- or full-scale setups.
- **Tools and technologies to inform treatment and management of contaminated water, including large volumes of water (Water treatment):** Contaminated water is flushed from a drinking water system during decontamination activities, or generated through wide-area decontamination (i.e., surface washing) efforts or by stormwater. Responders and water utilities need methodologies and technologies that can treat contaminated water from drinking water infrastructure. These technologies need to be tested in a full-scale setup.
- **Understanding the fate and transport of chemical, biological, and radiological contaminants in source water and drinking water, wastewater, and stormwater infrastructure to improve risk management decisions (Fate and Transport):** Understanding which contaminants are persistent on water and wastewater infrastructure is key in response to infrastructure decontamination and mitigation.
- **Characterizing potential exposure pathways and consequences of priority contaminants in wastewater and drinking water systems, including premise plumbing (Exposure):** Exposure to contamination from drinking water systems may not occur just through direct ingestion or contact with the water. It could occur due to aerosolization, mainly at wastewater treatment plants and from premise plumbing. Understanding how exposure could occur from water systems and how far contaminants spread will be needed.
- **Demonstrating and documenting the impact of cybersecurity vulnerabilities on internet-facing operating technology process control systems used to operate water and wastewater systems and identifying and evaluating response or mitigation actions that could counter the impacts of a cyber-attack (Cybersecurity):** Water infrastructure has been identified by the Department of Homeland Security (DHS) as a critical infrastructure sector and has been targeted for cyberattacks. It is unknown how cyberattacks may impact water and wastewater system operation. Understanding high-priority cybersecurity vulnerabilities will help develop mitigating capabilities for water utilities. These mitigating strategies and methods need to be developed and tested in a full-scale water system setup.

RA HS.5: Oil Spill Response Support

- **Toxicity protocols for products submitted to the NCPPS, including bioremediation, solidifier, surface washing, and herding agents, both for agent-only and agent mixed with oil:** There are continuing needs for the NCPPS to develop and refine the protocols for product effectiveness and toxicity that are used to inform regulatory actions.
- **Evaluate new reference oils testing for dispersant effectiveness, chemical characterization, and toxicity:** EPA is replacing the reference oils for listing chemical and biological agent products on the NCPPS that may be considered as response technologies to address an oil spill. It is necessary for EPA to evaluate new reference oil testing methods for dispersant effectiveness, chemical characterization, and toxicity.
- **Develop efficacy test protocols for surface washing agents, solidifiers, and oil herding agents, and determine the effect of long-term shelf life of products on efficacy results:** Efficacy test protocols are needed for oil spill treating agents including surface washing agents, solidifiers, and oil herding agents to determine their tailored requirements for fresh water and saltwater. The test protocols need to be developed for LC50s for agent/crude oil mixtures and impact assessments conducted for long-term storage of these products.
- **Additional new species for toxicity testing beyond m. beryllina and a. bahia for products, oil, and products mixed with oil for development of Species Sensitivity Distributions (SSDs) for potentially affected aquatic communities:** EPA uses standard test species for product listing. However, these species may not represent the sensitivity of other species in the environment. Additional information is needed on species from different taxa.
- **Biodegradation experiments on products in support of NCPPS (oil alone, oil plus product, product alone) in salt and fresh water to better assess fate of products and oil in the environment:** Some products on the NCPPS are not intended to be recovered from the environment (e.g., dispersants, herding agents). However, little information exists on certain fate processes (e.g., biodegradation).
- **Reference document as an informational guide on subsea blowout numerical models to better inform RRT decision-making:** Various oil spill near-field models are being used to evaluate nearfield dynamics of a blowout plume and the subsequent oil droplet sizes produced as a result of the turbulent energy involved and application of dispersants. Model outputs are used to determine the initial conditions for other trajectory models. These models use assumptions for input values such as dispersion efficiency for a given DOR and droplet size distribution. A comparison of the models, including the input assumptions and empirical data validation, is needed to assess how near-field model results determine the initial conditions for trajectory models.
- **Evaluation of submerged oil and floating oil slick detection assets:** New techniques and instruments are continuously developed to support monitoring of submerged and floating oil during spills. An evaluation of latest assets and developments is needed to calibrate and cross-reference instruments.
- **Characterization of toxicity and chemistry of in situ burns (ISB) residues:** In-situ burns (ISB) are a spill response option that involves igniting and burning slick oil. This response option is

considered in remote, wetland and Arctic environments. The information is needed for the formation of particulate air emissions and toxicity and chemistry of ISB residues to facilitate an assessment of hazards of burned oil.

RA HS.6: Waste Management

- **Resources that enable efficient, fast, and accurate decision-making, including planning, regarding waste and debris management for all disaster types. Resources should assist in standardization/formalization of disposal units and identification of staging/temporary storage areas based on needed storage capacity, ingress/egress requirements, and site operations. Selection criteria need to include community considerations (e.g., environmental justice):** Waste management presents considerable and persistent challenges throughout any large-scale disaster or a wide-area CBRN incident response and recovery. The major research needs are development of scalable CBRN waste treatment and reduction technologies, user-friendly planning tools for waste management, and a comprehensive resource for sustainable waste and debris management including staging, storage, and disposal.
- **For a wide-area Bacillus anthracis: Effective onsite treatment capacity for treating waste and how are waste acceptance criteria established and measured, including sampling and analytical protocols for waste media that are suitable for ERLN acceptance:** Establish an effective onsite capacity for treating waste following a wide-area biological incident, along with how waste acceptance criteria are established and measured.
- **Gap in available technologies for solid and aqueous waste treatment for a chemical threat incident, including on-site treatment technologies:** Hazardous solid waste disposal is costly. There is a gap in available technologies for solid waste treatment of homeland security priority chemical agents (e.g., Novichok, HD/L) following wide- area chemical incidents.
- **Gap in ability to identify waste staging/temporary storage prior to disposal associated with chemical threat incidents based on needed storage capacity, ingress/egress requirements, and site operations. Selection criteria need to include community considerations (e.g., EJ):** Responders need capability to identify safe and efficient waste staging/temporary storage sites prior to disposal associated with homeland security priority chemical agents (e.g., Novichok, HD/L).
- **Wide Area *Bacillus anthracis*: Continued development of self-help guidelines program for bio responses for coordination with internal and external partners:** There are continued needs to develop self-help guidelines for decontamination and waste management for homeowners, business owners, or their contractors in response to biological incidents. The guidelines need to be developed in coordination with federal, state, local, tribal, and territorial agencies.
- **Processes and resources to assist communities in sustainably managing materials under conditions of increasing frequency and magnitude of disasters:** It is very important to minimize the impact of waste management activities on the overall community recovery process. Communities need to sustainably manage materials pre- and post-disaster to reduce needed capacity in disposal facilities and overall impacts on the environment.

Topic 3: Community Engagement and Systems-Based Tools Supporting Resilience Equity

RA HS.7: Systems-Based Decision Making

- **Systems-based response, recovery, and resilience decision support methods and tools:** Decision-makers need to understand the interdependencies between the built and natural environments and associated impacts from response and recovery actions. Systems-based information, methods, and tools are needed to inform response and recovery actions following a natural disaster—especially climate change related disasters—or a chemical, biological, radiological, or nuclear contamination incident, and to improve the resilience of critical infrastructure to these scenarios.
- **Response and recovery communication tools:** The increased incidence of extreme weather events and natural disasters means that better response and recovery communication tools are needed to help water and waste infrastructure become more resilient. Message mapping and tools are needed to support communication and data sharing during response and recovery actions following a natural disaster or a chemical, biological, radiological, or nuclear contamination incident.
- **Contamination extent mapping and prediction tools and technologies:** Decision makers and stakeholders need to understand the likelihood and probability of various cascading impacts and have access to scalable tools and information to assist in planning, response, and recovery operations. Tools and technologies are needed to map and predict the contamination extent following a natural disaster, including climate induced disasters, or a chemical, biological, radiological, or nuclear contamination incident.

RA HS.8: Communities, Resilience, and Remediation

- **Success metrics and community social dynamics related to the social science of decision making:** After a disaster, EPA, state, and local responders may be tasked with safely disposing of disaster waste and debris in a way that does not further disadvantage overburdened populations—a logistically complex, emotional, and costly undertaking. Social dynamics among actors and institutions affect environmental cleanup and DWDM processes and outcomes. EPA and its state and local partners need to be able to navigate these dynamics on the ground.
- **Innovative Strategies for (Enhanced/Incorporating) Environmental Justice, Risk Communication, Building Trust, and Community Engagement during CBRN Incidents:** Effective community engagement and risk communication strategies are critical to conveying needed information before, during, and after an event. Building trust and social relationships with communities and other actors can help EPA achieve successful outcomes in cleanup work. Within the response continuum (preparedness, remediation, and recovery), research is needed in the areas of risk perception, community engagement and risk communication, and access to information.
- **Identifying vulnerable populations (including those facing compounding disasters), accounting for local priorities, and tool integration, improvement, and/or development:** When building community resilience, social considerations such as equity and vulnerability need to be included in the initial discussion before a disaster takes place. EPA regional staff are asked to help communities build resilience and need frameworks and tools to do so holistically.

Appendix 3: Output Descriptions

The following describe, in more detail, the ACE Research Program Outputs listed in Appendix 1. Outputs are planned under each Topic and respective Research Area (RA). It should be noted that the Outputs might change as new scientific findings emerge and are also contingent on budget appropriations.

Topic 1: Contaminant Characterization and Risk Assessment

RA HS2: Contaminant Characterization and Risk Assessment

Output HS.2.1: Developing Reliable Strategies, Data Management Capabilities, and Methodologies for Sampling, Processing, and Analysis to Address Contamination Incidents and Inform Mitigation and Remediation Decisions

Effective contaminant characterization, coupled with an understanding of the potential impact on public health, can play an integral role in site remediation and clearance. This Output will focus on developing research to support effective contamination characterization. Site characterization can inform decisions throughout incident response, including but not limited to the extent of contamination, assessment of decontamination efficacy, determination of waste streams, and re-occupancy and site reuse. Collectively, the HS tools developed under this Output for characterization, mapping, and data management will help local, state, tribal, and federal emergency response field personnel, and their supporting laboratories, more efficiently and confidently respond to incidents, enabling smoother transition of samples and data from the field to the laboratory to the decision-makers.

Output HS.2.2: Develop Capabilities to Address Persistence, Movement, and Related Phenomena to Understand Exposure Risk and Inform Mitigation and Remediation Decisions

Understanding contaminant fate and transport is important for assessing the risk of exposure during an incident and to inform sampling, decontamination, and waste management strategies. The ability to assess the persistence and movement of a contaminant in the environment, and potential continuous exposure risk over time, will play a crucial role when informing public health and remediation decisions. This Output will focus on identifying and quantifying issues related to the exposure, movement, and persistence of contaminants over wide areas and in water and wastewater systems. Research tools and models corresponding to contaminant fate and transport will be developed to inform decisions regarding sampling, decontamination, waste management, and operational countermeasures.

Topic 2: Environmental Cleanup and Infrastructure Remediation

RA HS.3: Wide-Area Decontamination

Output HS.3.1: Reliable Strategies, Tools, and Methodologies for Decontamination of Wide-Area Radiological Contamination Incidents

Wide-area radiological contamination incidents from natural disasters, accidents, and intentional releases will impact a large variety of infrastructures and environments, requiring informed mitigation and remediation strategies that facilitate an effective response. Research for this Output will focus on 1) Tools and practices for reducing potential for exposure of workers and the public to contaminants during decontamination operations; 2) Solutions for optimizing operational interdependencies during remediation, including decontamination and waste management; and 3) Stabilization and mitigation of

points of high contaminant concentration. The impact of this Output will be improved preparedness of EPA responders and communities to respond to and recover from radiological contamination releases.

Output HS.3.2: Reliable Strategies, Tools, and Methodologies for Decontamination of Chemical Contamination Incidents

Chemical contamination incidents that can impact a large variety of infrastructures and environments will require informed mitigation and remediation strategies to facilitate an effective response. Research for this Output will focus on 1) Containment technologies for chemicals of concern in the indoor and outdoor environments, 2) Decontamination decision support information associated with cleanup of indoor and outdoor environments contaminated with chemicals of concern, 3) Decontamination approaches for building materials and equipment contaminated with chemicals of concern, and 4) Decontamination line procedures associated with a Novichok incident response. The impact of this Output will be the improved preparedness of EPA responders and communities that need comprehensive remediation capabilities to respond to and recover from chemical contamination incidents resulting from warfare agent and fentanyl releases rapidly and effectively.

Output HS.3.3: Reliable Strategies, Tools, and Methodologies for Decontamination of Wide-Area Biological Contamination Incidents

Biological contamination incidents from natural disasters and intentional releases will impact a large variety of infrastructures and environments, requiring informed mitigation and remediation strategies to facilitate an effective response. The research for this Output will focus on 1) Concept of Operations (CONOPS) and strategies for wide-area remediation and contagion events; 2) Decontamination methods, effectiveness information, and risk reduction options for wide-area contagion and agricultural events; 3) Test Methods and evaluation of novel products and devices for possible EPA registration; and 4) Technical information and training for EPA responders and special team members on emerging and unknown threats. The impact of this Output will be the improved preparedness of EPA responders and communities that need comprehensive remediation capabilities to respond to and recover from biological contamination incidents rapidly and effectively.

RA HS.4: Water Systems Incident Response Support

Output HS.4.1: Tools and Methodologies to Inform Infrastructure Decontamination and Management of Drinking Water, Wastewater, and Stormwater

Resilient water infrastructure systems can facilitate quick and effective decision-making during emergency situations to ensure access to adequate water capacity and quality. This Output focuses on understanding the movement and persistence of contaminants in water and wastewater systems to inform decisions regarding detection, decontamination, waste management, and operational countermeasures. The priority is to provide tools and methodologies to facilitate resumption of operations in drinking water, wastewater, and stormwater systems, as well as protection of source water. The impact of this body of work will be a resilient water sector, with tools and methodologies to respond to drinking water, wastewater, stormwater, and source water contamination incidents and minimize the time that these systems are offline.

Output HS.4.2: Full-Scale Testing of Cyber Vulnerabilities on Water System Infrastructure and Evaluation of Response and Mitigation Actions

Resilient water infrastructure systems can facilitate quick and effective decision-making during emergency situations, including cyberattacks, to ensure access to adequate water capacity and quality. In partnership with OW, DHS, water utilities and private sector partners, the focus of this Output will be demonstrating and documenting the impact of cybersecurity vulnerabilities on internet-facing operating technology process control systems used to operate water and wastewater systems and identifying and evaluating response or mitigation actions that could counter or prevent the impacts of a cyberattack. Ultimately, the impact of this work will be a water sector with the tools and methodologies needed to prevent or mitigate high impact cyberattacks on both physical and SCADA infrastructure. This research could also lead to cybersecurity training for water utility operators on prevention and mitigation methods. Finally, cyber prevention and mitigation results will likely have impacts in other sectors. This is particularly true for the oil and gas industry, which uses hardware and SCADA that is similar to the water sector.

RA HS.5: Oil Spill Response Support

Output HS.5.1: National Contingency Plan Regulatory Support

The NCP includes a Product Schedule (NCPPS) for commercially available spill treating agents (dispersants, surface washing agents, herders, solidifiers, etc.). The Clean Water Act and the Oil Pollution Act[5] of 1990 give EPA the authority to prepare and maintain this schedule. The NCP also requires that the EPA maintain reference oils for product testing. To meet the continuing needs for the NCPPS, ORD research will develop and refine the protocols for product effectiveness and toxicity that are used to inform regulatory actions. This Output also provides spill preparedness guidance for emergency responders on product performance and evaluating tradeoffs to potentially impacted communities and ecosystems. This Output aims to 1) develop efficacy tests for surface washing agents, with evaluating product performance in fresh and salt waters; 2) develop toxicity procedures and threshold determinations for regulatory listing by establishing Lethal Concentration 50s (LC50) for a range of crude oils; and 3) evaluate potential reference oils for dispersant effectiveness, chemical characterization, and toxicity to enable OLEM to select new reference oils.

Output HS.5.2: Behavior, Monitoring, Fate and Effects of Oil and Spill Treating Agents

This Output covers research dedicated to characterizing the behavior, transport, fate and effects of various oils and spill agents, including diluted bitumen and low sulfur fuel oils, which can pose remediation challenges due to unique chemical and physical behavior. This Output meets the continued need to better understand the chemical characterization, biodegradation, weathering, and toxicity of a range of oils, oil residues and spill agents. Studies at the laboratory, tank and field scales improve our ability to minimize environmental and human impacts from spills and serve to improve numerical models of oil tracking. Development and evaluation of cutting-edge detection technologies improve slick and plume monitoring capabilities for decision making during skimming, burning and dispersant operations. Understanding behavior informs predictions of oil fate and transport, improves the selection of monitoring tools, and helps establish appropriate response, remediation and restoration methods including Net Environmental Benefit Analysis.

[5] Oil Pollution Act information can be found at epa.gov/enforcement/oil-pollution-act-opa-and-federal-facilities.

RA HS.6: Waste Management

Output HS.6.1: Advancing Approaches and Tools for Waste and Materials Management
To support decisions such as where to treat, dispose, or recycle incident waste and debris— including where to stage the waste, and how to transport it—the research in this Output includes the development and evaluation of scalable waste treatment technologies, particularly those that can be deployed on-site. Additionally, research under this Output seeks to advance, consolidate, and maintain the suite of waste management tools and run case studies to provide resources for the OLEM's All Hazards Waste Management Pre-Planning Tool (AHWMPPT)[6] and incident-specific information during a response, as well as to provide example scenarios to support emergency planners' needs to have realistic pre-incident scenarios on which to base their planning. Through this research, advanced technologies (e.g., imagery from aerial unmanned vehicles) will be developed and evaluated for estimation of waste, improving overall waste management capabilities and practices.

Topic 3: Community Engagement & Systems-Based Tools Supporting Resilience Equity

RA HS.7: Systems-Based Decision Making

Output HS.7.1: Systems-Based Information and Tools to Support Response and Recovery Decision-Making
Determining the most effective and efficient response and recovery actions following a wide-area contamination incident or natural disaster can be challenging. By providing systems-based information, methods, and tools, decision-makers will understand the interdependencies between the built and natural environments and associated impacts from the connected response and recovery actions of emergency mitigation, characterization, environmental cleanup, operations management, and waste management. This Output will support decision-makers in responding to and recovering from contamination incidents and natural disasters by presenting a systems-based approach that helps to identify effective and efficient actions.

Output HS.7.2: Models, Tools, and Information to Build Equitable Community Resilience to the Changing Climate Induced Disasters
The increased incidence of extreme weather events and natural disasters means that better and more resilient critical infrastructure is needed. Disasters can cause cascading and catastrophic impacts to infrastructure; in addition, chronic, incremental changes related to climate could make response/recovery to a CBRN incident more difficult (e.g., reduced snowpacks affect water supplies for wash water; increased temperatures affect personnel wearing personal protective equipment) and could cause CBRN contamination incidents. Understanding these changes and adjusting tools, models, and guidance is needed. This Output aims to assist decision makers in having timely access to information and the tools they need to ensure equitable community resilience when planning for and to responding to catastrophes, including those caused by climate change.

[6] For more information of AHWMPPT, please visit wasteplan.epa.gov/.

RA HS.8: Communities, Resilience, and Remediation

Output HS.8.1: Social Analysis of Remediation, Removal, and Disaster Waste and Debris Management (DWDM) Decisions and Outcomes

To enable equitable engagement in decisions and outcomes related to remediation, removal, and disaster waste and debris management (DWDM), EPA and its partners need to be able to navigate social dynamics among actors and institutions that affect environmental cleanup. This Output is intended to address the needs of responders to navigate community power dynamics and stakeholder conflicts; identify decision intervention points (for example, in external organizations and incident command structures); and improve EPA's ability to demonstrate that remediation and removal work has positive, measurable societal and environmental benefits. Social science research under this Output may support the potential development of tools or resources related to stakeholder process maps, pre-incident community education, metrics to assess societal benefits, and comparisons of community engagement processes and groups. Work in this Output will further bring social considerations into EPA's work related to remediation, removal, and disaster waste and debris management decisions and outcomes, including building equity into the decisions, successfully navigating conflicts, and improving EPA's ability to assess benefits of the work.

Output HS.8.2: Developing Effective Community Engagement Strategies for Building Trust, Addressing Environmental Justice Concerns, and Communicating Risks

Within the response continuum (preparedness, remediation, and recovery), research is needed to develop effective community engagement strategies for building trust, addressing environmental justice concerns, and communicating risks. Work in this Output focuses on elements of effective communication, including how to have successful engagements with communities (especially those historically underserved or left out of decision-making processes), building trust and relationships with communities, understanding how different communities perceive and evaluate risk, and how to learn who is trusted in the community and how information might flow before, during, and after an event. In this Output, products may be developed that identify and/or develop resources on culture, engagement, and building trust, with a focus on the community's perspective. Risk communication materials specific to preparedness, response, and recovery may also be developed. Effective community engagement can be bolstered by EPA staff having these additional cultural, communication, and trust-building resources.

Output HS.8.3: Social Considerations for Building Community Resilience

To include social considerations such as equity and vulnerability in initial discussions before a disaster takes place, EPA Partners (including staff in Regional Offices and other Programs connected to communities) need tools and frameworks to help communities holistically build resilience. EPA has several existing tools that need additional testing and enhancements to further meet these needs; for example, the Equitable Resilience Builder tool currently in development, and the Environmental Resilience Tools Wizard. In this Output, along with conducting the supporting research, existing tools will be tested and updated with additional features or modules. Development of additional social science resources and materials specific to responders and the communities they engage may also occur in this Output. Increased access to and use of EPA resilience tools, in addition to the tools' enhancements, can lead to improved inclusion of social considerations when building community resilience.

Appendix 4: Cross-Cutting Research Priorities

Working together on Agency priorities that cut across the six National Research Programs (NRPs), ORD will integrate efforts, provide a research portfolio aligned around the Agency's goals, and assist all of EPA's program and regional offices as well as states and Tribes. Where appropriate, the NRPs will combine efforts on the following cross-cutting priorities to conduct research that advances the science and informs public and ecosystem health decisions and community efforts. Although research efforts have been highlighted for each of these cross-cutting priorities, this does not mean that the research efforts only support that priority; the efforts may cut across priorities.

NRPs: Air, Climate, and Energy (ACE); Chemical Safety for Sustainability (CSS); Health and Environmental Risk Assessment (HERA); Homeland Security (HS); Sustainable and Healthy Communities (SHC); and Safe and Sustainable Water Resources (SSWR). The Strategic Research Action Plans for the NRPs are available on ORD's website at epa.gov/research/strategic-research-action-plans-2023-2026.

Environmental Justice

ORD's NRPs will integrate research efforts to identify, characterize, and solve environmental problems where they are most acute, in and with communities that are most at risk and least resilient. Research will strengthen the scientific foundation for actions at the Agency, state, tribal, local, and community levels to address environmental and health inequalities in vulnerable populations and communities with environmental justice and equity concerns. Coordinating research efforts will lead to a better understanding of how health disparities can arise from unequal environmental conditions, including impacts from climate change and exposures to pollution, and inequitable social and economic conditions. By working across NRPs, and through partner engagement, information, tools, and other resources will be developed that help support decision-making and empower overburdened and under-served communities to take action for revitalization.

Integrated Efforts Across National Research Programs	
ACE	Understand inequities in air pollution exposures and impacts, and impacts of climate change, accounting for social, cultural, and economic determinants that can lead to disproportionate exposures and impacts. Develop science to support effective interventions to reduce air pollution exposures and impacts, and adaptation and resilience measures to address climate impacts, including excessive heat (urban heat islands), flooding, and wildfires.
CSS	Investigate factors relevant to exposures for populations experiencing disproportionate adverse impacts from chemical exposures.
HERA	Expand the identification and consideration of information on susceptibility and differential risk in assessments, advance the evaluation of chemical mixtures and improve cumulative risk assessment practices to better characterize and assess health disparities.
HS	Assess and address community needs and vulnerabilities to ensure equitable incident management during disaster response and recovery by analyzing the community-specific cumulative impacts and the social implications of environmental cleanup; and by identifying potential interventions.
SHC	Identify risks and impacts to vulnerable communities and groups and improve the ability of communities to address cumulative impacts from contamination, climate (e.g., natural disasters and extreme events), and other stressors on health and the environment.
SSWR	Help provide clean and adequate drinking water and tools for stormwater management and urban heat island mitigation.

Climate Change

Understanding and addressing climate change impacts to human health and the environment is a critical component of ORD's research. To be effective, climate change research must be scientifically broad and systems-based. Where appropriate, the NRPs will integrate efforts to avoid duplicative efforts, fill critical gaps, and provide results that reflect the multiplicity of impacts and needs associated with climate change. Each NRP recognizes the critical need for continued communication with ORD partners to ensure that we are taking advantage of opportunities for collaboration, integration, and understanding.

Integrated Efforts Across National Research Programs	
ACE	Better understand and characterize air pollution and climate change and their individual and interrelated impacts on ecosystems and public health and identify and evaluate approaches to reduce the impacts of climate change through mitigation of climate forcing emissions, adaptation strategies, and building resilience in communities and ecosystems. Model energy, emissions, and environmental impacts of transformations in the nation's energy, transportation, and building sectors, and identify approaches to increase equitable benefits of those transformations.
CSS	Explore the use of newer analysis methods for identifying chemical contamination in environmental media after large catastrophic environmental events, such as wildland fires.
HERA	Continue development of assessments of air pollutants to inform climate policy efforts and leverage expertise, approaches, tools, and technologies in support of further climate change impact assessments.
HS	Enhance capabilities and develop new information and tools to maximize relevance and support for response and recovery from natural disasters related to climate change.
SHC	Integrated systems-approach research applicable to challenges that communities, including those with contaminated sites, face in preparing for and recovering from the impacts of natural disasters and climate change, ensuring that approaches are beneficial and equitable for the communities at risk.
SSWR	Improve resiliency of water resources and infrastructure to mitigate impacts related to climate change, including coastal acidification and hypoxia, harmful algal blooms, wildland fires, drought and water availability, stormwater flooding and combined sewer overflows, and urban heat islands.

Cumulative Impacts

Addressing the cumulative impacts of exposure to multiple chemical and non-chemical stressors is necessary for EPA to fulfill its mission to protect human health and the environment with the best available science. Cumulative Impacts refers to the total burden—positive, neutral, or negative—from chemical and non-chemical stressors and their interactions that affect the health, well-being, and quality of life of an individual, community, or population at a given point in time or over a period of time. It is the combination of these effects and any resulting environmental degradation or health effects that are the focus of ORD's cumulative impacts research. The NRPs will integrate efforts to improve understanding of cumulative impacts and develop and apply the necessary models, methods, and tools to conduct real-world assessments of cumulative impacts that result in both adverse and beneficial health and environmental effects. With this information, internal and external partners can

make informed, scientifically credible decisions to protect and promote individual, community, and environmental health.

Integrated Efforts Across National Research Programs	
ACE	Develop measurement methods and approaches to characterize ambient air quality and deposition, and human and ecosystem exposures to chemical (including criteria pollutants and air toxics) and non-chemical (including built environment, social, and climate-related) stressors, and health impacts from exposure to the combination of chemical and non-chemical stressors
CSS	Development and application of new approach methodologies to rapidly generate exposure and hazard information for chemicals, chemical mixtures, and emerging materials and technologies (including safer alternatives).
HERA	Research to advance the evaluation of chemical mixtures and improve cumulative risk assessment practices to better characterize and assess health disparities in communities with environmental justice and equity concerns.
HS	Through a focus on resilience equity, ensure that information and tools include the multitude of stressors impacting a community when used to support incident response. Research will recognize that resilience to an incident is directly impacted by the cumulative impacts of the incident and other stressors affecting a community.
SHC	Address the risks and impacts to improve the ability of communities to address cumulative impacts from contamination, climate, and other chemical and nonchemical stressors on health and the environment.
SSWR	Support human health ambient water quality criteria for chemical mixtures through research using bioassays and risk management, and assessment for exposure to groups of regulated and unregulated disinfection byproducts (DBPs) and opportunistic pathogens.

Community Resiliency

It is critical that communities have the knowledge and resources needed to prepare for and recover from adverse situations, such as natural disasters, contamination incidents, and failing infrastructure. Through combined research efforts, the NRPs will provide information and resources that support and empower communities to make science-based decisions to withstand, respond to, and recover from adverse situations.

Integrated Efforts Across National Research Programs	
ACE	Improve evaluations of climate change adaptation and mitigation measures and community resiliency to extreme events in a changing climate, such as wildfire, floods, heat waves, and drought—especially for vulnerable and disadvantaged communities experiencing environmental injustice.
CSS	Efforts relevant to chemical safety evaluations will be leveraged with other NRP activities.
HERA	Continue to expand the portfolio of assessment products to improve understanding of potential human health and environmental impacts of contamination incidents.
HS	Generate resources and tools for environmental cleanup, risk communication, outreach, building relationships, and community engagement to improve equitable community resilience for environmental contamination incidents and other disasters.
SHC	Increase resilience by reducing potential risks, promoting health, and revitalizing communities.
SSWR	Support coastal resilience by advancing monitoring, mapping, and remote sensing and by the economic valuation of coastal resources. Improve the performance, integrity, and resilience of water treatment and distribution systems through research on water infrastructure and water quality models.

Children's Environmental Health

From EPA's 2021 Policy on Children's Health, "children's environmental health refers to the effect of environmental exposure during early life: from conception, infancy, early childhood and through adolescence until 21 years of age." Environmental exposures that impact health can occur before conception, and during pregnancy, infancy, childhood, and adolescence; and include long-term effects on health, development, and risk of disease across lifestages. Much of ORD's research is relevant to communities, including susceptible and vulnerable populations. Where appropriate, the NRPs will combine efforts to conduct research that will inform public health decisions, advance our scientific understanding of early-life susceptibility to environmental stressors, and inform community efforts that create sustainable and healthy environments protective of all lifestages.

Integrated Efforts Across National Research Programs	
ACE	Explore air pollution and climate health impacts within different lifestages and populations, including overburdened groups. Assess vulnerabilities to air pollution for those with chronic illnesses and sequelae from respiratory viruses. Research social determinants of health, and air pollution impacts resulting from different exposure time-activity patterns.
CSS	Research will build the scientific foundation to predict adverse outcomes resulting from chemical exposures in various biological contexts, including early life-stage susceptibility.
HERA	Continue to evaluate health effects, over the course of a lifetime, from environmental exposure to stressors during early life (i.e., from conception to early adulthood) to inform decision-making and advance research on methods to properly characterize risks to children.
HS	Improve and develop decision-support tools and cleanup capabilities to make children less vulnerable during response to, and recovery from, contamination incidents.
SHC	Address the risks and impacts to vulnerable communities and lifestages, including underserved/overburdened communities, and improve the ability of communities to address cumulative impacts from contamination, such as site clean-ups of per- and polyfluoroalkyl substances (PFAS) and lead; climate, such as natural disasters and extreme events; and other stressors on health and the environment.
SSWR	Evaluate health effects and toxicity related to algal toxins and expanded research that will explore exposure risks for lead, DBPs, and—through quantitative microbial risk assessment models—for high priority opportunistic pathogens in drinking water (e.g., *Mycobacterium*, *Pseudomonas*, *Naegleria fowleri*).

Contaminants of Immediate and Emerging Concern

Contaminants of immediate and emerging concern (CIECs) include chemical substances that may cause ecological or human health impacts and are either new or existing contaminants of increased priority. The NRPs will work with EPA partners in the program and regional offices, along with input from Agency leadership, to identify the highest priority contaminants (broadly defined to include chemical, biological, and other

categories as appropriate), including those of immediate concern, such as PFAS and lead, that warrant further research attention.

Integrated Efforts Across National Research Programs	
ACE	Develop and evaluate measurement methods and approaches to characterize sources of air pollutants and climate forcing pollutants, such as measurement of emissions of criteria pollutant precursors and air toxics, including emerging concerns, such PFAS and EtO.
CSS	Continue to develop new approach methods for CIECs with a focus on applying these, as appropriate, for prioritization, screening, and risk assessment for decision making.
HERA	Continue and expand the portfolio of assessment products, as well as advance risk assessment models and tools, to better characterize potential human health and environmental impacts of new and existing contaminants.
HS	Predict the movement of chemical, biological, and radiological contaminants in the environment resulting from environmental contamination events and develop tools and methods for effective characterization, decontamination, and waste management.
SHC	Advance site clean-ups of PFAS and lead to protect vulnerable groups, especially children.
SSWR	Research on PFAS, including innovative drinking water and wastewater treatments, support for future drinking water regulations, the development of aquatic life criteria, management in water resources, and evaluation of land-applied biosolids; contaminants of emerging concern (CECs), lead, opportunistic pathogens, and DBPs in drinking water; cyanobacterial metabolites other than microcystin (e.g., anatoxin, saxitoxin, and nodularin); microplastics in sediments and surface water; and CECs (non-PFAS) in wastewater treatment systems and biosolids.