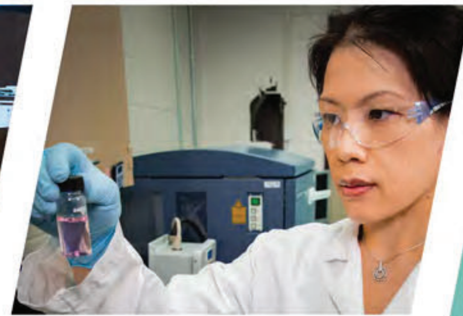
United States
Environmental Protection
Agency

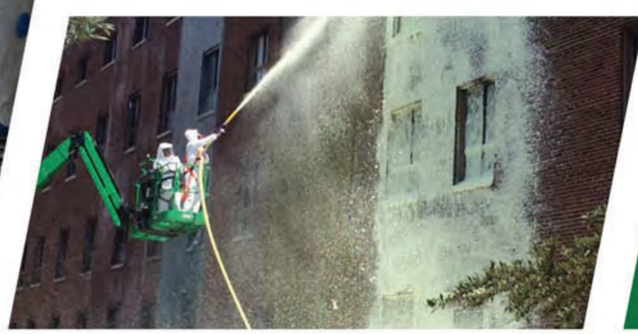
EPA 601/K-15/007 November 2015 www.epa.gov/research



Homeland Security

STRATEGIC RESEARCH ACTION PLAN

2019-2022



Office of Research and Development
Overview: Science for a Sustainable Future

Homeland Security Research Program

Strategic Research Action Plan, 2019 – 2022

DRAFT

November 15, 2018 version

Table of Contents

List of Acronyms

CAA	Clean Air Act
CBRN	Chemical, biological, radiological, and nuclear
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CIPAC	Critical Infrastructure Protection Advisory Committee
CONOPS	Concept of operations
CSS	Chemical Safety for Sustainability
CWA	Clean Water Act
HHS	U.S. Department of Health and Human Services
DHS	U.S. Department of Homeland Security
DOD	U.S. Department of Defense
DPAS	Decontamination Preparedness and Assessment Strategy
DWH	Deepwater Horizon
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERLN	Environmental Response Laboratory Network
ESAM	Environmental Sampling and Analytical Methods
ESF	Emergency Support Function
FAD	Foreign animal diseases
FSMA	Food Safety Modernization Act
HHRA	Human Health Risk Assessment
HSA	Homeland Security Act
HSPD	Homeland Security Presidential Directive
HSRP	Homeland Security Research Program
ICCOPR	Interagency Coordinating Committee for Oil Pollution Research
IMO	International Maritime Organization
NCP	National Contingency Plan
NCPPS	National Contingency Plan Product Schedule
NDRF	National Disaster Recovery Framework
NEBA	Net environmental benefit analysis
NRDA	Natural Resource Damage Assessment
NRF	National Response Framework
NRP	National Response Plan
NRT	National Response Team
NSTC	(White House) National Science and Technology Council
OAR	U.S. EPA Office of Air and Radiation
OCSPP	U.S. EPA Office of Chemical Safety and Pollution Prevention
OECA	U.S. EPA Office of Enforcement and Compliance
OEM	U.S. EPA Office of Emergency Management
OLEM	U.S. EPA Office of Land and Emergency Management
OPA	Oil Pollution Act
ORCR	U.S. EPA Office of Resource Conservation and Recovery
ORD	U.S. EPA Office of Research and Development
OW	U.S. EPA Office of Water
OWM	U.S. EPA Office of Waste Management

PAL	Provisional Advisory Level
PFAS	Per- and polyfluorinated alkyl substance
PFOA	Perfluorooctanoic acid
RCRA	Resource Conservation and Recovery Act
R&T	Research and Technology
SBIR	Small Business Innovation Research
SDWA	Safe Drinking Water Act
SHC	Sustainable and Healthy Communities
SSWR	Safe and Sustainable Water Resources
S&T	Science and technology
StRAP	Security Strategic Research Action Plan
USDA	U.S. Department of Agriculture
WCIT	Water Containment Information Tool
WLA	Water Laboratory Alliance
WSD	U.S. EPA Water Security Division
WSTB	Water Security Test Bed

Executive Summary

Caused naturally or by humans, environmental emergencies continue to challenge our nation. The use of chemical threats in Syria and the United Kingdom, the opioid epidemic, and several recent water system contamination incidents that affected hundreds of thousands of people, remind us of the impact that chemical contaminants can have on public health. Further, the radiological contamination following the Fukushima Daiichi nuclear disaster in 2011 demonstrated the significant impact and challenge of cleaning up large-scale contamination incidents. Smaller-scale incidents, such as the attempted ricin poisonings in several communities around the country, also highlight the ever-present threat of terrorism post 2001.

The U.S. Environmental Protection Agency (EPA) is responsible for helping communities prepare for and recover from disasters that result in threats to public health and the environment. The Office of Research and Development's (ORD) Homeland Security Research Program (HSRP) aims to increase the United States' capabilities to prepare for and respond to releases of oil and hazardous substances into the environment, as mandated by Congress. The hazardous substances involved can include chemical, radiological, nuclear, and biological materials. There are considerable gaps in our capabilities to address these risks, including understanding the behavior of contaminants when released into the environment, potential public exposures, determining where contamination is present that may pose an exposure risk, and cleaning up contaminated areas and infrastructure. Enhancing capabilities for response and remediation of contaminated areas and protecting water systems will improve our nation's resilience to environmental catastrophes.

The *Homeland Security Strategic Research Action Plan (StRAP)*, 2019-2022, is a four-year research strategy designed to meet the following objectives:

> **Research Objective 1:** Advance EPA's capabilities and those of our state, tribal, and local partners to respond to and recover from wide-area contamination incidents; and
>
> **Research Objective 2:** Improve the ability of water utilities to prevent, prepare for, respond to and recover from water contamination incidents that threaten public health.

EPA's HSRP is organized into three topics supporting these objectives: (1) contaminant characterization and consequence assessment; (2) environmental cleanup and infrastructure remediation; and (3) systems approaches to preparedness and response. Short- and long-term goals accomplished through research areas within these topics outline a strategy for addressing the objectives.

HSRP performs applied research that delivers relevant and timely methods, tools, data, technologies, and technical expertise in support of federal, regional, state, tribal, water system, and local community resilience. HSRP engages partners throughout the research life-cycle to ensure their needs are being met – from identifying scientific capability gaps, to performing research to address those gaps, to formulating and delivering timely and reliable products that fill those gaps, to implementing the products via collaborative field studies and exercises. HSRP products provide systems-based approaches to site characterization, risk assessment, and remediation (which includes waste management) to address large-scale contaminated areas and water systems. Federal, state, tribal, and local decision makers will have access to the information and tools they need to prepare for and recover from catastrophes involving environmental contamination incidents that threaten public health.

Introduction

The Homeland Security Strategic Research Action Plan (StRAP) for 2019-2022 is a four-year strategy to deliver research necessary to support the Environmental Protection Agency's (EPA) overall mission to protect human health and the environment, fulfill the EPA's legislative mandates, and advance cross-agency priorities identified in the FY2018-FY2022 EPA Strategic Plan (U.S. EPA, 2018a). This StRAP outlines how EPA's Office of Research and Development's (ORD) Homeland Security Research Program (HSRP) aims to meet the homeland security science needs of the EPA partners and stakeholders. EPA partners include EPA program and regional offices, federal agencies, state, and tribal governments supporting the protection of human health and the environment; stakeholders include local governments, non-governmental organizations, private industries, academic institutions and others with an interest or investment in public and environmental health.

The Homeland Security StRAP is one of six research plans, one for each of EPA's national research programs in ORD. The six research programs are:

- Air and Energy (A-E)
- Chemical Safety for Sustainability (CSS)
- Homeland Security Research Program (HSRP)
- Human Health Risk Assessment (HHRA)
- Safe and Sustainable Water Resources (SSWR)
- Sustainable and Healthy Communities (SHC)

EPA's six strategic research action plans lay the foundation for EPA's research programs to provide focused research that meets the Agency's legislative mandates and the goals outlined in the EPA and ORD Strategic Plans (U.S. EPA, 2018d). The StRAPs are designed to guide an ambitious research portfolio that delivers the science and engineering solutions EPA needs to meet its goals now and into the future, while also cultivating an efficient, innovative, and responsive research enterprise.

HSRP addresses science gaps related to remediation of environmental contamination that threatens public health and welfare, as well as science gaps related to environmental quality before, during, and after a disaster. In the U.S. National Response Framework (NRF) (U.S. DHS, 2016b) Emergency Support Function #10 (ESF-10) (U.S. DHS, 2008), EPA is designated as the lead agency in providing federal support to states in response to the release of oil or hazardous materials. Hazardous materials are defined by the U.S. National Contingency Plan (NCP) (U.S. EPA, 2018b) as hazardous substances, pollutants, and contaminants including chemical, biological, and radiological (CBR) substances. The NCP serves as the operational complement to the NRF, providing more specifics on EPA's role and responsibilities, as well as providing a strategic plan for responding to oil spills and other hazardous substance releases.

In addition, EPA has supporting roles under several other NRF Emergency Support Functions associated with cleanup, debris/waste management, and supporting water-related disasters. One example is EPA's supporting role under ESF-11 (U.S. DHS, 2016c) (led by the U.S. Department of Agriculture) in responding to "*any outbreak of a highly contagious or economically devastating animal/zoonotic (i.e., transmitted between animals and people) disease or any outbreak of an economically devastating plant pest or disease.*" EPA also supports local governments under the U. S. National Disaster Recovery Framework (NDRF) as a supporting agency in several Recovery Support Functions (U.S. DHS, 2016a). Through NDRF, support is provided to: (1) facilitate problem solving; (2) facilitate access to resources; and (3) to foster communication, coordination, and collaboration among state and federal partner agencies and non-governmental stakeholders.

In addition to these responsibilities, EPA is also designated as the Sector-Specific Agency lead for water and wastewater systems under the National Infrastructure Protection Plan and in response to Presidential Policy Directive 21 (PPD-21). As such, EPA also has a role in protecting water systems and supporting their resilience. More details on the NRF, NCP, PPD-21 and other mandates legislated to EPA are provided in the Statutory and Policy Context section.

HSRP helps EPA carry out its homeland security and emergency response mission by working closely with partners in EPA's program offices and regions, other federal agencies, states, and tribes to understand the potential threats and consequences of hazardous substance release. HSRP works in coordination with its partners and stakeholders to conduct research that gives decision makers the information they need for their communities and environments to rapidly recover after a disaster.

HSRP's general research approach is to adapt suitable methodologies that have proven effectiveness in a laboratory setting for success in real-world settings. Real-world settings can be challenging because affected environments are not pristine; grime and biofilms complicate the behaviors of sampling and cleanup technologies, thereby affecting responders' ability to sample and remediate sites. Furthermore, some response activities and decisions may occur in sequence where such activities are coupled to, or are dependent on, other response activities and decisions. Human behavior is not always predictable, stakeholder relationships must be negotiated, and risks can be difficult to communicate. HSRP develops information and tools for cleanup, waste management, characterization and assessment of hazards, and application of the latest information in decision making.

Research to Support the EPA Strategic Plan

In February 2018, EPA released its FY2018-FY2022 EPA Strategic Plan, which is designed to implement the Administrator's priorities for the next five years. This Strategic Plan identifies three overarching strategic goals: core mission, cooperative federalism, and rule of law and process (see Figure 1). EPA's research programs are aligned to the Strategic Plan and designed to ensure that the Agency successfully meets the goals and objectives articulated in the Strategic Plan.

Figure 1: FY2018-2022 EPA Strategic Plan

The first goal emphasizes EPA's Core Mission of improving air quality, providing clean and safe water, revitalizing land and preventing contamination, and ensuring chemical safety. HSRP directly supports this Core Mission through its applied research in response and remediation, a critical component of building resilience.

The second goal of EPA's Strategic Plan is Cooperative Federalism, which empowers the states and tribes in fulfilling environmental mandates. ORD has been working for the past six years to strengthen its direct relationship with states through partnerships with the Environmental Council of the States (ECOS) and the Environmental Research Institute of the States (ERIS). Over the past year, ORD implemented a Memorandum of Understanding with several health organizations, such as the National Environmental Health Association (NEHA) and the Association of State and Territorial Health Officials (ASTHO), to better engage the states and disseminate research to decision makers. ORD is also developing an Emergency Management State Engagement Strategy that will seek further collaboration with first responders, emergency managers, and others who rely on critical research information before, during, and after the response to a contamination incident.

Rule of Law and Process is the final goal of EPA's Strategic Plan. This goal includes the specific objective to prioritize robust science. ORD helps achieve this by conducting research and providing EPA programs and regions with the scientific support they need to develop innovative solutions to environmental challenges.

Statutory and Policy Context

Since the attacks of September 11, 2001 on the United States, the nation's homeland security enterprise was reconstructed, ultimately leading to better national protection from both natural and anthropogenic disasters. Prior to 9/11, EPA had authority and obligation to respond to emergencies, such as oil spills, and to develop research that would improve hazardous material removal actions primarily through the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Clean Water Act (CWA), and Safe Drinking Water Act (SDWA). Pesticide use may be necessary under some decontamination events, which is regulated by the Federal Insecticide, Fungicide, and Rodenticide Act.[1] In addition, the Robert T. Stafford Disaster Relief and Emergency Assistance Act gave EPA authority to prepare for and respond to disasters and emergencies (U.S. EPA, 2017). These responsibilities were further established through the NCP and Oil Pollution Act (OPA), which help guide the federal response to oil and hazardous-substance pollution incidents, with EPA as the lead for inland zones.

In the post-9/11 era, initial legislation directed the newly organized Department of Homeland Security (DHS) to coordinate executive agencies in developing research-based goals for countermeasures to chemical, biological, radiological, and nuclear (CBRN) threats ("Homeland Security Act," 2002). In addition to new legislation, executive orders and other actions also influence homeland security research. A major driver is Homeland Security Presidential Directive (HSPD) 5, which directed the development of the National Response Plan (NRP) in 2004 to bolster preparedness and response to emerging threats. HSPD 8,[2] released as a companion document to HSPD 5, directed development of the National Preparedness Goal (U.S. DHS, 2015) that established five Mission Areas of preparedness: (1) Prevention; (2) Protection; (3) Mitigation; (4) Response; and (5) Recovery. The Mission Area of "Response" requires the assessment of environmental hazards and directs EPA to "*detect, assess, stabilize, and clean up releases of oil and hazardous materials into the environment, including*

[1] https://www.epa.gov/pesticide-registration/pesticide-emergency-exemptions

[2] HSPD 8 has been replaced by the Presidential Policy Directive (PPD) 8, which establishes five categories of threat: natural hazards, human and animal infectious diseases, technological and accidental hazards, terrorist threats, and cybersecurity.

buildings/structures, and properly manage waste," in alignment with EPA's mission. The NRP was later superseded by the NRF (U.S. DHS, 2016b). This framework "sets the strategy and doctrine for how the whole community builds, sustains, and delivers the Response core capabilities identified in the National Preparedness Goal." (U.S. DHS, 2016b) The NRF has supplemental annexes that detail responsibilities, organization, and coordination for 15 specific areas that help ensure the success of the framework.

ESF-10, with EPA's its lead agency, can be activated by DHS during a federal response to a declared emergency. EPA also has independent authorities under CERCLA and CWA for response to applicable incidents. In addition, EPA serves as a support agency for seven other ESFs: Public Works and Engineering, Firefighting, Emergency Management, Public Health and Medical Services, Agriculture and Natural Resources, Public Safety and Security, and External Affairs.

Congress and the national security community recognized that incident response may need an approach that is distinct to specific sector needs. The Public Health Security and Bioterrorism Preparedness and Response Act required EPA and its partners to help water utilities conduct vulnerability assessments and develop emergency response plans. EPA's responsibilities include determining methods to prevent, detect, and respond to intentional and accidental CBR contaminations in water systems (U.S. EPA, 2018e). Furthermore, HSPD 7[3] helped define federal government roles and responsibilities within the homeland security enterprise for U.S. critical infrastructure. This directive designates EPA as the lead for drinking water and water treatment systems, and it requires EPA to "*identify, prioritize, and coordinate the protection of critical infrastructure and key resources in order to prevent, deter, and mitigate the effects of deliberate efforts to destroy, incapacitate, or exploit them.*"

The homeland security enterprise continues to evolve as incidents occur that challenge the framework for response and bring about new lessons-learned. These incidents can lead to legislative action, such as the Post-Katrina Emergency Management Reform Act, and identified vulnerabilities can lead to new Presidential Directives. This evolution of needs and directives further specifies EPA's role in incident response and, therefore, informs the design of the HSRP StRAP.

For a listing of legislation and executive actions that have shaped EPA's preparedness and response efforts, and hence HSRP, see Table 1.

Table 1: Homeland Security Research Program Supports Decisions Mandated by Legislation and Executive Actions

Legislation	Acronym	Website
Clean Air Act (1970)	CAA	https://www.govinfo.gov/app/details/STATUTE-84/STATUTE-84-Pg1676
Clean Water Act (1972)	CWA	https://www.govinfo.gov/app/details/STATUTE-86/STATUTE-86-Pg816
Safe Drinking Water Act (1974)	SDWA	https://www.govinfo.gov/app/details/STATUTE-88/STATUTE-88-Pg1660-2
Resource Conservation and Recovery Act (1976)	RCRA	https://www.govinfo.gov/app/details/STATUTE-90/STATUTE-90-Pg2795

[3] HSPD 7 was revoked by PPD 21, which states all plans developed pursuant to HSPD 7 remain in effect until specifically revoked or superseded.

Comprehensive Environmental Response, Compensation and Liability Act (1980)	CERCLA	https://www.govinfo.gov/app/details/STATUTE-94/STATUTE-94-Pg2767
Emergency Planning and Community Right-to-Know Act (1986)	EPCRA	https://www.govinfo.gov/app/details/STATUTE-100/STATUTE-100-Pg1613
Robert T. Stafford Disaster Relief and Emergency Assistance Act (1988)		https://www.govinfo.gov/content/pkg/USCODE-2015-title42/pdf/USCODE-2015-title42-chap68.pdf
Oil Pollution Act (1990)	OPA	https://www.govinfo.gov/app/details/STATUTE-104/STATUTE-104-Pg484
Federal Insecticide, Fungicide, and Rodenticide Act (1996)	FIFRA	https://www.govinfo.gov/app/details/STATUTE-110/STATUTE-110-Pg1489
Homeland Security Act (2002)	HSA	https://www.govinfo.gov/app/details/PLAW-107publ296
Public Health Security and Bioterrorism Preparedness and Response Act (2002)		https://www.govinfo.gov/app/details/STATUTE-116/STATUTE-116-Pg594
Post-Katrina Emergency Management Reform Act (2006)		https://www.govinfo.gov/app/details/PLAW-109publ295
Food Safety Modernization Act (2011)	FSMA	https://www.govinfo.gov/app/details/PLAW-111publ353
Executive Action	**Acronym**	**Website**
Homeland Security Presidential Directive-4 *National Strategy to Combat Weapons of Mass Destruction* (2002)	HSPD-4	https://www.hsdl.org/?abstract&did=860
Homeland Security Presidential Directive-5 *Management of Domestic Incidents* (2003)	HSPD-5	https://www.govinfo.gov/app/details/PPP-2003-book1/PPP-2003-book1-doc-pg229
Homeland Security Presidential Directive-9 *Defense of United States Agriculture and Food* (2004)	HSPD-9	https://www.govinfo.gov/app/details/PPP-2004-book1/PPP-2004-book1-doc-pg173
Homeland Security Presidential Directive-18 *Medical Countermeasures Against Weapons of Mass Destruction* (2017)	HSPD-18	https://www.hsdl.org/?abstract&did=456436
Presidential Policy Directive-22 *Domestic Chemical Defense*	HSPD-22	Classified
Presidential Policy Directive-8 *National Preparedness* (2011)	PPD-8	https://www.hsdl.org/?abstract&did=7423
Presidential Policy Directive-21 *Critical Infrastructure Security and Resilience* (2013)	PPD-21	https://www.govinfo.gov/app/details/DCPD-201300092
National Security Presidential Memorandum-14 *Support for National Biodefense* (2018)	NSPM-14	https://www.whitehouse.gov/presidential-actions/presidential-memorandum-support-national-biodefense/
Executive Order-13636 *Improving Critical Infrastructure Cybersecurity* (2013)	EO-13636	https://www.govinfo.gov/app/details/DCPD-201300091

Environmental Problems and Program Purpose

In 2001, a few grams of *Bacillus anthracis* (*B. anthracis)* spores (the causative agent for the bacterial disease anthrax) mailed through the U.S. Postal Service resulted in the contamination of several postal facilities and public and private buildings. EPA was tasked to support the cleanup of numerous facilities during the 2001 anthrax incidents. The cleanup process faced many challenges. At the time, there were no methods to determine which facilities were contaminated, no capabilities for cleaning up contaminated areas, no means to manage waste generated from cleanup activities, and the government did not fully understand the risk to workers and the public. The ultimate development and adaptation of methods for sampling, analysis, cleanup, waste management, and risk assessment were created on a site-by-site basis and resulted in cleanup efforts taking years and costing taxpayers hundreds of millions of dollars.

The resulting exposure of workers and the public, including five deaths attributed to inhalation of *B. anthracis* spores, made bioterrorism a reality in the United States. The reality of bioterrorism also highlighted the possibility of an ever-growing list of other potential threats (including biological, chemical, and radiological contaminants) being released in urban/suburban environments and the intentional contamination of water systems.

EPA and other federal agencies have invested considerable effort since the incidents in 2001 to build the nation's capabilities. Incremental advances have been made and standardized in: (1) early warning for biological threat release; (2) sampling and analysis methods for indoor areas; (3) cleanup methods for facilities; (4) waste management approaches; and (5) biological risk assessment methodologies. However, the United States continues to lack the full capability and capacity to effectively address large, wide-spread contamination incidents the size of, for example, lower Manhattan, or Washington DC's drinking water distribution system.

The scenarios that challenge our current capabilities are real threats. The 2011 Fukushima nuclear power plant disaster resulted in immense impacts to the public, environment, and the economy of Japan, further exacerbated by the lack of tools and technologies to address the challenge of large and complex environmental cleanup in an area the size of Connecticut. The international Ebola outbreak in 2014 demonstrated the challenges of environmental decontamination to stop the spread of disease and manage voluminous biological wastes resulting from cleanup actions and health care delivery. The few Ebola cases in the United States were enough to spotlight the challenges that would be faced in a wide-spread biological incident. A relatively mild accident like the backflow of a dilute industrial chemical into Corpus Christi's distribution system in 2017 caused a ban on water use for much of the city's 300,000 residents for approximately 4 days causing mass disruption to daily life and huge economic costs. A major incident, such as a highly toxic chemical warfare agent attack on a water system, would likely result in much greater impacts. Chemical warfare agents have been used multiple times recently in the Syrian civil war and in the United Kingdom, highlighting the threat and impact if used in the United States. Natural threats also continue, such as Hurricane Maria damaging much of Puerto Rico's drinking water systems, leading to a lack of safe water and increased waterborne disease incidents.

A disaster that results in wide-spread CBRN contamination over a large outdoor area, or throughout a water and wastewater system, presents a daunting challenge to EPA, state, tribal and local responders in carrying out their responsibilities. Once released into the environment, contaminants can spread via natural forces and human activities. For example, a contaminant released in an urban center can spread across the city by transportation systems, such as subways or airports, and into and out of buildings.

DHS ran a realistic simulation showing that an intentional release scenario[4] of a 100-liters of a *B. anthracis* spore slurry in Denver could result in many square miles of contamination, with associated public health and economic damages (U.S. EPA, 2012b).

Contamination can also spread from the initial release point to other communities. The potential for cross-media spread of contamination is depicted in Figure 2 and represents a sample of the complex scenario that large-scale contamination incidents present to communities.

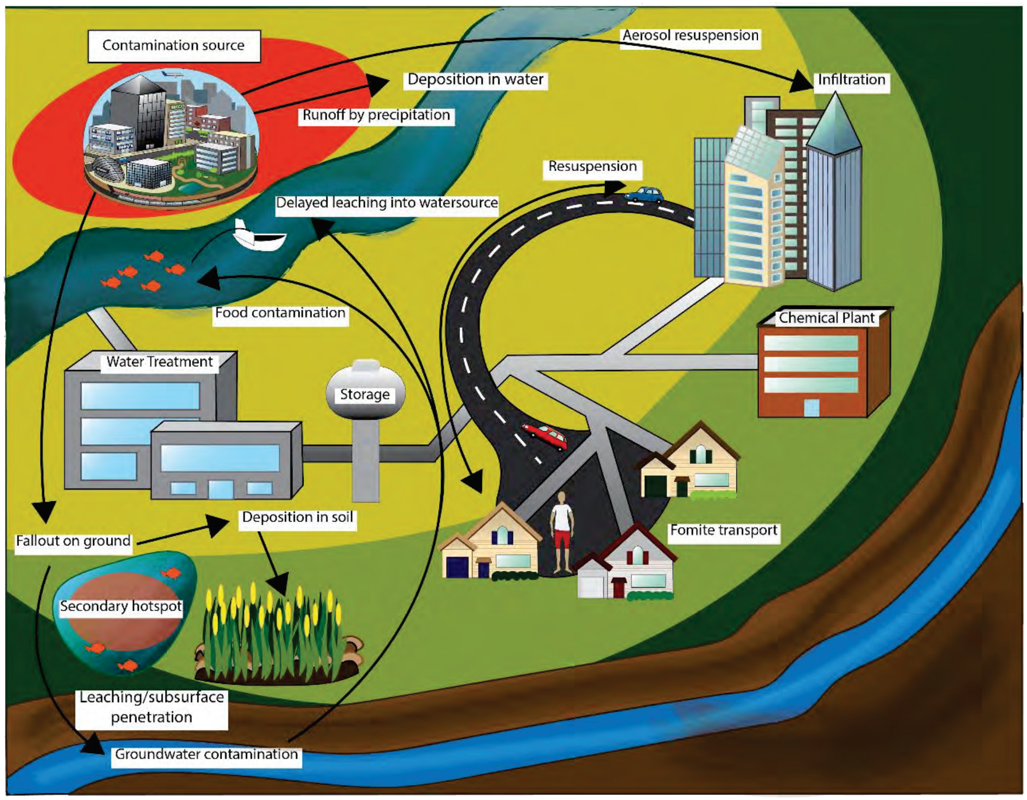


Figure 2: Schematic Overview of a Wide-Area and Water-System Contamination Incident for Scenario-Based Resilience Planning

Natural forces such as wind and water (e.g., rain and stormwater runoff) can distribute contaminants from one area to another. Human activities, such as walking and driving, can result in contaminants being picked up and transferred to other places or other people. These and other activities can result in contaminants deposited on surfaces being re-aerosolized, resulting in transport of the contaminants by air currents and the potential for subsequent human exposure. The transfer of contaminants on clothing, vehicles, or other inanimate objects can also play a major role in the spread of contamination.

[4] The Wide Area Recovery and Resiliency Project (WARRP) was conducted in 2011-2013 as interagency effort led by DHS Science and Technology Directorate to enhance the wide-area recovery capabilities to "e*nable a timely return to functionality, restore basic services, and re-establish social and economic order following a catastrophic incident.*" (U.S. DHS, 2012) The biological release scenario was a 100-liter *B. anthracis* spore slurry sprayed from a truck-mounted pesticide sprayer. This aerosol release was modelled to look at spread and deposition over Denver.

Drinking water systems can become contaminated by several mechanisms causing direct threats to public health. Distribution systems can become contaminated when source water becomes polluted to such an extent that treatment plants cannot remove the contamiatnion. Such source water contamination can result from releases by industrial sources caused by accidents or natural disasters. Distrubtion systems can be directly contaminated by industiral accidents, pipe breaks, or intentionally. to cause terror and economic losses.

There is also considerable uncertainy in the effectiveness of sampling methods to characterize wide-spread contamination, in decontamination methods to reduce or eliminate contamination in complex urban environments, and in the ability to manage the vast amount of waste that could be generated. Current methods used in previous, smaller-scale CBRN incidents are not readily suitable for deployment over large areas. The dynamic nature of the contaminant within the environment, coupled with the lack of readily-available tools, lead to considerable challenges in ensuring communities are resilient to disasters. The United States needs remediation methods that are rapidly deployable and scalable, with documented effectiveness. With readily-available approaches repurposed from other sectors, responders can adapt methods to address different-sized incidents and unanticipated challenges within finite budget and time contraints.

As a real-world example, consider the release of asbestos-containing ash from a warehouse fire in 2017 that caused wide area asbestos contamination of North Portland, Oregon. Asbestos-containing debris was thought to spread as far as two miles on each side of the Willamette River. EPA provided support to the Oregon Department of Environmental Quality to clean up debris and assess the potential for public exposure. This incident presented the challenge of determining where asbestos fibers might have settled over a 13-square mile area and raised concerns for suspended particle (dust) transfer of asbestos into residences. Researchers and responders had to address many questions, such as how to determine which areas were contaminated (both indoors and outdoors), what type of sampling was both effective and technically feasible over the potentially contaminated, large area, and the impact of wind, rain, and human activity on the redistribution of asbestos and, hence, the value of sampling results from a previous day. This incident provided a vivid example of the challenges that would be faced if CBRN contaminants are spread over an urban area.

Science to support response decisions prior to and during a disaster should consider long-term recovery. The decisions and priorities set by an impacted community prior to a disaster (prevention and protection pillars in the NDRF) and during the mitigation and response phase of a disaster have a cascading effect on the overall recovery (U.S. DHS, 2016a). The importance of community engagement highlights the need to understand the social-environmental system interactions as scienitific solutions to mitigation and response are developed. Contaminant movement, exposure, and susceptibility are affected by social as well as environmental systems. So too are decontamination actions and outcomes.

The dynamic nature of wide-area contamination (including indoor, outdoor, and water system impacts) highlights the complexity of response activities to ensure that communities across our nation are resilient to disasters. Although EPA's homeland security responsibilities related to the NRF ESF-10 focus primarily on mitigation and response, the ultimate purpose of resilience is for communities to recover rapidly from a disaster. Further, as the sector-specific lead for water and wastewater infrastructure, ensuring resilience of water systems also includes understanding and reducing vulnerabilities to contamination incidents.

Considering the general widespread contamination scenario discussed above, HSRP focuses on supporting community resilience to disasters by supporting decision makers in addressing questions such as:

- What tools and strategies are available for sampling wide areas or water systems to determine the extent of the contamination?
- How can movement of contaminants in the environment be predicted, monitored, or suppressed in support of sampling, cleanup, and public health decisions?
- How can detection, surveying, monitoring, and sampling information be used to guide public health decisions, including mitigating human exposure potential?
- How can wide areas and water systems be rapidly and safely cleaned up and returned to normalcy?
- How can water systems be protected against contamination incidents?

In addressing these questions through research, HSRP focuses on priority CBRN threat agents that challenge the current capabilities of response. Irrespective of the cause of the contamination, communities need capabilities and support for hazards impacting public health. Predicting the next disaster and its impacts is nearly impossible. Recent major disasters in the United States (e.g., West Virginia's water contamination incident in 2014, the Ebola virus outbreak in West Africa in 2014 and subsequent Ebola cases in the United States, and the avian flu outbreak in the poultry industry in 2015,) and abroad (e.g., Fukushima Daiichi Nuclear Power Plant accident in 2011) highlight the unpredictable nature of disasters and their consequences for communities. PPD-21 outlines a holistic approach to homeland security, which is known as the "all hazards" approach with respect to building resilience to disasters.[5] HSRP uses this approach in drafting the mission and design of this research program.

<u>Problem Statement</u>

Disasters often result in environmental contamination that can threaten public and environmental health. The United States is regularly affected by natural disasters, industrial accidents, and has been the target of intentional contamination incidents with a growing list of chemical, biological, and radiological agents. When scientifically-sound information is not readily available for the potential array of low-probability, high-consequence threats, communities cannot be resilient to these acute, environmental catastrophes.

<u>Program Vision</u>

Federal, state, tribal, and local decision makers have timely access to information and the tools they need to ensure community resilience to catastrophes involving environmental contamination that threatens public health and welfare.

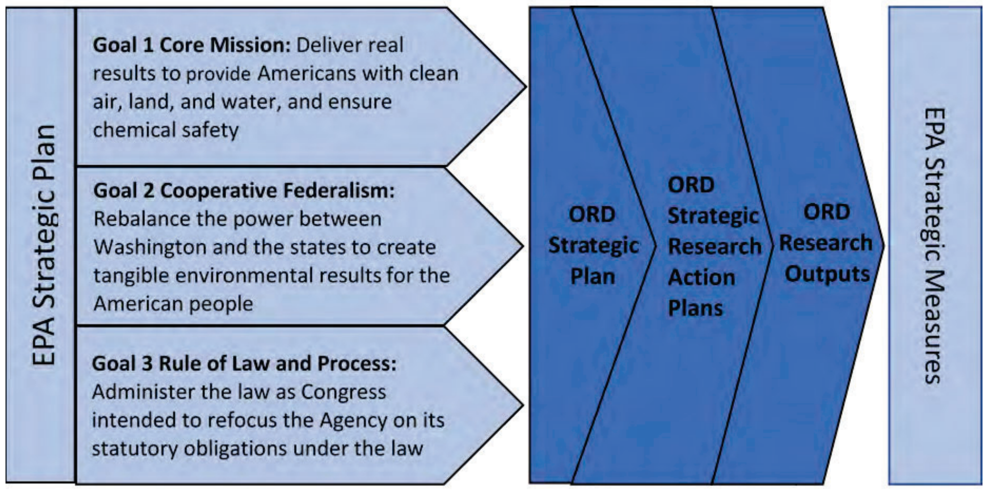
Program Design

The ORD StRAPs are guided by EPA's Strategic Plan and the draft ORD Strategic Plan. The StRAPs position ORD to contribute to EPA meeting its strategic measures, depicted in Figure 3. The HSRP StRAP provides a vision and blueprint for advancing homeland security research in ways that meet legislative and policy mandates and address the highest priority partner needs. HSRP supports EPA's responsibilities to prepare for and respond to acute disasters by conducting short-term, applied scientific research. The

[5] PPD-21 states "The Federal Government shall…take proactive steps to manage risk and strengthen the security and resilience of the Nation's critical infrastructure, considering all hazards that could have a debilitating impact on national security, economic stability, public health and safety, or any combination thereof."

foundation of the program focuses on CBRN contamination resulting from intentional or unintentional incidents.

Figure 3: ORD's Strategic Research Action Plans are driven by EPA's Strategic Goals and Objectives to contribute to EPA's Strategic Measures



HSRP collaborates with other ORD research programs and with other federal departments/agencies to address the most pressing needs related to an "all hazards" approach to disasters. HSRP also finds multiple uses of its research by applying, when appropriate, its products to EPA's needs that are not otherwise met. One example is the Ebola Outbreak in 2014. Although this was a natural outbreak with major response efforts led by the Centers for Disease Control (CDC), EPA's expertise was requested related to environmental cleanup and waste treatment and disposal. While HSRP had not done work specifically on Ebola virus, the program provided necessary expertise on environmental decontamination, personal protective equipment decontamination, and solid waste and waste-water management through adaptation of its work with other biological agents. Since the next disaster cannot be adequately predicted, an essential component of HSRP is the ability to adapt and apply its research to meet unforeseen challenges in a timely manner. By applying HSRP research on specific threats/scenarios more broadly, HSRP is helping address unforeseen threats and scenarios.

Developing resilience at the community level is a critical aspect of building sustainability, especially for communities that have greater exposure to disasters and are more vulnerable to their impacts. Communities that "prepare for, absorb and recover" (National Research Council, 2012) from disasters will, in turn, have more sustainable economic, environmental, and social systems. By developing and transitioning effective tools and guidance to community decision makers, including emergency management officials and water and wastewater utility owners and operators, HSRP is helping communities to prepare for and more rapidly recover from these incidents.

Building on 2016-2019 Program

The current (2019-2022) HSRP StRAP builds on the 2016-2019 StRAP(U.S. EPA, 2015) and the foundation set forth in the 2012-2016 StRAP (U.S. EPA, 2012a). The 2012-2016 StRAP recognized the interconnection of research efforts based upon the impact each decision has on other decisions during response and remediation activities. This overarching systems approach shows the cascading dependence of remediation activities upon one another and guides research planning to support detection, sampling analysis, threat mitigation, decontamination, and waste management research activities. This "systems approach"[6] also fostered the development of decision-support tools that incorporated the ability to estimate (forecast) the impact that one decision has on downstream options or total remediation time and cost. The systems approach was advanced in the 2016-2019 StRAP through systems-based tools that allowed researchers to model entire systems and aided decision makers in exploring trade-offs between response and remediation activities. HSRP research also made advancements in integrating analysis of the social and environmental systems that affect community resilience.

HSRP will use scenario-based planning to continue to refine priority needs and outputs over the course of 2019-2022 StRAP implementation. The 2019-2022 StRAP will continue to advance the overall systems approach, as well as the interconnection of response decisions, by implementing a scenario-based planning approach. This planning will involve HSRP partners and will include exercise scenarios on the regional and national levels, as well as scenarios modified from real-world incidents. For example, in the North Portland fire, modified scenarios could predict the impact that an anthrax-spore release would have posed to public health, instead of asbestos.

HSRP will also continue to focus on developing capabilities for communities to be resilient to large-scale disasters, employing the wide-area scenario view presented in Figure 2. The lessons-learned from large-scale incidents can be applied to smaller-scale incidents involving oil or other hazardous substances. The approach that HSRP has taken is to "plan big" and scale as needed for the incidents that actually happen (Lumpkins, 2017). Ongoing interagency efforts will continue to simulate and plan for these wide-area biological incident remediation capabilities. Toward that objective, HSRP and the Office of Land and Emergency Management (OLEM) Consequence Management Advisory Division will partner with DHS and the U.S. Coast Guard to conduct field-scale research on responses to a wide-area biological incident. This multi-year effort will include addressing critical gaps through laboratory and field-scale research. Efforts will also be made to initiate a focus on outdoor (wide-area) chemical releases and water contamination incidents with chemical and radiological threats. HSRP will also prioritize addressing emerging chemical threats to both wide areas and water systems. This includes addressing high priority needs of HSRP's partners with respect to emerging threats related to nation-state supported terrorism, as well as supporting communities to address increasing issues with opioid-contaminated sites (e.g., fentanyl).

Zoonotic disease has re-emerged over the last three decades to become a world-wide challenge. Additional understanding is needed of the complex relationships between zoonotic agents at the human-animal-environment interface to develop environmental countermeasures that would effectively stop the chain of infection. To address adverse exposures to, and ecological consequences of, zoonotic diseases, many federal agencies have adopted a One Health (One Health Initiative) approach to integrate multiple scientific disciplines (i.e., microbiology, ecology, environmental engineering, public health, industrial hygiene, veterinary, etc.) to attain optimal health for people, animals, and the environment. HSRP will work to integrate a One Health approach to better assess risks posed by

[6] Systems approaches, including systems-based solutions, aim to understand a system in totality through analyzing its various components while still understanding how these components interact. These approaches also aim to understand the system at many levels. In this context, the "system" here is the incident response and recovery efforts composed of many interconnected activities, such as constructing a sampling strategy, selecting a cleanup technology, and managing wastes.

biothreat agents and for conducting research to develop effective, environmentally-sustainable response strategies.

HSRP research will continue to be conducted at EPA facilities (intramural) and off-site (extramural) at grantee or contractor laboratories. Extramural research, funded through interagency agreements, grants, and contracts, complements and expands the intramural research program by engaging the agency with the nation's leading scientists and engineers. This broad engagement is particularly valuable where additional expertise and capabilities are needed from the scientific community to provide an expanded strategic response to an environmental challenge and to address important gaps in scientific expertise. EPA also participates in similarly focused Small Business Innovation Research (SBIR)[7] efforts established by the Small Business Innovation Development Act of 1982.

ORD recognizes that EPA program and region, state, and tribal partners must respond to emerging, unforeseen needs that can benefit from ORD research and technical expertise. In these situations, ORD works with partners to balance the relative importance of these emerging needs with other research activities and to ensure agreement in any changes in research direction with respect to available resources. HSRP promotes the development of innovative commercial technologies to address environmental challenges. HSRP does this through vehicles including SBIR, innovative incentive programs including citizen prizes/awards to drive crowd sourcing of inventive approaches, and ORD internal innovative challenges (e.g., Pathfinder Innovative Projects).

This StRAP outlines priority research efforts for 2019-2022. These efforts are intended to address the highest priority needs identified by HSRP's EPA program and regional partners and reflect the needs of states, tribes, and local communities with respect to EPA's Homeland Security responsibilities. HSRP also undertakes a systematic examination of potential threats and opportunities (i.e., horizon scanning) to identify scientific challenges that may rise in importance from emerging technologies. For example, recently-developed genome editing technologies are poised to revolutionize the use of biotechnology to benefit mankind. Yet, these technologies could also result in unintended consequences on public health and the environment or be used to develop novel threat agents. Demonstrated by the recent outbreaks of the Ebola, Zika, and avian flu viruses, we should expect unanticipated disease outbreaks to continue to challenge public and animal health and the environment. The increasing capability of computation approaches will revolutionize the prediction of scientific properties (e.g., chemistry, toxicology), enhance decision-support tools, and help manage environmental systems (e.g., monitor whole watersheds including water distribution systems). However, as such advances become more affordable/accessible, they could have unintended consequences, accentuating the importance of understanding how such effects could be detected and minimized. Finally, recent uses of chemical warfare agents in Syria and the United Kingdom warn of an increased use of these agents that can have impact beyond the intended targets. HSRP serves as a foundation for anticipating and communicating scientific issues of which EPA and other stakeholders must be aware, and for ensuring that the research designed to address high priority needs related to existing threats can also support response to all hazards (anticipated and unforeseen).

[7] https://www.epa.gov/sbir

Solutions-Driven Research

ORD is renewing and expanding its commitment to producing research that addresses real-world problems and helps EPA program and regional offices, state and local agencies, as well as tribal organizations, to make timely decisions based on science. This commitment includes exploring ways to improve research processes through the application of a solutions-driven research framework. Solutions-driven research emphasizes:

1) Planned partner and stakeholder engagement throughout the research process, starting with problem formulation and informing all elements of research planning, implementation, dissemination, and evaluation
2) A focus on solutions-oriented research outputs identified in collaboration with partners and stakeholders
3) Coordination, communication, and collaboration both among ORD researchers and between researchers and partners to develop integrated research that multiplies value to partners and stakeholders
4) Application of research outputs in cooperation with partners and stakeholders to solve complex environmental problems, and to test the feasibility, appropriateness, meaningfulness, and effectiveness of the research-driven solutions

ORD will also study how we engage with stakeholders and partners and how we design and conduct research to inform solutions to their most pressing environmental problems. ORD will continue to support research outputs after they are delivered to partners and stakeholders, and will evaluate the usefulness and effectiveness of this research in helping solve the identified environmental and public health problems. This application of translational science will help ORD continually improve and increase the value of our research to our partners and stakeholders. Translational science is a widely practiced approach developed by the National Institutes for Health[8] to “understand the scientific and operational principles underlying each step of the translational process,” which moves science along the path from lab research to practical solutions in real world circumstances.

ORD is adopting a 3-pronged strategy for solutions-driven research:

1) Apply principles of solutions-driven research broadly across ORD’s six national research programs
2) Conduct pilot translational science projects that apply and evaluate methods of solutions-driven research to planning, conducting, applying, and evaluating integrated research that addresses a well-defined and unmet need of partners and stakeholders
3) Conduct case studies of previous and current research activities that embody the principles of solutions-driven research, which will help inform a list of best practices

Risk communication is a central factor in solutions-driven research, allowing people to understand their risks and adopt protective behaviors, as well as informing risk management decisions. ORD will emphasize advances in the science of risk communication and apply best practices for communicating risk to different audiences across HSRP and the other national research programs. Risk communication allows people to understand the likelihood and potential magnitude of adverse effects from exposure to CRBN and adopt protective behaviors, as well as informing risk management decisions. The science of

[8] https://ncats.nih.gov/

risk communication includes research on the social contexts of how information is disseminated, interpreted, and acted upon, *e.g.,* analyzing stakeholder values and risk perceptions. Throughout our research programs and as a central tenet of translational science, ORD will be emphasizing both advances in the science of risk communication and application of best practices for communicating risk to different audiences. HSRP's research on the social science of decontamination and resilience will inform this effort.

EPA Partner and Stakeholder Involvement

Numerous EPA program offices and regions implement EPA's homeland security responsibilities. EPA's Office of Homeland Security, within the Administrator's Office, coordinates all activities relating to homeland security. HSRP's primary partners include EPA's Office of Water (OW), OLEM, and each of the Agency's ten regional offices across the country. Additional EPA partners include OCSPP, the Office of Air and Radiation (OAR), the Office of Enforcement and Compliance (OECA), and the Office of Policy's Office of Sustainable Communities. HSRP also engages with state and local agencies and water utilities to ensure their input is included in research activities.

End-users of HSRP research will find scientific products most useful if they are closely involved with the research program from the outset. The HSRP partner-engagement process involves working together diligently on each step of output development, identifying and prioritizing research needs, implementing research studies, and designing and delivering useful outputs. HSRP considers its partners in the research to be EPA program offices and regions, federal agencies, states, tribes, and local government. Other stakeholder beneficiaries of HSRP products include non-governmental organizations, industry, communities, and others who directly benefit from or are users of HSRP outputs. HSRP's research partners are directly involved in the research efforts conducted under this StRAP through planning, implementation, and transitioning/translation of outputs.

HSRP addresses prioritized needs based on specific problems identified through defined interactions with HSRP's partners. The process of understanding and prioritizing the needs of HSRP's partners is collaborative and involves discussion of current capabilities and desired end states and is informed by DHS-led threat assessments. EPA's mission and strategic direction further informs prioritization of needs. In addition, water utilities convey their needs through the water sector's Critical Infrastructure Protection Advisory Committee (CIPAC) (U.S. DHS, 2018), managed out of DHS and co-led by EPA's OW. This group periodically releases research priorities, such as the Roadmap to a Secure and Resilient Water and Wastewater Sector (Water and Wastewater Sector Strategic Roadmap Work Group, 2017), and these priorities inform HSRP research on this topic. For oil spill-specific needs, HSRP coordinates with EPA partners and other federal agencies, including the National Oceanic and Atmospheric Administration (NOAA), the U.S. Coast Guard, and the National Response Team (NRT).

Much of the implementation and enforcement of homeland security responses is operationalized at local, state, and tribal levels. EPA serves mostly in a technical support role to these decision makers and first responders, as well as to water and wastewater utilities. Input from these partners is relayed to the EPA regional and program offices, who then incorporate this information into the programmatic needs that are transmitted to HSRP. ORD will also seek state, tribal, and local input more directly during the implementation of the 2019-2022 StRAP through execution of ORD's State Engagement Strategic Plan and HSRP's Emergency Management State Engagement Strategy.

HSRP collaborates extensively with other federal agencies whose missions support environmental disaster response, particularly those where there is overlapping or complementary mission space with EPA. HSRP works closely with the DHS, Department of Defense (DOD), Department of Health and Human Services (HHS), USDA, and others to leverage their homeland security/environmental disaster science efforts. These interactions range from high-level strategic planning and coordination managed by the White House's National Science and Technology Council[9] to staff collaboration on individual research efforts. Table 2 shows these agencies and their response roles and areas of research collaboration. HSRP also leverages DOD's CBRN decontamination and fate and transport research.

Using the systems understanding of disaster preparedness and response, and identifying high priority research needs, HSRP is organized by topics under which there are specific research areas. The work in the research areas produces bodies of data, tools, models, and technologies ("outputs") to address the capability needs expressed by our partners to solve the problems of vulnerability to wide-area contamination and vulnerabilities of water utilities to water contamination incidents that threaten public health. The anticipated FY19-22 outputs, organized by topic and research area, are listed in Appendix 1. HSRP will engage the relevant partners as members of product and output development teams, working together on the research to ensure that products and outputs adequately address needs. This includes working together to determine the format of products and outputs and communication strategies with stakeholders. In addition, Appendix 2 tabulates the HSRP research that can be used to support specific state needs, as identified through EPA's engagement with the Environmental Council of the States.

Table 2: HSRP Research Collaborations with Federal Partners in the Environmental Response Context

	Federal Response Leads for Environmental Aspects of Disasters				
	EPA and U.S. Coast Guard	**HHS**	**USDA and Department of the Interior**	**U.S. Army Corps of Engineers**	**DHS for federally-declared disasters**
Role	Cleanup of oil and hazardous materials	Supplement public health, medical, behavioral, or human services	Protect Nation's agriculture, natural, and cultural resources	Support critical infrastructure and environmental response post-disaster	Coordination of federal response (as required)
Area of HSRP Research	CBRN response and remediation	Exposure science, sampling and analysis methods	Carcass disposal and decontamination of agricultural facilities	Water infrastructure protection and waste management	CBRN threat and risk assessment, mitigation, remediation, and community resilience

[9] ORD HSRP participates on the National Science and Technology Council's (NSTC) Committee on Environment and the Committee on Homeland and National Security.

Integration Among Research Programs

EPA's six research programs work together to identify and address science challenges. Coordination efforts can range from formal integration across the programs, to collaboration among EPA scientists working on related issues. Based on feedback from EPA programs and regions, state and local agencies, tribal organizations, other federal agencies, and ORD scientists, HSRP is working in several cross-ORD areas (Appendix 3). These include:

- **Wildland fires:** Wildfires can affect air quality and drinking water quality. HSRP is concerned with the fate and transport of contaminants from contaminated areas during wildland fires. The fire in North Portland discussed earlier demonstrated the potential for contaminants to be spread by fire. Since the Fukushima Daiichi disaster, there are considerable areas of forest in Japan that remain radiologically contaminated. These forest areas are difficult to remediate and can remain a source of exposure or spread of contamination; forest fires are a potential method of spreading this contamination to uncontaminated or cleaned-up areas.
- **Per- and polyfluoroalkyl substances (PFAS):** PFAS research within ORD is focused on developing and applying scientific information and tools to enable states, tribes, and EPA regional and program office partners to make informed decisions to protect public health and the environment. The research is designed to support cross-EPA and cross-federal efforts. HSRP is concerned with the release of PFAS-related chemicals during emergency response activities, including the use of fire-fighting foam containing PFAS. HSRP is addressing this by testing and developing on-site treatment methods for contaminated water.
- **Lead (Pb):** The cross-ORD lead effort is focused on answering the question, "How can EPA mitigation efforts/techniques and coordinated multimedia assessments most effectively reduce exposures and blood lead levels for the most vulnerable children in the United States?" HSRP is continuing to develop water infrastructure modeling tools that can assist water utilities in understanding the impact of changes in their systems on lead concentrations in drinking water. HSRP is also continuing to test sensors that can indicate contamination in water.
- **Resilience:** The cross-ORD resilience effort is focused on integrating ORD's work preparing for and recovering from disasters, including extreme weather events and accidental and intentional contamination incidents, to serve the safety and resilience goals of EPA regions and programs and ORD's state, tribal, and local partners and stakeholders. HSRP focuses on understanding the problem and developing solutions so that communities have the information and resources they need to effectively respond to all hazards resulting from disasters.

SSWR and HSRP will also increase collaboration and leverage work on sensors to detect contamination in water and methods to improve water infrastructure. This includes efforts by HSRP and SSWR to provide analytical methods and occurrence assessments, health effects, and treatment assessments for emerging contaminants. HSRP and SSWR also provide resources and tools to maintain drinking water infrastructure performance and integrity. HSRP and SSWR will continue to work together to provide technical support to states and tribes for water treatment, analytical methods, and risk assessments. SHC, A-E, and HSRP will continue to leverage efforts related to enhancing community resilience to disasters, including waste management. Together, the research efforts of SHC, A-E, SSWR, and HSRP strive to enhance resilience to near and long-term impacts of disasters.

Research Program Objectives

The HSRP StRAP is focused on addressing two primary research objectives. One primary research objective is to advance EPA capabilities to respond to wide-area contamination incidents. Terrorist-related incidents or natural disasters can result in wide-area contamination with hazardous materials, including oil spills or CBRN agents or materials. Wide-area contamination includes contamination of the built environment (both inside and outside of buildings and semi-enclosed infrastructures such as subways or arenas) and the natural environment. EPA needs effective and affordable cleanup strategies and methods so that affected communities can successfully and rapidly recover. After a wide-area contamination incident occurs, HSRP products can assist in determining the nature and extent of the problem, assessing risk, choosing the best cleanup approach, and managing the resulting contaminated wastes. Communities are also looking to EPA for ways to holistically assess their environmental resilience to disasters.

The second objective is to improve the ability of water utilities to prevent, prepare for, and respond to water contamination that threatens public health. Disasters, anthropogenic or naturally occurring, can impact the ability of water and waste-water utilities to function, including the potential disruption of drinking water supplies to municipalities. To support disaster preparedness, HSRP develops modeling tools that aid the design and operation of water and waste-water systems in a way that decreases their vulnerability to disasters. HSRP has developed tools, technologies, and data to support post-incident responses. Following an incident, HSRP research helps water utilities detect contamination, determine the extent of contamination, assess risk, treat the water, take mitigative actions, and decontaminate any infrastructure. Collectively, these efforts reduce vulnerabilities and improve resilience of water systems when faced with disasters.

Science Challenges

Because this program supports state, tribal, and local community emergency planning for time-critical response to disasters, HSRP results must be available in easily accessible, usable, and concise formats for decision makers. HSRP aims to deliver science-synthesis products into the hands of end-users by making this information available through existing, widely-used information databases, and supporting this work with technical assistance. The primary metric of the success of the program is the use of its research in decision-support tools, databases, guidance, and training developed by EPA partners and external stakeholders. The objectives and corresponding science challenges (questions) being addressed by the program, under each of the objectives, are documented below.

Objective 1: Advance EPA's capabilities and those of our state, tribal, and local partners to respond to and recover from wide-area contamination incidents

- What are indicators and metrics of resilient communities, including social, cultural, economic and environmental variables, that influence resilience?
- What tools and strategies are available for determining the extent of environmental contamination in wide-area incidents?
- How can the movement and fate of contaminants over wide areas (both indoors and outdoors) be understood to inform sampling methods and strategies, mitigation, decontamination, waste management, and public health decisions?

- What are the verified sample collection and analysis methods, strategies for characterization of contamination, and methods to assess exposure pathways that better inform risk assessment and risk management decisions after a wide-area contamination incident?
- What technologies, methods, and strategies are effective for mitigating the impacts of the contamination and for reducing the potential exposures?
- What technologies, methods, and strategies are best suited (minimize cost while protecting human health and the environment) for cleanup of indoor and outdoor areas, including management of waste?
- How do social system dynamics affect decontamination actions and outcomes?
- How can HSRP organize its research in an easy-to-use format for EPA partners and state, tribal, and local decision makers?

Objective 2: Improve the ability of water utilities to prevent, prepare for, respond to and recover from water contamination incidents that threaten public health

- What tools and strategies are available for determining the extent of contamination in water systems?
- How can the movement and fate of contaminants in water systems be better understood to inform sampling methods and strategies, mitigation, decontamination, and public health decisions?
- What are the verified sample collection and analysis methods, strategies for characterization of contamination, and methods to assess exposure pathways that allow a water utility to protect public health and return to service quickly?
- What methodologies and strategies are most effective (minimize cost while protecting human health and the environment) and accepted (e.g., social, cultural, economic) for water infrastructure decontamination and water treatment?
- What effective methodologies can be developed to manage contaminated water for safe handling and discharge?
- How can HSRP organize its research in an easy-to-use format for EPA water partners and water utilities?

Research Topics

The needs identified with HSRP's program office and regional partners are summarized at high level by the science questions under each of the two research objectives discussed in the preceding section. The research to address the specific needs associated with these science questions is then organized under seven research areas that are associated with specified research topics. These research areas are based upon analysis of the identified needs and their correlation with respect to the objectives and science questions and the response categories identified with respect to ESF-10.

Under ESF-10 in the NRF, EPA supports states and local communities in the cleanup of oil and hazardous contaminants released into the environment that threaten public health. This includes the remediation of critical infrastructure, such as water and wastewater utilities. Efficient remediation plans need to be developed for safe and rapid response and recovery. These remediation plans rely on an effective assessment of the nature and extent of the contamination and its potential impact on public health. Decision makers need to know where the contamination is located and where it may spread to make public health decisions (such as evacuation), hazard mitigation decisions, and ultimately, cleanup decisions. Assessing the impact of the environmental contamination on public health must be made through an understanding of the exposure potential. Further, cleanup decisions rely on an understanding of the behavior of contaminants in the environment. For example, will contaminants remain a persistent public health threat or will they attenuate naturally? This type of information is essential for decision makers when developing remediation plans to support response and recovery.

When developing decontamination and waste management plans, decision makers use information from the characterization of the contaminated area, the nature of the contaminant and its interaction with the environment, and the impact of the contaminated environment on public health. They then couple this with information on capabilities for site-specific decontamination and waste management options. Decontamination options depend on how effective methods are for inactivating, neutralizing, or removing the CBRN contaminant from the environment. Effectiveness depends on site-specific conditions (including the characteristics of the environment), the surfaces upon which the contaminants are bound, the contaminant, and their interactions. For example, in 2007, EPA supported the state of Connecticut in remediating a house that was contaminated with *B. anthracis* spores from imported animal hides. The house was fumigated in the winter, and, unfortunately, the target conditions of maintaining the house at 75^{o}F and 75% relative humidity could not be met. HSRP research was used on-site to determine the potential impact on efficacy and what adjustments to the process (e.g., increasing the fumigant concentration or increasing the fumigation time) could be made to improve the chance of a successful decontamination.[10]

Waste management is also intricately connected to decontamination options, since waste is generated during all response activities, starting with initial sampling. The waste includes materials that are removed and treated as waste prior to decontamination, materials removed after site decontamination and treated as waste, and materials generated as waste due to the decontamination process. Choices of decontamination technologies and application methods drive the types and amount of waste generated. Decision makers need to understand the impact of decontamination options on waste management, and vice versa, to develop efficient remediation plans. Further, having suitable waste management options significantly increases the overall efficiency of the remediation by enabling effective handling, storage, treatment, transport, and disposal of waste, thereby increasing the overall number of decontamination options.

Understanding the trade-offs among site characterization, decontamination, and waste management is critical for the decision maker. Trade-offs among response options will be necessary in the recovery from a wide-area incident when resources are limited, illustrated by the events of Chernobyl and Fukushima. Decision makers need the best available science and the capabilities during an incident. For example, extensive characterization sampling can aid in selection of decontamination options, including which specific areas require decontamination and which may not. While this extensive sampling may reduce overall decontamination costs, it may increase the cost and duration of the overall remediation due to the number of environmental samples required (both in terms of sample collection and time and cost for analysis). Alternatively, using available lines of evidence (i.e., multiple pieces of information that together provide an indirect indication of the likely effectiveness of a decontamination), decontamination can be conducted without extensive initial characterization, although it might increase decontamination cost and impact (e.g., waste generation). Decision makers can more efficiently

[10]The incident in Danbury, CT was due to a drum-maker importing animal hides from Africa that contained naturally occurring *B. anthracis* spores. The drum-maker and his son, residing in the house, developed cutaneous anthrax. During the preparation of the hides for making drums, *B. anthracis* spores were released from the hides and resulted in contamination of the resident's shed (where he made the drums) and his house. Additional information can be found at: https://www.newstimes.com/news/article/Danbury-house-free-of-anthrax-101815.php (last accessed July 24, 2018).

remediate sites by simultaneously assessing the effectiveness and efficiency of sampling, decontamination, and waste management options and their trade-offs. The ability to remediate contaminated areas rapidly is a key factor in building resilience to possible disasters. For intentional contamination incidents (such as acts of terrorism), minimizing the consequences through such resilience can reduce the threat.

In alignment with the ESF-10 response framework and based upon the above understanding of response decisions supporting recovery, HSRP's seven research areas are aligned under three topic areas: (1) contaminant characterization and consequence assessment; (2) environmental cleanup and infrastructure remediation; and (3) system approaches to preparedness and response. The research topics and areas are shown in Table 3.

Table 3: List of Topics and Research Areas in HSRP

Research Topic	Research Area
Contaminant characterization and consequence assessment	Contaminant Fate, Transport, and Exposure
	Contaminant Detection/Environmental Sampling and Analysis
Environmental cleanup and infrastructure remediation	Wide-Area Decontamination
	Water Treatment and Infrastructure Decontamination
	Oil Spill Response
	Waste Management
System approaches to preparedness and response	Tools to Support Systems-based Decision Making

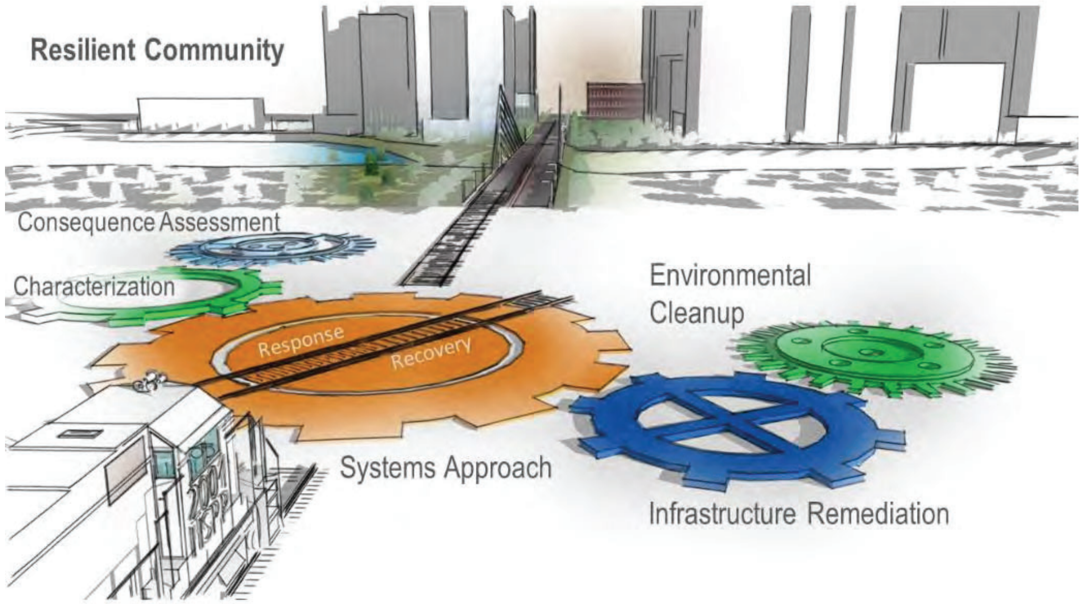
These research topics are also critical, interdependent emergency response activities. For example, decisions about how to clean up a contaminated site may affect the decision on how best to characterize the site as cleanup progresses. Thus, the research efforts that comprise these topics are designed to reflect and support this interdependent system of activities. Figure 4 illustrates the interconnectedness of the research topics and how they must work together within a systems (holistic) view of preparedness and response, to successfully "drive the train" of bring resiliency to our communities.

<u>Topic 1: Contaminant Characterization and Consequence Assessment</u>

Effective contaminant characterization provides for understanding the extent and nature of the environmental contamination. Information on contaminant characterization coupled with an understanding of exposure potential can be used to inform the potential consequences of the contamination on public health. Characterization is an essential part of response and remediation efforts. Following a CBRN incident or oil spill, EPA may support or lead site characterization and remediation of contaminated water systems and wide areas. Additional characterization of the site may be required during cleanup operations to assess progress and determine waste streams and to inform site re-occupancy and reuse decisions (sometimes referred to as clearance decisions). EPA's OLEM founded the EPA Environmental Response Laboratory Network (ERLN)[11], including the Water Laboratory Alliance (WLA)[12], to establish the capability and capacity for analyzing environmental samples for site characterization, clearance sampling, and remediation after national-scale incidents.

[11] https://www.epa.gov/emergency-response/environmental-response-laboratory-network
[12] https://www.epa.gov/waterlabnetwork

Figure 4: Schematic diagram of the systems view of HSRP research topics and areas, in support of response and recovery to build resilient communities



Risk assessment is informed by characterizing the nature and extent of the environmental contamination and understanding of the potential impact of exposure to the contaminated environment on public health. Remediation decisions are made to reduce the risk related to exposure to environmental contamination. However, using environmental characterization data in a risk assessment is not straightforward, particularly for microbial contamination, due to the uncertainty and variability in the field data as well as uncertainty in how to estimate exposure to the contaminant in the environment. For effective response and remediation, decision makers must have capabilities to rapidly detect contamination, to determine the extent of the contamination, to understand the behavior of the contaminant in the environment, and to assess the impact of the contaminated environment on public health. Many decisions makers may not have ready access to such capabilities.

The research under this topic is planned and executed under two research areas. The first research area addresses how contaminants behave in water systems and the built and natural environment, including the development of capabilities to support decision makers in their assessment of the threat that the contamination poses to public health. The second research area is focused on developing contaminant detection, environmental sampling, and analytical capabilities. Combined, these two research areas provide essential information to support environmental response and remediation decision making to protect public health and the environment.

Research Area: Contaminant Fate, Transport, and Exposure

Cleanup after a wide-area contamination incident will be complex and resource intensive. Knowledge of the persistence, movement, and associated phenomena over wide areas is a key element to inform decision making regarding cleanup and restoration. For example, during the Gotham Shield[13] exercise, impacted state and local decision makers sought information from EPA on the impact of impending rain on their response actions. Such fate and transport issues are closely linked to understanding the risk of exposure and the development of sampling, decontamination, and waste management strategies. Exposure assessment information and models can inform sampling, decontamination, and waste management strategies and decisions, particularly for microbial contamination.

The unintentional or intentional introduction of harmful contaminants into drinking water distribution systems can affect a relatively large area, which could impact the storage tanks, pipes, and pumps used in water distribution systems, service connections to buildings, and water-consuming appliances such as water heaters. Fate and transport information informs actions such as decontamination of water infrastructure, which allow reuse of the system. Additionally, to inform where physical security or other measures are needed to reduce vulnerability of water systems, information and models can help assess the consequences resulting from exposures to CBRN contaminants.

This research area focuses on identifying and quantifying issues related to movement and persistence of contaminants over wide areas and in water and wastewater systems. The work addresses gaps in understanding to inform decision makers and gaps identified as needs by EPA programs and regions. Research is conducted at the bench- and pilot-scale to understand fate and transport, which will inform decisions regarding sampling, decontamination, waste management, and operational countermeasures. This research area also focuses on assessing exposure to contaminants, for example, through understanding the implications of the sampling results.

Program, regional, state, and/or tribal needs

Research needs related to fate and transport and exposure assessment, in general, provide a foundational basis to inform other parts of HSRP, including sampling, decontamination, and waste management. These needs generally fall into the following areas:

- Persistence of contaminants in and on different types of infrastructure
- Movement of contaminants within and between different types of infrastructure
- Understanding how movement and persistence of contaminants can affect sampling strategies, decontamination, and risk assessment

Addressing needs in the above areas will inform decision makers in addressing topics such as:

- Understanding how data collected in the field can be used to estimate exposure following a release
- Assessing the consequences of CBRN contaminant introduction into water systems to support vulnerability assessments, including understanding the movement and persistence of contaminants in pipes and premise plumbing
- Understanding of the fate and transport of CBRN contaminants to inform public health and mitigation decisions, including determining the impact of natural forces such as rain and sunlight on the fate and persistence of contaminants

---

[13] Operation Gotham Shield was an exercise conducted by FEMA in 2017 testing civil response capabilities to a nuclear weapons attack in the New York City area.

For wide areas, understanding the ability of a contaminant released into the environment to continue to pose an exposure threat is important in remediation decision-making. The persistence of a chemical or biological agent depends on environmental conditions (e.g., temperature, relative humidity, sunlight, etc.) and the material in or on which the chemical or biological agent is bound. For some contaminants, natural attenuation (where naturally-occurring degradation processes are used to reduce the concentration and subsequent exposure) is a viable cleanup option under some circumstances. The impacts of wind and precipitation events, and their ability to move contaminants within an outdoor area, may have a profound impact on subsequent public health risk and on the ability of responders to contain and mitigate the contamination. These incidents can also spread contamination into venues that were previously uncontaminated, including storm and sewer collection systems as well as drinking water sources.

Research in this area informs public health and mitigation decisions by addressing the fate and transport of CBRN agents once released into the environment. An example of an output under this research area is a synthesis of information on the fate and persistence of chemicals on surfaces, which will inform sampling and remediation decisions (Appendix 1, Output #3). Research in this area, such as understanding the transport of *B. anthracis* spores will feed into outputs developed under other research areas (e.g., informing vehicle decontamination by understanding where contamination may end up within vehicles passing through contaminated areas) (Appendix 1, Output #12). Figure 5 shows an example of research in the aerosol wind tunnel in EPA's facility in Research Triangle Park, NC to assess the re-aerosolization and spread of *B. anthracis* surrogate spores due to human activity, including responders' activities.

For water systems, it's critical to understand how contaminants may adhere to corrosion products or biofilms on pipe walls, which could prolong contamination by desorption, leaching, or otherwise detaching from the surface and into the water over time. Contamination could also impact drinking water treatment plants, wastewater treatment facilities, and storm and sewer collection systems. To better understand the behavior of contaminants in water infrastructure, this research area develops innovative processes for prediction of the fate and transport. Researchers examine the fate and transport of contaminants in drinking water and wastewater systems at bench, pilot, and full-scale. Data on decontamination and contaminant persistence in drinking water and wastewater infrastructure will be included in the Water Contaminant Information Tool (WCIT)[14]. HSRP researchers are developing innovative methods for modeling contaminant fate and transport to enhance water utilities' ability to manage contaminated source water (e.g., water in rivers that is treated for drinking water) and contaminated overland flow. Researchers will develop a tool that predicts the fate and transport of radiological and biological contamination in stormwater in a wide-area urban setting (Appendix 1, Output #4 and Output #5).

To support risk-based site-specific decisions during response incidents, decision makers must have methods to assess exposure pathways and exposure models for CBRN contaminants. Exposure-based modeling is a mature field for traditional chemical contaminants like conventional pesticides, but

[14] https://www.epa.gov/waterdata/water-contaminant-information-tool-wcit

modeling efforts for exposure to biological agents are limited. People's exposure to contaminants depends on human activities and on the how the contaminant behaves in the environment. Research conducted under this area develops or modifies existing exposure modeling tools to support these strategies. For example, models for water-based exposures are being developed and incorporated into a tool that estimates consequences for entire water systems (Appendix 1, Output #2). Another set of example outputs are Provisional Advisory Levels (PALs). PALs are quantitative risk values for short duration exposures, that exceed safe levels, used to inform emergency actions like evacuation and cessation of water service (Appendix 1, Output #1).

Figure 5: Assessment of reaerosolization of *B. anthracis* surrogate spores due to typical and response-related human activity (Aerosol Wind Tunnel at EPA's Facility in Research Triangle Park, NC)

Research Area: Contaminant Detection/Environmental Sampling and Analysis

Decisions regarding remediation are based largely on the results of infrastructure or site characterization sampling (to establish the extent of contamination) and on clearance sampling (to evaluate the efficacy of the cleanup). The recovery of contaminated areas and infrastructure will be hindered by a lack of consensus on contaminant detection capabilities, sampling strategies, sample collection procedures, and sample analysis methodologies.

HSRP, working with its partners, will address critical gaps related to this research area by evaluating current detection capabilities, developing and/or refining sampling strategies, developing innovative sample collection techniques, and providing sample processing and analysis methodologies. The goal of this research is to develop, synthesize, and compile the protocols into user-friendly and readily-available tools for the EPA response community and homeland security partners and stakeholders. Overall, HSRP provides the science needed to establish detection and sampling strategies for wide areas and water systems. This work will provide the maximum amount of information regarding the extent of contamination while minimizing the sampling and laboratory resources required.

Program, regional, state, and/or tribal needs

Advances have been made in environmental contaminant detection, sampling strategies, sample collection, and sample analysis. However, major gaps remain in these areas, especially as they apply to wide-area biological releases. The currently-accepted surface sampling methods are not practical for wide-area responses because they are very time-consuming, labor-intensive, and require many samples. Strategies that significantly reduce the cost and time associated with site-characterization and clearance sampling are needed to effectively respond to a wide-area incident. Surface sampling approaches that expand collection areas or pool samples collected using historic methods have demonstrated the potential to achieve effective sampling coverage of large areas while reducing the resources required. These "composite sampling" methods have considerable advantages over historical sampling methods that covered more discrete sample sizes. New sampling methods will, therefore, be further developed to support decision makers during characterization of wide-area incidents (Appendix 1, Output #8).

In support of these approaches, HSRP is conducting sample collection research to refine historical methods and develop new and innovative approaches. These methods will be able to sample and analyze complex environmental matrices such as underground transit systems and outdoor urban areas. HSRP is developing field-deployable protocols using novel and pioneering techniques that include pathogen concentration techniques, commercially available robotic cleaners, wet vacuum-sampling devices, native air filters (e.g., heating, ventilation and air conditioning filters), and activity-based air sampling. HSRP will develop outputs that describe sample collection methods for different environmental media (outdoor construction surfaces, soil and vegetation, air). This will be reported in an overall collection method summary (Appendix 1, Output #6 and Output #8) and added to the online sample collection information document that is part of the Environmental Sampling and Analytical Methods (ESAM) online tool.

The ESAM program[15] continues to be a major focus for HSRP. ESAM is a website that supports the entire environmental characterization process. ESAM includes searchable method queries and downloadable documents for use by responders and the public. During an environmental response, ESAM provides responders and laboratories with the single best available sample collection and analysis method. When using ESAM, decision makers have confidence in the integrity of the data, can quickly interpret what the data mean, and can readily communicate its meaning to the public. HSRP ensures that ESAM includes methods for the highest priority contaminants and is continually updated with the most recent methods. Collectively, the HSRP ESAM detection and sampling and analysis tool will help local, state, tribal, and federal emergency response field personnel and their supporting laboratories more efficiently respond to incidents, enabling smooth transitions of samples and data from the field to the laboratory to the decision makers (Appendix 1 Output #10).

HSRP is also looking to address sampling and analysis of bio-contaminated solid waste and wastewater (including water from the decontamination processes) in coordination with the OLEM's ORCR and OW's Office of Waste Management (OWM). Sampling and analysis of solid and liquid waste generated during remediation will be needed to determine if the waste requires treatment or has been adequately treated to allow for transportation as conventional solid or liquid waste. Currently, there is no federal regulatory framework for management of bio-contaminated waste, therefore each state regulates the requirements separately. Regardless of whether regulations specify sampling requirements, response personnel will need effective and feasible waste sampling strategies and methods so that waste treatment/disposal facilities can safely accept treated waste. HSRP will modify existing methods or

[15] https://www.epa.gov/homeland-security-research/sam

create new ones to characterize bio-contaminated solid waste and wastewater. Sampling protocols for these methods will be released as outputs (Appendix 1 Output #6 and Output #8) in addition to inclusion in ESAM.

HSRP researchers are also developing sampling and analysis methods to address emerging chemical threats, including nation-state supported threats and responding to illegal drug manufacture fueling the opioid (e.g., fentanyl) crisis in states and tribes. Local, tribal, state, and federal partners have expressed significant needs regarding characterization, cleanup, and waste management alternatives for these emerging threats, notably the chemical risks posed by abandoned illegal drug manufacture sites or the evolution of chemical agents that do not lend themselves to current rapid detection methodologies. Without sampling and analysis methods, response personnel are very limited in making informed decisions on the extent of contamination, efficacy of cleanup, and proper waste disposal options. HSRP will develop an output that summarizes chemical sample collection and sample analysis methods for environmental media (Appendix 1 Output #6); these methods will also be added to the online tool. Existing modeling and mapping capabilities for sampling strategies will be updated to utilize optimal locations and methods (Appendix 1, Output #7 and Output #9).

Topic 2: Environmental Cleanup and Infrastructure Remediation

After understanding the extent of the contamination and accessing its potential impact on public health, EPA may then be responsible for supporting the cleanup of oil or hazardous contaminants and mitigating their impact on human health and the environment. EPA has a long history and extensive expertise in cleaning up contamination associated with accidental spills and industrial accidents. However, remediating CBRN contamination released over wide areas, such as outdoor urban centers or impacted water systems, is a responsibility for which EPA lacks substantial operational experience. Such release, including oil spills, can pose a continual challenge with long-standing consequences.

Cleanup includes having the capability to address contaminants in all media within the built and natural environment. DOD has expertise in the tactical decontamination of personnel and equipment, but this expertise is not directly applicable to the decontamination of public facilities and outdoor areas. These areas have a variety of porous surfaces and might require more stringent cleanup goals for public re-occupation. Furthermore, water systems pose considerable additional challenges. Contamination of drinking water can occur through the direct introduction of CBRN substances into the distribution infrastructure, through compromises in the integrity of the distribution lines, or via a contaminated raw water supply entering a treatment plant through a water intake. Direct distribution system contamination can result from acts of terror or inadvertent disruptions such as manmade breaks or cross connections. Intentional, accidental, or natural contamination can enter drinking water supplies via contaminated stormwater runoff, wastewater and industrial outfalls, or transportation/industrial incidents.

HSRP activities in this topic aim to fill the most critical scientific gaps in the capabilities of EPA's response community (identified by HSRP's program office and regional partners) so that, when needed, EPA can make the most informed mitigation and remediation decisions. Understanding social, cultural, behavioral, and economic factors is also critical to inform effective response decisions that will ultimately lead to recovery. EPA's tools, methods, and technologies for disaster preparedness and response are designed to improve the ability of our communities, including water utilities, to rapidly recover from a disaster (or contamination incident). To support research needs related to cleanup, HSRP has four research areas under this topic. The first wide-area decontamination research area develops capabilities for addressing hazardous contaminants in the environment, including indoor and outdoor areas. The second research area focuses on addressing needs related specifically to water treatment and decontamination of water systems. Research to support response to oil spills is addressed under the third research area. The fourth research area addresses capabilities associated with waste management as part of the response and remediation efforts.

Research will continue to evolve to focus on scalability of cleanup methods and application of the research to additional hazards inside and outside of the traditional CBRN paradigm (as needs and threats emerge). Related to water systems, the focus will continue to move towards more field-scale assessments and improving the overall resilience of water systems to disasters.

Research Area: Wide-Area Decontamination

Wide-area contamination requires comprehensive remediation capabilities to help impacted communities recover rapidly and safely. Decision makers developing a remediation strategy seek to identify and secure the most applicable decontamination methods and resources (e.g., workers, equipment, materials, etc.) to execute the identified methods.

For example, critical infrastructure (e.g., government, health care, school, transportation, energy, communication) in the contaminated area must be restored quickly to minimize both direct and indirect impacts. Wide-area contamination may pose a direct impact on the local community due to health impacts and denial of services, including possible relocation. Surrounding communities may also be (secondarily) impacted, such as through people being unable to commute to work or denial of services obtained from the directly impacted area.

HSRP’s decontamination research outputs can be used to support decision makers in selecting decontamination options with consideration for safety, resource demand, logistics, training, availability, and technology necessary to remediate a wide-area incident. Researchers will develop methods and critical information for response strategy development and to inform the decision-making process.

Program, regional, state, and/or tribal needs

Following a wide-area incident, local response authorities need access to decontamination methods that are effective, feasible, and versatile for various contamination situations. Since there is no universal decontamination method that is applicable for all combinations of environments and contaminants, decision makers seek information to help them decide on the most appropriate site-specific approaches. Information to assist decision makers includes understanding the effectiveness and impact of various decontamination approaches for contaminated areas depending on conditions and priorities (e.g., urgency, contamination level, surface/media types, *etc.*) for remediation.

Rapid decontamination methods are needed to clean up critical infrastructure and enable continuous operation. Examples of critical infrastructure include water and wastewater utilities (discussed in the next research area), hospitals, electrical power utilities, and transportation systems. Some critical infrastructure contains sensitive and valuable instruments/equipment: the decontamination process must be designed to protect this equipment from damage so that the infrastructure can be returned to service promptly. Research is needed to develop methods that can be deployed rapidly and are compatible with critical infrastructure components. As part of the summary outputs supporting biological and chemical threat response, HSRP will produce specific outputs that describe decontamination methods for these threats that are compatible with sensitive and valuable items (Appendix 1, Output #12, Output #13, Output #15, and Output #16).

Decontamination of public and residential areas is challenging due to the complexity of the material types and their different uses within communities. Common outdoor surfaces such as soil, concrete, brick, and asphalt pose significant decontamination challenges due to their porous and reactive nature. To meet the capability gap posed by outdoor surfaces, HSRP will continue to evaluate and develop decontamination methods that are effective for outdoor surfaces under various environmental conditions. Results will be summarized in summary outputs (Appendix 1, Outputs #11, #13, #15, and #16), as well as informing the development of trade-off and strategic-consideration decision-support tools (Appendix 1, Output #14).

Response to contamination incidents affecting residential and commercial areas may be delayed until resources are available, as federal, state, tribal, and local government resources are devoted to critical infrastructure. Research is needed to develop feasible decontamination methods for residential and commercial areas that are widely-available, user-friendly, economical, and safe. To meet this need, widely-applicable decontamination methods will be identified by surveying: (1) CBRN decontamination methods previously used by national and international agencies; (2) common equipment available in municipalities (such as street sweepers, orchard sprayers, sanitation trucks, and snow plows) that could be re-purposed to support remediation; and (3) household maintenance activities for indoor and outdoor decontamination (including social, cultural, behavioral, and economic factors).

The methods identified will be developed as a field-usable decontamination option via laboratory and field studies. Figure 6 shows one example of this, depicting an orchard sprayer that could be used to rapidly spray liquid decontaminants over large areas. Decontamination methods using common municipal or commercial equipment and household maintenance activities are innovative approaches that will reduce contamination exposure to the public and decrease the need for decontamination resources that may be needed elsewhere. HSRP will also conduct research to develop gross decontamination methods that can be safely and rapidly deployable for remediation. While these methods may not achieve an ultimate cleanup goal, they can help to reduce exposure potential until additional decontamination methods can be deployed as necessary. An example output from this research is listed in Appendix 1 as Output #15, providing decision makers information on widely-available and user-friendly decontamination options for wide-area radiological incident response.

Remediation of a CBRN wide-area incident requires an extensive number of decisions that span numerous areas of expertise. These decision points, and the tools and models that support them, are tightly intertwined and should employ a holistic solution. HSRP will produce user-friendly tools to assess numerous factors (e.g., efficacy, availability, logistics, worker training, diminishing returns) that can be considered when selecting the most appropriate decontamination options following a wide-area incident. Information regarding an array of decontamination methods will be incorporated into these decision-support tools (Appendix 1, Output #14). To ensure the tools are relevant and easy to use, HSRP will request input from local, state, tribal, and federal governments as part of the output development process.

Figure 6: Demonstration of the use of an orchard air blast sprayer for the decontamination of a subway station during an operational technology demonstration

Research Area: Water Treatment and Infrastructure Decontamination

Resilient water infrastructure systems can facilitate quick and effective decision making during emergency situations to ensure access to adequate water capacity and quality. Decontamination of drinking water systems following intentional contamination, or after a natural disaster (e.g., pipe breaks, storms, earthquakes) is critical for effectively resuming operation and restoring water distribution for drinking purposes, as well as other applications such as fire protection, hospital, and industrial use. For example, EPA Region 6 in Texas requested assistance to address contamination from an asphalt emulsifying agent, Indulin AA-86, that had contaminated Corpus Christi's water supply leading to a temporary suspension of use. ORD scientists provided data on flushing chemical contaminants to help with the cleanup. ORD also helped the region evaluate the toxicity and possible risks associated with ingesting water contaminated with Indulin AA-86 and the water-soluble salt from the product. The researchers established a health-based action level for the contaminant in support of an immediate need by the region, state, and the city to protect public health.

Drinking water distribution systems, household plumbing, and appliances are increasingly vulnerable to interruption in service from a terrorist attack, industrial accident, or extreme weather events. Water systems can also be impacted significantly if their source water is affected by natural disasters and/or spills of industrial chemicals and oils. This vulnerability presents operational challenges in maintaining good water quality to protect human health and ensure water availability for fire protection and other vital uses. Natural and man-made incidents further exacerbate the declining integrity of our aging water infrastructure. Regardless of the source of contamination, the ability to reliably and cost effectively decontaminate miles of distribution system pipes and plumbing is critical to rapidly returning the system to service. Making swift and effective decisions will help minimize impacts to partners, the time to return to service, and associated costs.

Wastewater infrastructure is also vulnerable to contamination incidents. Depending on the contaminant, the incident may impact the operation of wastewater treatment (e.g., worker safety, sludge, aeration), which in turn can disrupt wastewater collection or result in the discharge of untreated waste to receiving waters. Contaminants in the wastewater treatment process may result in those contaminants ending up in the biosolids. Contaminated biosolids may not be able to be re-used (e.g., land application) and result in an additional waste stream from the incident.

Program, regional, state, and/or tribal needs

HSRP works with EPA partners to understand and address their needs, and with the Association of State Drinking Water Administrators[16] and the Association of Clean Water Associations[17] to ensure that the research developed and implemented also supports their needs. These stakeholders are on the front lines supporting water and wastewater systems in responding to operational and emergency response challenges.

One of HSRP's priorities is to provide tools and methodologies to inform decontamination of water infrastructure, management of the contaminated water, and resumption of operations. Discussions with the drinking water management community and recommendations from Water CIPAC emphasize the importance of water infrastructure decontamination and testing of methods and technologies on a large-scale system, representative of a real drinking water distribution system. To address this need, HSRP constructed the Water Security Test Bed (WSTB)[18] in Idaho to conduct water infrastructure research at the full-scale (see Figure 7). Through operational technology demonstrations and exercises (e.g., tabletops, full-scale exercises), WSTB research can also be used by emergency response and water-sector communities to fully understand the operation, application, and performance of these tools and techniques. HSRP plans to expand current research to include additional contaminants and scenarios, such as:

- decontamination methodologies (including automatic flushing) for various contaminants
- consequences of a cyberattack on water distribution systems
- effectiveness of in-line contaminant detectors
- wash-water treatment methodologies
- water system modeling tools

Example outputs from this work include summarizing decontamination approaches for water infrastructure (Appendix 1, Outputs #19 and #21), including methods to extrapolate the research for contaminants not directly addressed (Appendix 1, Output #18) and methods to support disinfection for *Legionella pneumophila (*Appendix 1, Output #20*).*

EPA also supports wastewater utilities by providing tools and data that help them respond to and recover from contamination incidents and other disasters. To support this need, HSRP will address how wastewater utilities (both infrastructure and personnel) and collection systems might be impacted by and/or treat CBRN contaminated waters. Results from this work will include technical data to support uniform, sole source guidelines issued by OW, OWM, industry, and others (e.g., OSHA) to inform wastewater utilities as they adopt response plans to address wastewater contaminated with high-consequence pathogens or radiological contamination.

---

[16] https://www.asdwa.org/
[17] https://www.acwa-us.org/
[18] https://www.epa.gov/homeland-security-research/water-security-test-bed

Data from HSRP's water infrastructure and decontamination research will be used in tools developed by OW and the response community, including state, tribal, and local responders. Contamination of source waters will be addressed through the Drinking Water Source Vulnerability and Emergency Management Tool (planned for FY20), which identifies upstream hazards using geographic information system (GIS) databases and models to determine travel time to downstream drinking water intakes, as well as leading edge, peak, and trailing edge contaminant levels. The technical basis for a water/wastewater decontamination and treatment technology tool will be developed for integration into WSD's Decontamination Preparedness and Assessment Strategy (DPAS), scheduled for release in FY19 (Appendix 1, Output #17).

The enhanced capability of water systems to predict future system behavior and evaluate the implications of response decisions will improve emergency response and shorten the time needed to resume operations. As such, real-time modeling tools can support accurate hydraulic and water quality predictions. Modeling tools can also enable rapid and effective decisions. HSRP has developed tools and technologies[19] to assist water infrastructure systems in identifying, evaluating, and improving their resilience to man-made or natural disasters, whether by changing operations or by redesigning and retrofitting the infrastructure. These system-specific tools need to be tested and adapted to be applicable for wastewater, storm water, source water, and water reuse applications (Appendix 1, Output #22). In addition, a complete watershed system approach needs to be explored to examine the effects of one system perturbation on another.

Initial HSRP research efforts have focused on developing prototype decision-support tools for drinking water systems. HSRP will focus on expanding these tools to "all hazards", validating their results with real-world data, and using the tools in case study applications with partner drinking water utilities. These tools will help decision makers manage and respond to incidents.

[19] Information on existing EPA tools developed by HSRP can be found at https://www.epa.gov/homeland-security-research.

Figure 7: Aerial view of the Water Security Test Bed

Research Area: Oil Spill Response Support

EPA is responsible for responding to and assessing environmental releases of oil that occur over land, on 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. Atypical oil spills (e.g., deep sea and prolonged releases such as the 2010 Deepwater Horizon spill) have resulted in greater awareness of the capabilities and limitations of spill response methods available for use today and also of the ecological and human health concerns associated with certain spill mitigation technologies. Similarly, smaller and more frequent spills occur each year, which also have human health, ecological, and economic concerns for impacted communities. Ecological issues concerning oil and spill-treating agent toxicity on aquatic flora and fauna, their fate in the environment, and the effects on impacted shorelines and wetlands are of concern for the federal, state, tribal, and local governments, as well as impacted communities, especially those who rely on aquatic resources for their livelihood.

HSRP's innovative research helps to achieve more efficient and effective management of oil spills with respect to preparedness, emergency response, and fate and transport. ORD provides critical products that address key science questions in support of the OEM and OW. Products help to formulate guidance and rulemaking with respect to preparation for and response to releases. In addition to EPA program offices, this research informs technical support to the regions, states, tribes, and other regulatory authorities. This research has fostered strong collaboration with NOAA, the U.S. Coast Guard, Department of Interior's Bureau of Safety and Environmental Enforcement, and U.S. Geological Survey (USGS). Additionally, this research effort is in collaboration with Canada's Department of Fisheries and Oceans, the American Petroleum Institute, and other industry members. Needs related to this research area are developed in coordination with EPA and federal partners. EPA participates on the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR)[20] with fifteen federal agencies. The

[20] https://www.dco.uscg.mil/ICCOPR/Members/

committee focuses on providing updates on oil research, discussing collaboration plans, and developing ways for research to translate to response efforts.

Program, regional, state, and/or tribal needs

The NCP includes a Product Schedule (NCPPS) (U.S. EPA, 2018c) for commercially available spill-treating agents (e.g., dispersants, surface washing agents, herders, solidifiers). The CWA and the OPA give authority to EPA to prepare and maintain this schedule. The NCP also requires that EPA maintain reference oils for product testing. HSRP develops and refines the protocols for product effectiveness and toxicity that are used to inform regulatory actions. This research also provides guidance for emergency responders on product performance and trade-offs to potentially impacted communities and ecosystems. Research in support of this guidance is dedicated to:

- NCPPS efficacy protocol development: currently, the focus includes, but is not limited to, developing efficacy tests for surface washing agents, solidifiers, and chemical herders, and evaluating product performance in fresh and salt waters (Appendix 1, Output #24).
- Toxicity of oil and spill treating agents: developing toxicity procedures and threshold determinations for regulatory listing and establishing LC_{50} values (i.e., the lethal concentration required to kill 50% of the species population tested) for a range of crude oils (Appendix 1, Output #26).
- NCP reference oil evaluation: evaluating potential reference oils for dispersant effectiveness, chemical characterization, and toxicity to enable OEM to select new reference oils (Appendix 1, Output #25).

In addition, efficient oil spill response requires the ability to characterize the behavior, transport, fate, and effects of various oils and spill agents rapidly, including diluted bitumen, which is particularly difficult to remediate and exhibits unique chemical and physical behavior. To protect communities and ecosystems, further research is needed on the chemical characterization, biodegradation, weathering, and toxicity of a range of oils and spill agents. Studies at the bench-, laboratory-, and field-scale improve our ability to minimize environmental and human impacts from spills and serve to calibrate numerical models of oil tracking. Understanding environmental behavior informs predictions of oil fate and transport and helps establish appropriate response, remediation, and restoration methods, including Net Environmental Benefit Analysis (NEBA) Natural Resource Damage Assessment.[21] Research supporting these needs includes:

- Degradation of oil and spill treating agents: characterization of fate processes (e.g., biodegradation) and toxicity of oil exposed to NCPPS agents that are not intended to be recovered from the environment, and evaluate degradation of oil encapsulated in ice or under sediments (Appendix 1, Output #23).
- Oil toxicity and exposure pathways: evaluate unconventional oils, including diluted bitumen, to determine the fate and transport when discharged to the aquatic ecosystem, and evaluate additional new species for toxicity testing beyond current test species for oil-agent mixtures (Appendix 1, Output #25).

[21] NEBA is used to balance trade-offs during oil spill response for considering the most appropriate options to minimize the impact of the spill. Additional information on NEBA can be found at http://www.oilspillprevention.org/oil-spill-cleanup/oil-spill-cleanup-toolkit/net-environmental-benefit-analysis-neba (last accessed July 24, 2018).

- Behavior of oil and spill-treating agents at laboratory-, tank-, and field-scale: this effort includes comparative analyses of spill detection sensors, determining oil behavior for validation of subsea blowout models, evaluating agent effectiveness as a function of oil weathering and environmental conditions, and assessing *in situ* burn efficiencies.

A portion of ORD oil spill research is reserved for emergency response technical support, spill exercises and area planning, interagency working groups, and emerging issues (e.g., Arctic spill planning and increased shipment of diluted bitumen via rail, barge, and pipeline). Focus topics are ever-evolving but current research is dedicated but not limited to:

- Oil tracking tools and emergency response technical support: evaluate oil spill detection assets and establish cutting-edge technologies for oil slick thickness estimates for decision making in skimming and burning (Appendix 1, Output #27).
- Spill planning and guidance formulation: interagency coordination activities, including research on International Maritime Organization dispersant guidelines, National Response Team science and technology factsheet updates, and formulating the six-year Interagency Coordinating Committee for Oil Pollution Research plan.

ORD oil spill research includes experiments over large scales such as spill simulations using wave tank facilities, like Ohmsett at the Naval Weapons Station Earle in NJ (Figure 8, left panel), and at small scales for evaluating the performance of spill-treating agents on the NCP Product Schedule (Figure 8, left panel).

Figure 8: Photo of spill simulations using the Ohmsett wave tank facility at the Naval Weapons Station Earle in NJ (left panel) and laboratory evaluation of the performance of spill-treating agents (right panel).

Research Area: Waste Management

During a wide-area CBRN incident, particularly in an urban area, there can be enormous challenges related to waste management. Currently, there is no federal regulatory framework for bio-contaminated waste. The existing disposal capacity for radiologically-contaminated waste is likely only a fraction of what would be needed in a large-scale radiological or nuclear incident. Environmental remediation after the Fukushima Daiichi accident has been estimated to have generated over 37 million tons of waste, much of it soil.[22] Waste staging and on-site waste minimization and treatment will be critical to allow remediation efforts to proceed. The waste streams include solid materials impacted by the contamination incident as well as waste generated through the decontamination process. In addition to solid waste, large volumes of contaminated water may be generated through decontamination activities. As a marker of how challenging waste management can be for highly pathogenic or toxic contaminants, the single Ebola patient in New York City generated 352 drums of waste (335 drums from patient treatment, 17 drums from apartment cleanup) and the total cost for disposal was $1,120,000.[23]

Water infrastructure can become contaminated due to an intentional act (e.g., terrorist attack) or an unintentional incident (e.g., natural disaster). Large volumes of contaminated water may be generated during flushing of contaminated infrastructure or decontamination operations. With the current goal of trying to contain and treat as much of the waste on-site (by discharging to surface water, a wastewater treatment plant, stormwater, or combined systems), these waste streams may be difficult to manage[24].

Program, regional, state, and/or tribal needs

Decision makers need sound science and tools to assist in planning for and conducting waste management activities effectively. Information is needed to:

- Support effective staging of waste and waste minimization and treatment, as well as the fate and transport of contaminants in disposal facilities.
- Prove the ability of existing treatment technologies (e.g., incineration) to destroy acutely toxic chemicals when they are associated with building materials and other materials that may be contaminated after an incident.
- Test and further develop scalable water treatment and containment methods (potentially recycling the water for further use) to support effective management of contaminated water.
- Predict the effectiveness of treatment methods for contaminants that lack treatment data in preparation for unknown water system contamination threats.

To support these needs, HSRP will develop an all hazards tool on EPA's Geoplatform[25] that analyzes GIS layers to determine optimal waste staging locations, estimates the cost, time, and logistical requirements associated with transporting large volumes of waste, and assists state, tribal, and local governments in determining optimal waste transport options and routes. HSRP will also continue to develop tools to support estimations of waste volumes that are needed for development of waste management plans, including evaluation of advanced technologies (e.g., aerial photography, remote sensing) for waste estimation post-incident. Ultimately, HSRP will develop synthesis documents that will be incorporated into decision support tools that assist state, tribal, and local governments in developing

---

[22] This estimate was derived from materials presented by the Government of Japan, Ministry of the Environment. The presentation is titled "Environmental Remediation in Japan", dated March 2018, and accessed at http://josen.env.go.jp/en/pdf/progressseet_progress_on_cleanup_efforts.pdf (last accessed July 24, 2018).

[23] This information was provided by EPA Region 2 in a presentation that can be accessed at https://www.nrt.org/site/download.ashx?counter=3098 (last accessed July 24, 2018).

[24] Discharging to Hazardous Material Water Treatment Facilities is also an option in some areas of the country.

[25] https://epa.maps.arcgis.com/

their waste management plans, pre- and/or post-incident[26], and executing them. Specifically, the program will integrate its tools into EPA's forthcoming pre-planning waste management and response tool (Appendix 1, Outputs #28 and #31).

HSRP will continue to develop and test methods for CBRN-contaminated waste minimization and waste treatment (Appendix 1, Output #32). Efforts range from developing field-usable treatment technologies for pathogen-contaminated waste (Appendix 1, Output #30)—a key gap identified during the recent Underground Transit Restoration Operational Technology Demonstration[27] (see Figure 9)—to developing treatment technologies for chemical threat-contaminated building and outdoor materials. Because current existing processes for recycling and salvage cannot currently be used to manage waste, innovative approaches will also be developed to manage niche waste streams, like vehicles.

Chemical contaminants, biological agents, and radiological agents ending up in water and other complex matrices (e.g., wastewater collection systems) during emergency situations pose significant and often unique treatment challenges. Some of these contaminants (e.g., PFAS in firefighting foam) can be generated during initial response activities. HSRP is evaluating on-site water treatment technologies to address the need for treating chemically-contaminated water on-site or at the contamination source (Appendix 1, Output #28). This research will inform a water treatment selection framework within the OW's DPAS tool (see Appendix 1, Output #17).

Decision makers and waste treatment operators need information to facilitate their acceptance of waste for treatment or disposal. For example, to assist informed decision making regarding the acceptability of CBRN wastewater for drain disposal and treatment, HSRP will examine the impact of contaminated water on wastewater infrastructure. HSRP will also develop management options, like those needed for management of contaminated biosolids and membranes. HSRP will also work to understand the characteristics of the treated water and how it might impact wastewater, stormwater, or combined sewer systems so that utilities have the information they need to make decisions regarding acceptability (Appendix 1, Output #29). HSRP will share information on difficult-to-treat perfluorooctanesulfonic acid (PFOS) and shorter chain perfluoroalkyl sulfonic acids in collected wash water with ORD's Safe and Sustainable Water Research program, recognizing the cross-program interest, along with leveraging other research of mutual interest.

---

[26] EPA has developed guidance on how to construct pre-incident waste management plans and provided resources to support their development. Please see: https://www.epa.gov/homeland-security-waste/waste-management-benefits-planning-and-mitigation-activities-homeland#preincident

[27] The Underground Transport Restoration Project was a collaborative effort between U.S. DHS, U.S. EPA, and local stakeholders designed to develop capabilities for the rapid return to service of underground transportation systems after a biological incident.

Figure 9: Testing of on-site solid waste treatment approaches.

Topic 3: Systems Approaches to Preparedness and Response

HSRP works to ensure that decision makers and responders have knowledge of and access to the latest capabilities supporting response and remediation. Information related to incident detection, site characterization, and the behavior of the contaminant in the environment is critical for assessing the potential impact of the contaminated environment on human health. This information is also important to consider when developing remediation plans designed to clean up the environment and reduce potential subsequent impacts on human health. Decisions related to sampling, decontamination, and waste management should consider site-specific information that factors into trade-offs. Decision makers need access to tools and information built from a systems approach where each of these research areas is brought together through their interdependencies and relative impacts. This topic area addresses the development of systems-based tools by pulling together the connected elements of the previous two research topics (contaminant characterization and consequence assessment, environmental cleanup and infrastructure remediation) to provide technical support and decision-support tools. This topic focuses on ensuring that information is readily and easily accessible during an emergency. HSRP research under this topic is focused on developing models, methods, and decision-support tools for the responders and decision makers.

Research Area: Tools to Support Systems-based Decision Making

During a wide-area incident, the response community needs tools to rapidly assess the incident, including access to emerging technologies capable of surveying, detecting, and monitoring the event. HSRP models and tools enhance the timeliness of disaster recovery by providing metrics and decision support. These tools help decision makers select the optimal technologies for characterizing or remediating environments after various CBRN agent-related incidents. The response community also needs tools that consider timeframes and cost to evaluate viable options from economic or social standpoints, and they need tools that retain flexibility in remediation activities due to the complexity, uncertainty, and dynamic nature of a wide-area incident. HSRP recognizes the need to develop a baseline model and simulation tools for comparing or measuring decisions against the true resiliency of a community.

Program, regional, state, and/or tribal needs

A great number of decision-support tools have already been developed under HSRP, covering a wide range of hazards. These support tools individually consume separate sources of data, making them susceptible to becoming obsolete and costly to update. The response community has sought EPA's assistance in developing a centralized and routinely-maintained database for monitoring and surveying the latest decontamination, mitigation, and waste treatment technologies/methods (Appendix 1, Output #33). A database could store up-to-date data derived from HSRP literature reviews, studies, and tools in a web-based searchable platform, greatly enhancing response, planning, and preparedness capabilities and efficiencies. HSRP will also develop and integrate a cost model for predicting the economic and social survivability of urban areas according to a range of geographically-specific criteria (Appendix 1, Output #34). The model could then connect to other HSRP tools (such as the Waste Estimation Support Tool[28]) to provide end-users with a tool to assess community viability based on selected technologies.

In addition to selecting the best technologies and considering resource needs, the consequences of remediation activities and the impact to the follow-on activities must be carefully considered. The effectiveness of remediation activities is difficult to predict due to the complexity, uncertainty, and dynamic nature of a wide-area incident. HSRP plans to develop a tool that can simulate the remediation effectiveness of various response activities that will be helpful for a wide-area response (Appendix 1, Output #35). This work will build on support tools that already exist and will provide quantitative estimation for the following items:

- How the selection of certain methods (decontamination, sampling, and waste treatment) would impact the overall remediation
- Bottlenecks in the remediation activities
- Resource availability and demand for remediation
- Testing of future decision-support-tool feasibility before development/deployment
- Testing of future methods/technologies before investment.

Another significant gap for a wide-area incident is the need to collect and communicate data effectively. Inefficiencies in this process can hamper recovery efforts and potentially put lives and the environment at risk. There is a need to develop a framework and identify potential technologies for collecting and synthesizing information to better inform situational awareness, decision making, and management of data during a response. This includes communication of information to decision makers, ultimately to inform the public regarding exposure risks, what can be done to reduce these risks, and on federal, state, tribal, and local response activities. HSRP will address this gap through by developing tools for community stakeholders to conduct self-assessments of their community environmental resilience to disasters (Appendix 1, Output #36).

[28] https://www.epa.gov/homeland-security-research/waste-estimation-support-tool

Anticipated Research Accomplishments and Projected Impacts

Some of the anticipated research accomplishments from across HSRP and their intended impacts or outcomes are highlighted below.

Advancing Resources for Characterization after a Wide-Area Contamination Incident

HSRP is developing ESAM[29] as a comprehensive online source for all information needed to conduct characterization activities after a CBRN incident. During a large environmental response, ESAM provides responders and laboratories with the single best available sample collection and analysis method. When a single method is used, those making decisions based on the data can feel confident about data integrity and can more easily interpret and communicate the information. Over the period of the StRAP, the analytical methods and sample collection information contained in ESAM will be updated. Sampling procedures and information will be added to support the development of sampling strategies. New methods for sample collection will be developed and added for priority biological agents on urban and outdoor surfaces and in air, solid waste, and wastewater. Sample collection methods for chemical threats in water and on surfaces will be developed for inclusion in ESAM.

Developing a Decontamination and Water Treatment Technology Selection Tool

Water contamination incidents continue to threaten the delivery of clean water. To address this concern, HSRP will continue to conduct pilot to field-scale technology testing for water infrastructure decontamination and water treatment. Findings from this research, as well as previously completed research, will be used to construct a tool to assist water utilities in selecting decontamination and water treatment technologies. The tool will consider technology efficacy and operational considerations when providing the end-user options for the selection of an appropriate technology. The tool will be developed in collaboration with technology end-users and incorporated into OW's DPAS, a tool used directly by water utilities to prepare for and respond to water contamination incidents.

Improving Approaches for Response to Emerging Chemical Threats

Fentanyl and its analogs (e.g., carfentanil and 3-methyl fentanyl) are compounds of increasing concern to states, tribes, and local public health and environmental agencies due to their increased availability, extreme toxicity, and increasing misuse. HSRP will continue to address state, tribal, and local needs related to fentanyl and its analogs by developing sampling and analysis methods and proven decontamination options in environmental matrices (specifically, surfaces and water). To assist in interpreting these data and informing emergency response activities, HSRP will develop exposure values that describe health effects based on dosage. The ability of decontamination techniques to clean up fentanyl and its analogs on different types of surfaces (porous and non-porous) will be assessed initially at the lab-scale, prior to testing methods in the field for transition to responders. The development of sampling, analysis, and decontamination methods will provide an update to the recently released fentanyl fact sheet for responders, filling gaps in knowledge and capabilities that were recognized during the development of the fact sheet. Field demonstrations and updates to the fact sheet will provide an opportunity to transition the most effective sampling and decontamination methods to end-users. This

---

[29] https://www.epa.gov/homeland-security-research/environmental-sampling-analytical-methods-esam-program-home

research will allow EPA to make cleanup recommendations and offer solutions to first responders across the country.

Scalable Approaches for Remediation after a Wide-Area Radiological Incident

Federal government cleanup resources will be extremely stretched after a wide-area radiological incident, like the Fukushima Daiichi Nuclear Power Plant Accident. Innovative decontamination approaches that can be safely employed by the public and state, tribal, and local government will be needed. HSRP is developing the technical information required for state, tribal, and local agencies to develop self-help decontamination instructions for owner/occupants or their contractors. HSRP is also developing radiological and nuclear response-specific "how-to" documents for operators on the use of municipal, construction, farm, and critical-infrastructure-specific equipment. These resources will greatly increase local communities' self-sufficiency after a wide-area radiological or nuclear incident and decrease the time needed to recover.

Field-sale Assessment and Demonstration of Wide-Area Biological Response Capabilities

HSRP partners often express the high priority need for capabilities and information to support response to a wide-area biological incident, specifically response to a large urban area intentionally contaminated with *B. anthracis* spores. Over the course of this 4-year StRAP, HSRP, in coordination with OLEM, and in close collaboration with other EPA partners and stakeholders, including states, regions, and other federal agencies, plans to work with the DHS Science and Technology Directorate and the U.S. Coast Guard to develop wide-area biological response capabilities and test them in the laboratory and in the field, resulting in generic guidance and tools to support a wide-area biological incident response. These efforts will then culminate in a field-scale (operational) wide-area biological response demonstration to assess and improve developed capabilities.

Conclusion

HSRP works with EPA program and regional, federal, state, tribal, and local partners, and other stakeholders, to improve the nation's resilience to "all hazards". HSRP works closely with these partners and stakeholders to understand the challenges posed by CBRN threats, including oil spills, regardless of the cause of the contaminant/threat release and to develop capabilities to aid in rapid response. This response includes capabilities to support pre-incident planning, detection of contamination, characterization of the environment to determine the extent of contamination and its potential threat to public health, mitigating the hazard, cleanup of the contaminated environment including built infrastructure, and effectively managing the waste generated. The program vision is that federal, state, tribal, and local decision makers have timely access to the information and tools they need to ensure community resilience to catastrophes involving environmental contamination that threatens public health and welfare.

HSRP takes technologies and methodologies that have been successfully demonstrated at the laboratory-scale and investigates how these technologies can be implemented at full-scale in the real world. In real-world situations, responders contend with varied considerations such as the impact of dirt and grime, resource limitations, prioritization of infrastructure for cleanup, and the impact of technologies on other aspects of the response (e.g., sampling, decontamination, waste management). The program focuses on providing decision makers with relevant information they can use when considering their site-specific situation and requirements.

HSRP focuses on understanding the cascading impacts of response decisions and activities. The program focuses on developing capabilities using a systems view and develops decision-support tools that enable decision makers to have ready access to the latest science information and to analyze decision trade-offs.

An underlying principle of the program is to understand the capabilities of communities and residents as they addressed historical and emerging threats and how this experience factors into the current and future state of community environmental resilience. The program's focus is on the many challenges associated with wide-area contamination, including improving the nation's water infrastructure protection and resilience. Proven characterization, risk assessment, and cleanup approaches provide a deterrence to terrorist activities because timely and effective responses serve to minimize the overall impact of an incident (Pavel, 2012).

References

Homeland Security Act, Pub. L. No. 107-296, 116 Stat. 2135 Stat. (2002 November 25, 2002).

Lumpkins, D. (2017). Plan Big, Even to Respond Small. Retrieved from https://www.domesticpreparedness.com/resilience/plan-big-even-to-respond-small/

National Research Council. (2012). *Disaster Resilience: A National Imperative*. Retrieved from Washington, D.C.:

One Health Initiative. One Health Initiative. Retrieved from http://www.onehealthinitiative.com/

Pavel, M. K. a. B. (2012). How to Deter Terrorism. *The Washington Quarterly, 35*(2), 21-36. doi:https://doi.org/10.1080/0163660X.2012.665339

U.S. DHS. (2008). *National Response Framework - Emergency Support Function #10 - Oil and Hazardous Materials Response Annex*. Washington, D.C. Retrieved from https://www.fema.gov/pdf/emergency/nrf/nrf-esf-10.pdf.

U.S. DHS. (2012). *Denver UASI All-Hazards Regional Recovery Framework*. Washington, D.C.: U.S. Department of Homeland Security.

U.S. DHS. (2015). *National Preparedness Goal*. Washington, D.C. Retrieved from https://www.fema.gov/media-library-data/1443799615171-2aae90be55041740f97e8532fc680d40/National_Preparedness_Goal_2nd_Edition.pdf.

U.S. DHS. (2016a). *National Disaster Recovery Framework*. Washington, D.C. Retrieved from https://www.fema.gov/media-library-data/1466014998123-4bec8550930f774269e0c5968b120ba2/National_Disaster_Recovery_Framework2nd.pdf.

U.S. DHS. (2016b). *National Response Framework*. Washington, D.C. Retrieved from https://www.fema.gov/media-library-data/1466014682982-9bcf8245ba4c60c120aa915abe74e15d/National_Response_Framework3rd.pdf.

U.S. DHS. (2016c). *National Response Framework - Emergency Support Function #11 - Agriculture and Natural Resources Annex*. Washington, D.C. Retrieved from https://www.fema.gov/media-library-data/1473679204149-c780047585cbcd6989708920f6b89f15/ESF_11_Ag_and_Natural_Resources_FINAL.pdf.

U.S. DHS. (2018, October 29, 2018). Critical Infrastructure Partnership Advisory Council. Retrieved from https://www.dhs.gov/critical-infrastructure-partnership-advisory-council

U.S. EPA. (2012a). *Homeland Security Strategic Research Plan*. Washington, D.C. Retrieved from https://www.epa.gov/sites/production/files/2014-06/documents/hs-strap.pdf.

U.S. EPA. (2012b). *WARRP Waste Management Workshop*. Washington, D.C. Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/warrp_workshop_report_0.pdf.

U.S. EPA. (2015). *Homeland Security Strategic Plan 2016-2019*. Washington, D.C. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/strap_2016_hs_508.pdf.

U.S. EPA. (2017, August 31, 2017). Emergency Planning and Response Authorities. Retrieved from https://www.epa.gov/emergency-response/emergency-planning-and-response-authorities

U.S. EPA. (2018a). *FY 2018-2022 EPA Strategic Plan*. Washington, D.C. Retrieved from https://www.epa.gov/planandbudget/strategicplan.

U.S. EPA. (2018b, April 4, 2018). National Oil and Hazardous Substances Pollution Contingency Plan (NCP) Overview. Retrieved from https://www.epa.gov/emergency-response/national-oil-and-hazardous-substances-pollution-contingency-plan-ncp-overview

U.S. EPA. (2018c, October 9, 2018). NCP Product Schedule (Products Available for Use on Oil Spills). Retrieved from https://www.epa.gov/emergency-response/ncp-product-schedule-products-available-use-oil-spills

U.S. EPA. (2018d). *ORD Strategic Plan 2018-2022*. Washington, D.C.

U.S. EPA. (2018e, February 14, 2018). Water System Security and Resilience in Homeland Security Research. Retrieved from https://www.epa.gov/homeland-security-research/water-system-security-and-resilience-homeland-security-research

Water and Wastewater Sector Strategic Roadmap Work Group. (2017). *Roadmap to a Secure and Resilient Water and Wastewater Sector*. Washington, D.C.: WaterISAC Retrieved from https://www.waterisac.org/sites/default/files/public/2017_CIPAC_Water_Sector_Roadmap_FINAL_051217.pdf.

Appendices

Appendix 1: Summary table of Proposed Outputs for Homeland Security Research Program (FY2019 -2022)

The following table lists the expected Outputs from the Homeland Security Research Program, organized by topic. It should be noted that the Outputs may change as new scientific findings emerge. Outputs are also contingent on budget appropriations. The Research Need that the Output is addressing is provided in the table; these needs were defined through the HSRP's partner involvement process. Specific research Products to address these Outputs will be identified and implemented through continued engagement with partners.

Research Area	Program, Regional, State and/or Tribal Need	Output Title
Topic: Contaminant Characterization and Consequence Assessment		
1. Fate, Transport, and Exposure	Review, Clearance, and Dissemination of Provisional Advisory Levels (PALs) for high priority chemical contaminants	1) FY20 - PALs for hazardous chemicals and PALs User Guide
	A process to determine a cleanup goal for chemical warfare agents and their degradates	2) FY20 - Quantitative chemical risk assessment and evaluation of chemicals for prioritization during water contamination incident remediation
	Fate of chemical contaminants of interest in media requiring decontamination	3) FY21 - Fate of persistent chemical agents and pesticides in porous or permeable materials informing remediation options
	Understanding and applying fate and transport of chemical, biological, and radiological contaminants resulting from water infrastructure contamination to improve risk management decisions	4) FY21 - Summary of research on biological contaminant fate, transport, and inactivation in water and wastewater systems to inform mitigation decisions
	Develop and evaluate tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), management of the contaminated water, and return to service	5) FY22 - Development of Stormwater Operational Tool to predict fate and transport of biological and radiological contaminants
Detection/ Environmental Sampling and Analysis	Need for continuance of systematic development of sampling and analytical methods for analysis of priority chemical agents (for example CWAs, precursors, degradates, TICs) and their degradation products for all environmental matrices (this includes waste matrices).	6) FY20 - Chemical sample collection methods for environmental matrices and protocols for target chemical analysis

Research Area	Program, Regional, State and/or Tribal Need	Output Title
	Development of methods and tools to identify sampling locations and strategies within water infrastructure	7) FY20 - Strategies for use of simulation tools and modeling to identify sampling locations within a water distribution system and building plumbing systems
	Sampling methods and strategies are needed for outdoor urban surfaces Strategies for sample collection, processing, and analysis methods for persistent biological agents or biotoxins in solid wastes, including decontaminated wastes Development of sample collection and analysis methods for drinking water contaminants of interest. (CBR contaminants and biotoxins)	8) FY21 - Biological sample collection methods for environmental matrices and protocols for target biological agent analysis
	Assessment of emerging technologies to enhance surveying/detection/monitoring capabilities for wide-area incident response application	9) FY21 - Indoor contaminant mapping capabilities for supporting radiological remediation decision making
	Need for continuance of systematic development of sampling and analytical methods for analysis of priority chemical agents (for example CWAs, precursors, degradates, TICs) and their degradation products for all environmental matrices (this includes waste matrices) Development of Rapid and High-Throughput Methods for Analysis of Pathogens in Characterization and Post-Decontamination Samples	10) FY22 - Selected Analytical Methods for Environmental Remediation and Recovery 2022
Topic: Environmental Cleanup and Infrastructure Remediation		
Wide-Area Decontamination	Need data on wide-area, outdoor decontamination efficacy and application parameters for B. anthracis, including the effectiveness of various types of washdown and rain in reducing spore concentrations on surfaces, vegetation, and soil, and research supporting strategies for remediating urban environments including the exterior of high rise buildings	11) FY21 - Decontamination methods for *B. anthracis* contaminated outdoor surfaces
	Persistence, fate and transport, and methods to prevent the transport of spore-forming biological agents in natural environments (including waterways) and in/on built infrastructure	12) FY21 - Decontamination options for *B. anthracis* spore-contaminated vehicles

Research Area	Program, Regional, State and/or Tribal Need	Output Title
	Need data on wide-area, outdoor decontamination efficacy and application parameters for non-anthrax biological agents, including the effectiveness of various types of washdown and rain in reducing concentrations on surfaces, vegetation, and soil, and research supporting strategies for remediating urban environments including the exterior of high rise buildings	13) FY21 - Decontamination options for wide-area biological agent (non-anthrax) contaminated surfaces
	Need methodologies for decontamination of critical infrastructure; including, transportation infrastructure such as rolling stock and subway tunnels. This need not only includes determination of effective methods, but developing an assessment of the impact and methods suitable for high value materials and equipment	14) FY22 - Decision Support Tool to Aid Development of CBRN Wide Area Remediation Strategy
	Decontamination and Waste Volume Reduction Methods for Wide-Area Remediation Self-Help Decontamination and/or Risk Reduction Measures/Tools/Practices	15) FY22 - Widely-available and user-friendly decontamination options for wide-area radiological incident response
	Effective decontamination methods for porous or permeable materials for CWA and other HS chemicals of concern. Nondestructive and operational decontamination methods for CWAs and TICs on sensitive equipment, rolling stock, valuable items, and records	16) FY22 - Decontamination technologies for indoor/outdoor surfaces and vehicles contaminated with persistent hazardous chemicals
Water Treatment and Infrastructure Decontamination	Develop and evaluate tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), management of the contaminated water, and return to service	17) FY20 - Decontamination and Water Treatment Technology Selection ("How-to") Tool
		18) FY21 - Summary of decontamination approaches tested at the bench, pilot-scale, and at the full-scale water security test bed for contaminated drinking water infrastructure
		19) FY21 - *Legionella pneumophila* disinfection results related to biofilm- and aerosol-associated forms

Research Area	Program, Regional, State and/or Tribal Need	Output Title
		20) FY21 - Methods for homeowner decontamination of post-service connection plumbing and appliances
	Treatment and disposal options for large volumes of chemical agent-contaminated drinking water and wastewater – this includes decontamination of wash water	21) FY21 - Methods to determine water treatment and infrastructure decontamination options when efficacy data are not available for CBR contaminants
	Water infrastructure systems (drinking water, wastewater, stormwater, source water, and water reuse) need to be resilient to man-made and natural disasters, with the ability for rapid response	22) FY22 - Situation Awareness Tool for water security and infrastructure applications that utilizes real-time analytics and modeling framework
Oil Spill Response Support	Emergency Response to Oil Spills: 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)	23) FY22 - Behavior of oil and spill treating agents at laboratory-, tank-, and field-scales
	Develop efficacy test protocol for surface washing agents, solidifiers, and oil herding agents, as well as determine fate of these agents in salt and fresh waters	24) FY22 - NCP product schedule efficacy protocol development
	Subpart J Regulatory Support: Evaluate new reference oils testing for Dispersant Effectiveness, Chemical Characterization, and Toxicity	25) FY22 - NCP reference oil evaluation
	Emergency Response to Oil Spills: Evaluate additional new species for toxicity testing beyond M. beryllina and A. bahia for dispersants and dispersants mixed with oil Subpart J Regulatory Support: Development of material and method procedures, and toxicity threshold determinations, for regulatory listing Subpart J Regulatory Support: Need LC50s for crude oils.	26) FY22 - Oil and spill treating agent toxicity and exposure pathways
	Improving oil slick thickness estimates for decision making on skimming and burning.	27) FY22 - Oil tracking tools and emergency response technical support

Research Area	Program, Regional, State and/or Tribal Need	Output Title
	Emergency Response to Oil Spills: Evaluation of oil spill detection assets	
Waste Management	Treatment and disposal options for large volumes of biological agent-contaminated water	28) FY21 - Information to assist on-site treatment of CBR contaminated water
	Treatment and disposal options for large volumes of chemical agent-contaminated drinking water and wastewater– this includes decontamination wash water	29) FY22 - CONOPS for scalable on-site treatment of *B. anthracis* contaminated waste
	Best management practices for staging, segregating, and transporting waste contaminated with biological agents	30) FY21 - Tools and information to aid in CBR-waste minimization, staging/storage, treatment, transport, and disposal
	Comprehensive resource which enables efficient, fast, and accurate decision making regarding sustainable waste and debris management	31) FY22 - Integration of HSRP and other emergency response and waste tools
	Develop and evaluate tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), management of the contaminated water, and return to service	32) FY22 - Informed decision making for CBR wastewater drain disposal and wastewater treatment plant acceptance
Topic: System Approaches to Preparedness and Response		
Tools to Support Systems-based Decision Making	Centralized and routinely maintained database for monitoring, surveying, decontamination, mitigation, and waste treatment technologies/methods	33) FY19 - Database for storing and distributing data on remediation activities for use in all-hazards response and recovery research, operations, and tools
	Assessment of emerging technologies to enhance surveying/detection/monitoring capabilities for wide-area incident response application	34) FY22 - A time-based model for evaluating economic and social costs of a wide-area CBRN incident
	Need for a user-friendly decision-support tool that assists in the prioritization of remediation activities	35) FY22 - GIS-based tool for assessing bio/rad risk based on location-specific environmental factors
	Water infrastructure systems (drinking water, wastewater, stormwater, source water and water reuse) need to be resilient to man-made and natural disasters with the ability to respond rapidly	36) FY22 - Summary of resilience tools for community and water networks including associated case studies

Appendix 2: State Needs Reflected in ORD Research Planning

The table below lists the state needs identified in the 2016 Environmental Council of States (ECOS) survey and in discussions with ORD in spring of 2018. These needs are aligned to the ORD Research Areas planned in the ORD StRAPs. Additional research designed to meet the state needs identified here, and additional state needs, may be found in other ORD National Research Program Strategic Research Action Plans.

Source	*State Need*	*HSRP Activities*
	Air	
ECOS Media Specific Meetings	Prescribed burns/wildfires and emission factor work with KS and R7 (NE)	Assessment of the potential spread of contamination from wildland fires
	Water	
ECOS 2016 Survey	Water and Wastewater Infrastructure	Resilience of water and wastewater infrastructure
ECOS Media Specific Meetings	More work on wastewater treatment plants and landfills (MI)	Research on wastewater treatment plants' acceptance of wastewater after a biological incident; wastewater treatment of chemical, biological, and radiological contaminants from a wide-area incident, on-site treatment of chemical, biological, or radiological contaminated water, including water contaminated with PFAS from emergency response operations
	Emerging Contaminants	
ECOS 2016 Survey	Manage new chemicals of emerging concern and existing chemicals	Environmental sampling, analysis and clean-up methods for emerging chemical threats
	Adapt and respond to emergencies	Support for response and environmental remediation to environmental contamination incidents
	Waste/Remediation	
ECOS 2016 Survey	Emerging contaminants (*e.g.,* PFAS)	Environmental sampling, analysis and clean-up methods for emerging chemical threats
	Cross-Media	
ECOS Media Specific Meetings	PFAS • Need remediation techniques to accompany EPA's work on analysis/detection (OK) • Actual health or environmental impacts of PFAS (currently only speculation exists) (TN)	On-site water treatment options for PFAS contaminated water from emergency response operations, such as water contaminated with PFAS from fire-fighting foam

Appendix 3: Cross-cutting Research Issues

The following table lists research issues and activities coordinated across the ORD national research programs.

Research Issue	A-E	CSS	HHRA	HSRP	SHC	SSWR
Ecosystem services	• Secondary NAAQS • Near road & urban air quality • Wildfires • Extreme heat	• Ecotoxicity	• Eco risk assessment		• Site recovery • Health promotion • Community revitalization • Ecosystem services	• Secondary NAAQS
Lead			• Regulatory models • Risk Assessment	• Sensors and water infrastructure modeling, including contaminant fate and transport	• Locations • Exposure data & evaluated models • Innovative solutions	• Water treatment systems • Drinking water quality sampling • Risk Assessment • Sensors & Water Infrastructure
Nutrients	• Atmospheric deposition of airborne nitrogen and phosphorus to ecosystems	• Toxicity testing				• Sensors and Water Infrastructure(w/SHC) • N & Co-pollutants • Toxicity Testing (w/CSS)
PFAS	• Air and emissions sampling and control potential	• Analytical standards • Adverse outcome pathways • Rapid toxicity testing	• Risk characterization	• Treatment of contaminated water from emergency response activities, including use of PFAS containing firefighting foam	• Tech Support • F&T at contaminated sites and landfills • Estimating human exposure	• Analytical methods • Remediation • Waste-water treatment • Toxicity Testing
Resilience	• Sector-based approaches to resilience • Assessment of trends and development of scenario to support			• Emergency preparedness and response for all hazards	• Indicators of long term resilience • Preparation and response to natural disasters	• Coastal Resilience • Stormwater

Research Issue	A-E	CSS	HHRA	HSRP	SHC	SSWR
	adaptation and resilience for extreme events					
Wildland fires	• Models and measurement methodologies • Vulnerable ecosystems and human populations • Approaches to mitigate risks			• Fate and transport of contaminants during wildland fires, *e.g.*, fire in asbestos contaminated area	• Models and measurement methodologies	