Fate and Behavior Tools Related to Inland Spill Response—Workshop on the U.S. Geological Survey's Role in Federal Science Support

Open-File Report 2020–1063

U.S. Department of the Interior
U.S. Geological Survey

Front cover. Cleanup of submerged oil on the Kalamazoo River near Marshall, Michigan, after the July 2010 pipeline release of diluted bitumen (Photograph by Faith Fitzpatrick, U.S. Geological Survey).

Back cover. Meeting at the U.S. Geological Survey Upper Midwest Water Science Center, Middleton, Wisconsin, on December 12, 2017 (Photograph by Faith Fitzpatrick, U.S. Geological Survey).

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Abbreviations

ADIOS	Automated Data Inquiry for Oil Spills (National Oceanic and Atmospheric Administration)
DOI	U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
ESI	Environmental Sensitivity Index (National Oceanic and Atmospheric Administration)
GIS	geographic information system
GNOME	General NOAA Operational Modeling Environment (National Oceanic and Atmospheric Association)
ICS	Incident Command System
ICWater	Incident Command Tool for Drinking Water Protection (U.S. Environmental Protection Agency)
IOSPP	Inland Oil Spill Preparedness Project (U.S. Department of Interior)
MCR	Midcontinent Region (U.S. Geological Survey)
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NHD	National Hydrography Dataset (U.S. Geological Survey)
NHDPlusV1	National Hydrography Dataset Plus, Version 1.0
NOAA	National Oceanic and Atmospheric Administration
NRDAR	Natural Resource Damage Assessment and Restoration (U.S. Department of Interior)
NRT	National Response Team
OPA	oil-particle aggregate
OR&R	Office of Response and Restoration (National Oceanic and Atmospheric Administration)
ORSANCO	Ohio River Valley Water Sanitation Commission
OSC	on-scene coordinator
RRT	regional response team
RSMS	Riverine Spill Modeling System (Ohio River Valley Water Sanitation Commission)
SSC	science support coordinator (National Oceanic and Atmospheric Administration)
UMRBA	Upper Mississippi River Basin Association
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
VOC	volatile organic compound
WSC	water science center

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Executive Summary

There is a growing body of tools available for science support for determining the fate and behavior of industrial and agricultural chemicals that are rapidly injected ("spilled") into aquatic environments. A 2-day roundtable-style workshop was held by the U.S. Geological Survey (USGS) in Middleton, Wisconsin, in December 2017 to describe and explore existing Federal science support for spill fate and behavior tools used for inland spills, ongoing and new fate and behavior studies, and science gaps in planning and response tools as part of the USGS Midcontinent Region's efforts to include spill response as part of its strategic plans. A total of 28 attendees representing a variety of Federal, State, and regional entities presented on programs and tools used in various aspects of spill response. Most programs and tools discussed were for spills in riverine environments but tools and applications for spills in lakes, on land surfaces, in urban storm sewer networks, and groundwater also were discussed. A primary workshop focus was to facilitate communication and increase potential for future collaboration among agencies for inland spill science support. The role and need for more USGS science support within the inland spill community was discussed. Enhanced communication is needed within the USGS and the U.S. Department of the Interior science programs, as well as within and among other agencies that do emergency planning and response. A main conclusion of the workshop was that there are untapped resources of the USGS outlined in the agency's science strategy that could strengthen science support for fate and behavior tools in inland areas, especially in the Upper Mississippi River, Ohio River, and Great Lakes Basins where large freshwater resources overlap with dense corridors of oil and hazardous substances, with transportation networks, and with large populations centers.

Fate and behavior tools are being developed quickly for inland spill response by multiple Federal agencies in partnership with local and regional entities. Applicability of these tools ranges from planning and preparedness, to the early stages of spill response for protection of human life and property, and to the application of monitoring and models to assess the long-term consequences of spills. Key findings from the workshop, with an emphasis on potential further development of USGS science support, include the following:

- The national and regional response to spills occurs within an established system that must be respected by all parties involved in spill response. The USGS's role is to support spill responders who are physically working at a spill scene, deploying booms and using other efforts to contain and recover spilled materials.

- The USGS has tools that have been used throughout spill response operations, from early response to recovery and restoration. Developing a more formal role for the USGS to participate in science support for inland spills on a consistent basis is a desired outcome. This will require the USGS to improve internal and external communication and would be best accomplished by assigning one or more coordinator positions within the agency to plan and oversee USGS spill-response efforts. More involvement of the USGS on National and Regional Response Teams, especially in the realm of the Science and Technology Subcommittees, will go far in increasing external communication and integration of fate and behavior tools.

- Rapid response to spills requires modeling and mapping of plumes and associated time-of-travel estimation for a range of stream sizes across the United States. Many existing models use USGS streamgage data and the USGS National Hydrography Dataset. Nearly all existing models would benefit from updated linkages to USGS StreamStats and its soon-to-be released time-of-travel estimates, real-time velocity, stream morphology, and slope data. Integrating USGS tools with those from other agencies could be done to better serve the larger spill response community.

- A problem is that existing models to rapidly predict plume extent, as well as more followup/longer-term fate and transport models, can be unknown or unavailable to spill responders. Thus, creating and strengthening linkages among USGS scientists skilled at using these tools is needed to support spill response with the on-scene responders.

- Research for inland spill fate and behavior done outside of an immediate spill response can assist with spill planning and preparedness by (1) revealing sites likely to experience spills in the future (high-risk sites) and (2) understanding how a spilled substance might behave under a range of environmental conditions. However, USGS research on this topic has been scarce and subject to funding availability. Examples include the 2010 Line 6B Spill release into the Kalamazoo River in Michigan, where the USGS provided science support for a variety of fate and behavior tools for stream and impoundment environments. A long-term research site in Bemidji, Minnesota, provides important insights into transformations and longevity of spilled oil in groundwater and groundwater-surface water interactions.

- Linking stream models to other components of this inland environment, including groundwater, overland flow, and karst, is needed. Stream network data can be linked to underground conduits such as storm sewers and karst groundwater systems. Stream models can also be linked with geospatial data such as that contained in U.S. Environmental Protection Agency's interactive mapping tools.

- The USGS is uniquely qualified to collect water-quality data during spills in the United States because of its many geographically dispersed water science centers, its knowledge and preparedness for flood measurement and documentation, and its cadre of skilled water-quality employees. Rapid-deployment gages, used for floods, could also be used for spills if they included spill-specific sensors. Coordinated expertise at USGS water and environmental science centers can be used for monitoring spill effects and for assessing risk to water quality and ecological communities.

- Scientists at the USGS have proven capable of providing science coordination and technical assistance within the Incident Command Structure at the request of the lead on-scene coordinator. This external coordination, as well as internal communication within USGS Water, Hazards, and Ecosystems Mission Areas, could be improved by establishing and naming a USGS spills coordinator. Scott Morlock, Jo Ellen Hinck, and Faith Fitzpatrick are currently (2017) serving in informal coordination roles in addition to their traditional duties.

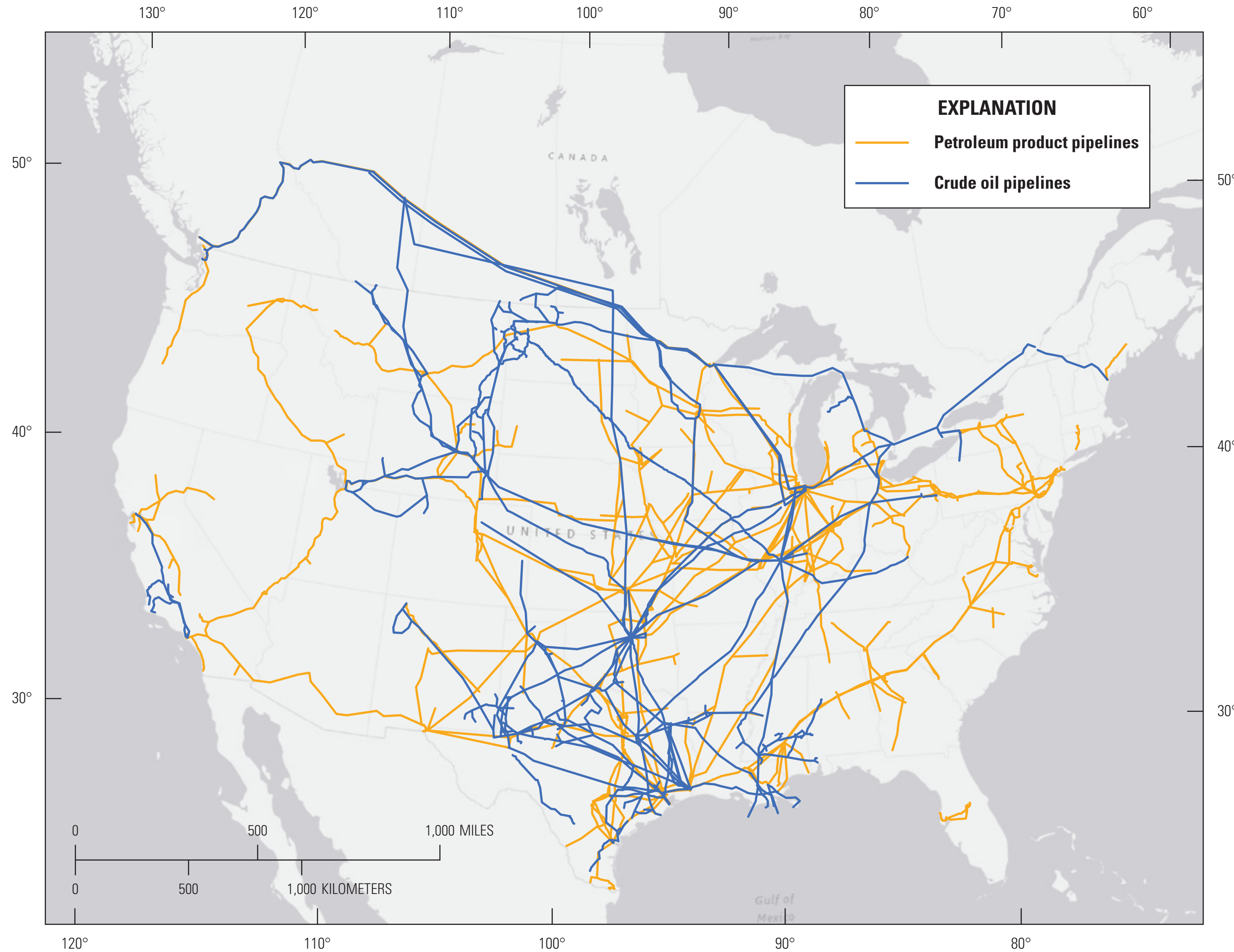
Introduction

Each year, thousands of emergencies involving oil spills or the release (or threatened release) of hazardous substances are reported in the United States. Emergencies range from small- to large-scale spills requiring prompt action and evacuation of nearby population (U.S. Department of the Interior, 2020a).

The impetus for increased science support for spill response, and by extension this workshop, was the increase in inland transport and storage of crude oil and related spill risks of crude oil and related products during the past decade near rivers, lakes, and estuaries within the Great Lakes Region, Upper Mississippi River, and Ohio River Basins from expanded inland drilling and oil extraction techniques. Tar sands crude oil extracted from North America is refined primarily in the Great Lakes States. Crude oil extracted from western North America (especially North Dakota) is transported by rail, pipeline, and vessel throughout the Great Lakes and eastern U.S. States to refineries along the Great Lakes (fig. 1). The age and quality of the infrastructure used to transport crude oil poses an additional increased risk for a spill (Great Lakes Commission, 2015).

A 2-day workshop (December 12–13, 2017) on fate and behavior tools related to incidents of spills on inland waters (hereafter referred to as "inland spills") was convened by the U.S. Geological Survey (USGS) Midcontinent Region at the Middleton, Wisconsin, office of the USGS Upper Midwest Water Science Center (WSC) through Midcontinent Region funding. The main objective of the workshop was to facilitate communication, mainly among Federal agencies, regarding existing and future planning and response tools for inland spill fate and behavior. A specific goal was to better define the potential role of the USGS in providing science support for other Federal agencies charged with leading inland spill response under the National Oil and Hazardous Substance Pollution Contingency Plan (NCP; 33 U.S.C. 1321(c)(2); 42 U.S.C. 9601–9657; read more at https://www.epa.gov/emergency-response/national-oil-and-hazardous-substances-pollution-contingency-plan-ncp-overview). Workshop presentations included overviews of agency roles and responsibilities in spill response, as well as fate and transport tools. A total of 28 attendees participated either in person or remotely and represented agencies including the USGS, the U.S. Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of the Interior (DOI), and the U.S. Fish and Wildlife Service. Details for the workshop agenda and attendees are in appendix 1.

The USGS has historically assisted in post-spill hazard science through the DOI's Natural Resource Damage Assessment and Restoration (NRDAR) Program and through process-based research that can inform future spill hazards. The DOI NRDAR Program completes damage assessments, the first step toward resource restoration, that help provide the foundation for determining needs (DOI, 2020b). The NRDAR



Base modified from the Energy Information Administration, 2018
World Geodetic System of 1984

Figure 1. Major petroleum product and crude oil pipelines. Rail transport not shown for clarity.

Program is in partnership with applicable State, Tribal and Federal trustee agencies. USGS post-spill hazard science is aimed at providing infrastructure that can be used in future spill-response scenarios and in predicting outcomes for spills. These areas of research exist because of past spills where the USGS has been a part of rapid-response science efforts. The following subsections provide examples of USGS post-spill water-hazard science.

The Federal Role in Oil-Spill Response

The U.S. Government, in conjunction with State, Tribal, and certain foreign Governments, has developed a comprehensive preparedness and response system for oil spills. The U.S. Coast Guard (USCG) and the EPA are the designated Federal lead agencies for preparing for, and responding to, oil spills. The DOI Office of Environmental Policy and Compliance (https://www.doi.gov/oepc/regional-offices) regional environmental officers also fulfill a substantial support role for oil-spill preparedness and response. The NCP established the National Response Team (NRT) and its roles and responsibilities in the national response system. These include planning and coordinating responses, providing guidance to regional response teams (RRTs), coordinating a national program of preparedness planning and response, and facilitating research to improve response activities. The EPA and USCG share lead roles within the NRT, with the EPA having jurisdiction over land-based spills and the USCG over the open waters of the Great Lakes as well as navigable sections of large rivers within the United States. The USCG is also the lead agency responsible for establishing funding for oil spills under the National Pollution Funds Center Oil Spill Liability Trust Fund (USCG, 2006).

The NRT includes 13 RRTs (fig. 2). Each RRT, which is co-chaired by the EPA and the USCG, maintains a regional contingency plan and has State and Federal representation. The RRTs provide planning, policy guidance, and coordination during spills. The RRTs provide assistance during an incident if requested by the on-scene coordinator (OSC; https://nrt.org/site/regionmap.aspx).

In an inland spill response scenario, the DOI and U.S. Department of Agriculture are natural-resource trustees (NOAA is the trustee for marine sanctuaries). The science-support coordinators (SSCs) at NOAA's Office of Response and Restoration (OR&R) provide continuous science support for oil-spill responses mainly, but not limited to, the marine and coastal settings. NOAA's SSCs serve on the NRT and RRTs.

Federal agencies, including the USGS, may be called upon to provide assistance in their respective areas of expertise, as in section 300.175 of the NCP, during an oil or hazardous substance spill. The USGS role defined in the NCP is: "Performs research in support of biological resource management; inventories, monitors, and reports on the status of and trends in the Nation's biotic resources; and transfers the information gained in research and monitoring to resource managers and others concerned with the care, use, and conservation of the nation's natural resources. USGS biologic research laboratories can advise and support NCP responses. USGS can also provide support services related to geology, hydrology (groundwater and surface water), geospatial information, and natural hazards."

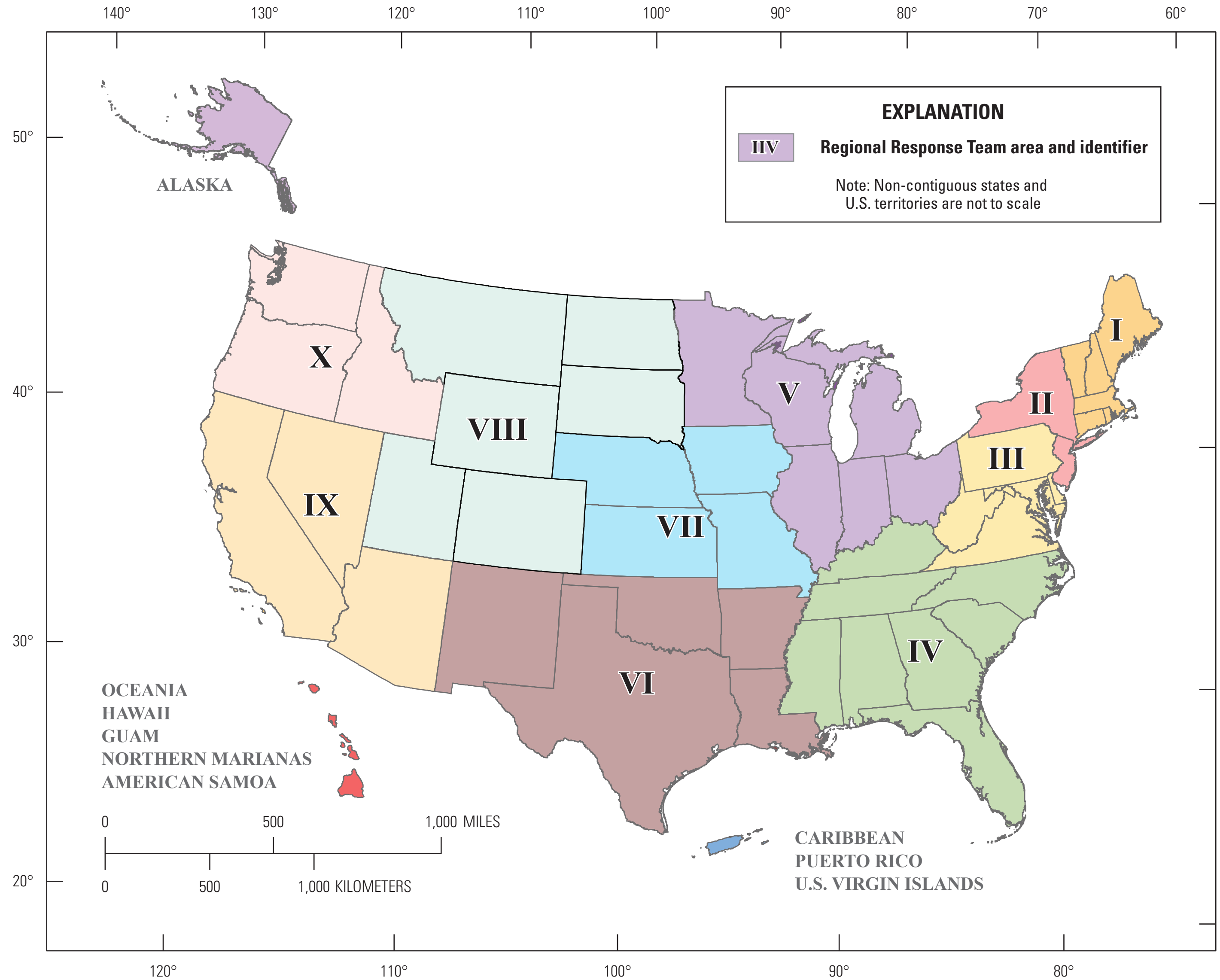
Workshop Rationale and Goals

The workshop had an overarching goal to facilitate communication mainly among Federal agencies with these specific goals:

- Describe the roles of Federal and regional entities to spills that are near and threaten inland waterbodies,
- Describe existing tools for spill fate and behavior,
- Describe ongoing and new efforts to develop spill-response tools,
- Identify and discuss gaps in scientific knowledge and applications, and
- Begin to formulate pathways and framework to further coordination and communication of new tools to the larger inland spill planning and response community across the DOI, NOAA, and the EPA.

Discussion sessions were scheduled in the last part of both days of the workshop. The discussions included, but were not limited to, identifying common areas of interest among the agencies present at the meeting and how to increase communication to improve collaboration; the science and data needs for spill response; and gaps that currently exist that USGS or other entities could address collaboratively.

From the USGS perspective, the Midcontinent Regional Director identified three main questions for the workshop partners: (1) how can USGS capabilities support partner needs; (2) what are the tools that the USGS can supply; and (3) what are the gaps in knowledge and abilities that the USGS may be able to address? The Midcontinent Regional Director also asked workshop partners to consider in addition to specific fate and transport tools, are there applications to NOAA's National Water Model (https://water.noaa.gov/about/nwm), USGS models under development for the Integrated Water Prediction Program (https://www.usgs.gov/mission-areas/water-resources/about/message-associate-director-water), or NOAA's Great Lakes Coastal Forecasting System (https://www.glerl.noaa.gov/res/Programs/ipemf/GLCFS_nextgen.html)? Finally, he directed participants to discuss how recent developments in the USGS Streamflow Statistics and Spatial Analysis Tools (StreamStats), time-of-travel (TOT) equations, or updates in the USGS National Hydrography Dataset (NHD) could be useful to spill fate and behavior tools.



Base modified from U.S. Environmental Protection Agency and U.S. Census Bureau 1:5-meter-scale digital data, North American Datum of 1983.

Figure 2. Regional Response Team areas.

Federal and Regional Spill Science Support and the U.S. Geological Survey's Role

Federal agencies and regional organizations that had presence at the workshop were DOI, NOAA, EPA, USGS, Upper Mississippi River Basin Association (UMRBA), and Ohio River Valley Water Sanitation Commission (ORSANCO) and are involved at various capacities in science support for inland spill fate and transport tools or models. Representatives from UMRBA and ORSANCO were included because of the large regional coverage of those organizations and resulting need for coordination among multiple levels of planning and response entities.

The following brief overviews were extracted from notes and slides from workshop presentations and in some cases augmented with information from websites. These overviews are intended to (1) provide background to the reader to gain understanding of the role of the entities present at the workshop; (2) describe how the USGS is currently contributing to the work of that entity in the spill response arena, if at all; and (3) identify how USGS science can be applied, if applicable. Links to resources are provided where possible for more information.

U.S. Department of the Interior Inland Oil Spill Preparedness Project

The DOI Inland Oil Spill Preparedness Project (IOSPP) has the overall objectives of improving DOI's ability to prepare for and respond to inland oil spills to protect the Nation's natural and cultural resources, historic properties, and DOI lands, resources, and interests (DOI, 2020c). Secondly, the project establishes and maintains an operational base that will result in more timely and effective DOI response to inland oil spills. The project is coordinated through the Office of Environmental Policy and Compliance and the Office of Restoration and Damage Assessment under the Office of Policy and Environmental Management.

Part of the DOI's spill response mission is to fund work by its Bureaus that fall under selected focus areas. The focus areas within the IOSPP currently include the following:

- Inland oil spill vulnerabilities assessment for DOI lands and resources,
- Enhanced DOI bureau participation in contingency planning,
- Enhanced DOI training for inland oil spill preparedness and response,
- Enhanced DOI participation in inland oil spill exercises and drills,
- Education and outreach to DOI intergovernmental partners, and
- Scientific support for inland spill preparedness and response.

The USGS engagement in spill response can be made more effective in several ways. Recognizing the spill response has an established structure and engaging with that is the first step. USGS has expertise and the methods and tools to address complex science questions that are often at the forefront in spill response. DOI programs like the IOSPP are opening doors, and USGS representation at RRT meetings, spill training, and exercises with Federal, State, and Tribal partners will help establish USGS as a full partner.

National Oceanic and Atmospheric Administration

NOAA's OR&R responds to more than 150 oil and chemical spills in U.S. waters every year (OR&R, 2020b). During an oil spill in coastal waters, OR&R's role is to provide scientific support to the USCG officers in charge of response operations. In some instances, NOAA will provide science support to the EPA in inland settings.

The SSC position in NOAA may be designated by OSCs as the principal advisors for scientific issues, communication with the science community, and coordination with scientific studies. The five questions that NOAA SSCs ask when responding to a spill are

1. What happened?
2. Where could it go?
3. What could it affect?
4. What harm could it cause?
5. What can be done to help?

NOAA's OR&R has developed response software and other products for specifically modeling oil and chemical fate and transport; published numerous job aids, field guides, and manuals; conducted leading research in oil spill and hazardous materials response; and collectively published about 1,000 scientific papers (OR&R, 2020c).

U.S. Environmental Protection Agency

The EPA maintains a 24-hour spill response line for inland spills of oil and other hazardous substances covered under the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C. §9601 et seq.) also known also as Superfund (EPA, 2020a, 2020b). The on-duty phone officer may be from EPA's National Response Center or from a local fire department or State agency. The OSCs from EPA RRTs get involved for national emergencies or when local or State emergency response agencies need more support. The jurisdictional boundaries of the EPA and the USCG are determined by origin and level of impact, with the two agencies typically coordinating resources in areas of potential overlap such as Great Lakes harbors and estuaries. The EPA evaluates the spill according to the four-step process in figure 3.

Emergency response at the EPA includes air and land as well as water-related incidences. Inland spill science-support resources include fate and transport models, equipment and techniques, fact sheets on chemical behavior, and application for research laboratories. As part of the RRTs, NOAA SSCs are available to provide EPA OSCs with science support for spill response. The USGS provided science support to EPA OSCs during the 2010–14 Line 6B Oil Release spill response for the Kalamazoo River in Michigan (Dollhopf and others, 2014).

U.S. Army Corps of Engineers

Representatives from the U.S. Army Corps of Engineers (USACE) were not present at the workshop, but the USACE has an active role in spill response (USACE, 2010). Spill response is referred to in the setting of USACE initiated spills, but the USACE is involved in hydraulic and hydrodynamic modeling on navigable rivers that can be applied and useful for fate and behavior tools. The USACE's models were used for describing the fate of diluted bitumen from the 2010 Kalamazoo River spill (Fitzpatrick and others, 2015; Hayter and others, 2015).

U.S. Coast Guard

A representative from the USCG 9th District, which covers the Great Lakes (USCG, 2020), was not present at the workshop. The USCG mainly uses the expertise of NOAA's SSCs and oil spill fate and transport tools as well as the expertise from the NRT and RRTs.

The OSCs from the EPA and USCG coordinate spill response in rivermouths and shorelines along the Great Lakes. These areas represent the opportunity and need for melding inland, coastal, and open water spill fate and behavior tools.

Upper Mississippi River Basin Association

The UMRBA is a regional inter-State organization that includes Illinois, Iowa, Minnesota, Missouri, and Wisconsin to coordinate the States' river-related programs and policies and work with Federal agencies that have river responsibilities (UMBRA, 2020). UMRBA is involved with nearly all aspects of large river management including hazardous spills. The UMRBA has recently published several documents related to spills including an updated spill response plan and resource manual, emergency field guides, and geographic response plans and site specific response strategies for the individual segments of the river created by the lock and dam structure of the Upper Mississippi River (UMBRA, 2015).

Ohio River Valley Water Sanitation Commission

The ORSANCO maintains communication for emergency response and coordinates spill response tools across eight States, three of which are in RRT V (ORSANCO, 2018a). The ORSANCO member States (Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia) cooperate to improve water quality in the Ohio River Basin. ORSANCO operates monitoring programs to check for pollutants and toxins that may interfere with specific uses of the river (ORSANCO, 2018b). ORSANCO's role in spill response is in four areas: communications; water-quality monitoring; analytical support; and time-of-travel modeling. Because the Ohio River is a boundary between States for much of its length, any spill represents a potential inter-State impact.

U.S. Geological Survey Water Mission Area Role

Goal 4 in the USGS Water Science Strategic Plan refers to USGS assistance as "Anticipate and respond to water-related emergencies and conflicts" and lists the following objectives: "(1) Identification of current and future threats to communities from water-related hazards; (2) Development and deployment of observational systems for identifying and tracking hydrologic hazards, making operational decisions during extreme hydrologic events, and providing data for recovery; (3) Through an understanding of the conditions leading to water shortages that result in conflicts, provide assistance to communities in finding science-based solutions when conflicts occur; and (4) Providing tools that allow managers to detect and respond to emergencies related to water-quality degradation of all kinds—natural, accidental, and intentional" (Evenson and others, 2013, p. 19). There is a need to further address how the USGS goals fit within a framework of research, planning, and operations for future spills.

One of the main spill-related roles of the USGS is to provide scientific support to the DOI's NRDAR program (USGS, 2020). The NRDAR program has guided the restoration of natural and cultural resources throughout the United States as well as internationally. USGS scientists provide support to the NRDAR program by conducting research and providing technical expertise to determine the extent to which natural resources have been impaired as the result of hazardous substance releases and supporting restoration activities for the recovery of those resources.

The USGS Water Mission Area and WSCs have occasionally participated in spill response when another agency has requested their assistance. However, within most USGS WSCs, there are no spill-specific plans; rather, they only have

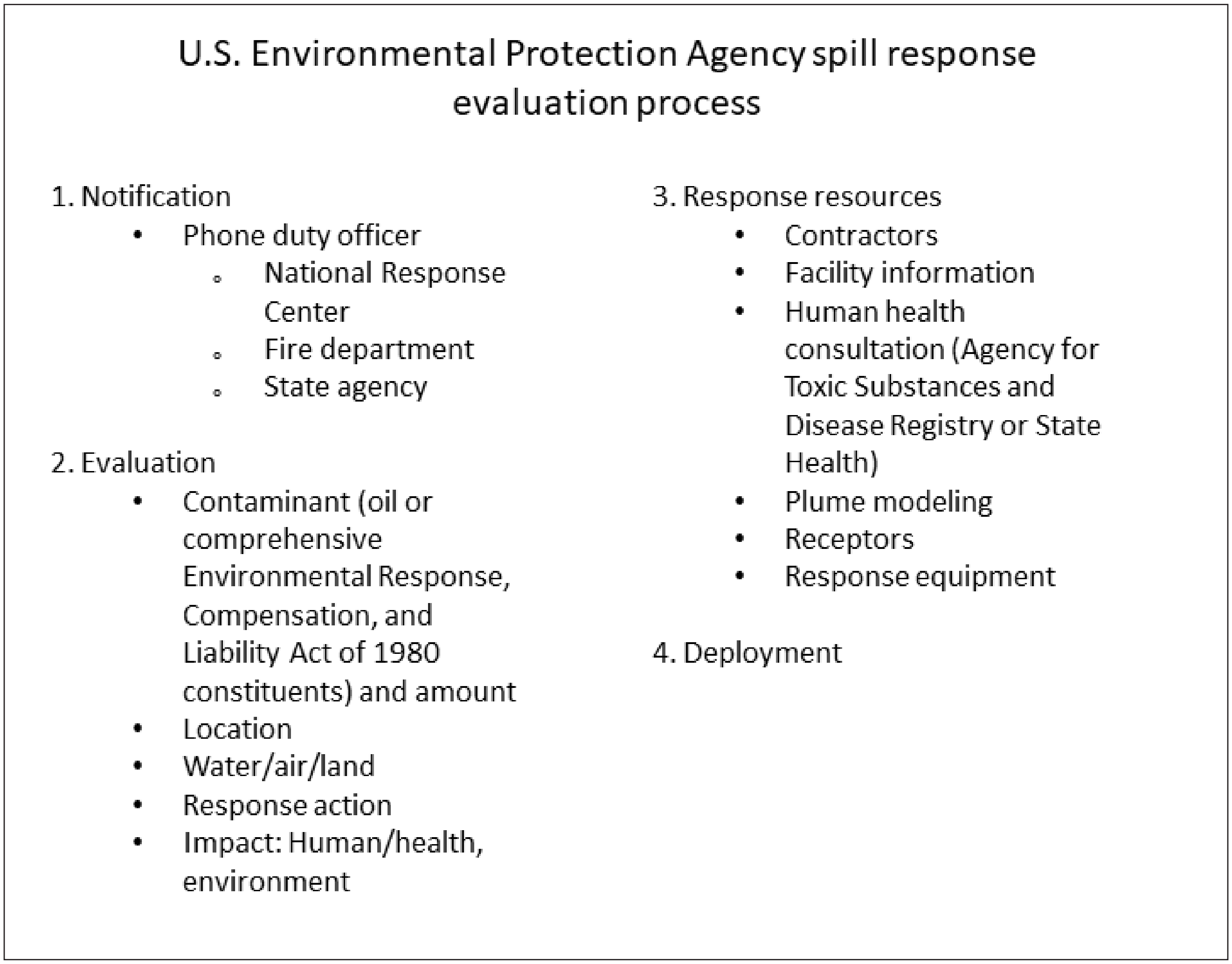


Figure 3. U.S. Environmental Protection Agency's spill response evaluation process (modified from J. Gulch, U.S. Environmental Protection Agency, written commun., 2017).

flood plans that call for collection of discrete water-quality samples during extreme events. The geographic distribution of WSCs and in-house water-quality expertise make them a logical choice for local hydrologic knowledge and to assist with spill-related sampling efforts.

Two large recent spills that the USGS responded to include the 2010 Deepwater Horizon Spill in the Gulf of Mexico and the 2010 Line 6B Pipeline Release into the Kalamazoo River in Michigan. As part of the DOI, and in coordination with the USCG, the USGS participation in the 2010 Deepwater Horizon Oil Spill response was by helping to establish baseline conditions in water and sediment chemistry prior to and after the spill reached the shoreline (USGS, 2016). The USGS continued additional sampling after the spill reached shore. Teams of scientists collected samples from barrier islands and coastal wetlands in Texas, Louisiana, Mississippi, Alabama, and Florida critical to fish and wildlife in the Gulf of Mexico.

The USGS participation in the spill response to the 2010 Line 6B release near the Kalamazoo River (U.S. Environmental Protection Agency, 2016) consisted of USGS personnel assisting EPA in operations and environmental planning as part of a Unified Incident Command. At the request of the OSCs, the USGS efforts included flood-inundation mapping, scientific support coordination, and technical assistance in operations and environmental planning units. The USGS assisted EPA in developing a science-based multiple lines of evidence approach for cleanup (Dollhopf and others, 2014). One component of the approach was the development of multiple fate and transport models for submerged oil and oiled sediment at different spatial and temporal scales (Fitzpatrick and others, 2015).

At the National Crude Oil Spill Fate and Natural Attenuation Research Site in Bemidji, Minn., USGS researchers, in coordination with a larger team of about 40 researchers, are studying the long-term fate, transport, and environmental health effects of crude oil in the subsurface from a 1979 pipeline release of crude oils into a shallow aquifer in Bemidji, Minn. (Delin and others, 1998). The researchers are studying the remaining crude oil as it continues to move through three environmental components near the water table—a separate fluid phase, as dissolved petroleum constituents in groundwater, and as vapors in the unsaturated zone. Native microbes that are converting the petroleum derivatives into carbon dioxide, methane, and other biodegradation products are also being studied (Baedecker and others, 2018; Trost and others, 2018; Warren and Bekins, 2018).

Inland Spill Fate and Behavior Tools and Models

Existing inland spill fate and behavior tools presented at the workshop included time-of-travel tools, fate and behavior models, and applications to broader inland environments including groundwater and karst. The tools cover a range of rapid to not-so-rapid assembly times, as well as a variety of spatial extents (fig. 4). The following sections are overviews from workshop presentations. The presentations are examples of tools and models and are not meant to be an all-inclusive listing.

U.S. Geological Survey StreamStats and Time-of-Travel Tools

The USGS StreamStats web application (https://streamstats.usgs.gov/ss/) provides a publicly available geographic information system (GIS)-based platform that provides information used by many organizations for water-resource planning and management and for engineering. StreamStats is a national program that is driven by local needs, and all StreamStats functionality is developed as web services. Every State has its own application with its own tools and priorities; some are more advanced than others based on level of investment, needs, or both. As an example, Indiana has interactive maps for estimating peak-flow statistics and bankfull-channel dimensions (Robinson, 2013). Another new application is in the St. Louis Metropolitan area, where developers added a combined sewer network system to StreamStats (Southard and others, 2020).

The USGS, as part of an IOSPP activity, is planning to develop additional StreamStats-based web services to provide tools that will be useful to employees of the DOI and others for planning for and responding to oil spills. Four web services are planned, allowing users to do the following:

1. Estimate travel times and concentrations between an actual or hypothetical spill location and a downstream location where there may be critical infrastructure, such as a municipal water intake, using Jobson's equations (Jobson, 1996) or newer equations in development. Estimates will be provided for the leading edge, peak, and trailing edge, and peak concentration under the most-probable velocity and the maximum-probable velocity of the spilled oil.
2. Search upstream within a specified distance or travel time from a selected location to identify locations of potential spills, such as pipelines, railroads, road crossings, and storage depots.
3. Estimate the real-time flow at a spill site based on the flow per unit area at a nearby real-time streamgage that is selected based on whether the streamgage is on the same stream as the spill site, and the proximity and difference in drainage area between the spill site and the streamgage.
4. Display the locations of previous USGS travel-time studies on a map and retrieve the data generated by those studies.

National Oceanic and Atmospheric Administration Fate and Behavior Modeling Tools

NOAA's OR&R supports the General NOAA Operational Modeling Environment (GNOME) Suite for oil spill modeling (OR&R, 2020a; NOAA, 2012). The suite of tools includes GNOME and Automated Data Inquiry for Oil Spills (ADIOS; table 1) with a new web interface. The suite of tools is under active development and testing.

U.S. Environmental Protection Agency Ohio Mapping Project

Internet-based resources for spills, including air monitoring evaluation flowcharts, habitat and species fact sheets, Incident Command System (ICS) forms and references, inland response tactics manuals, and vendor protocols, are being compiled by the EPA onto RRT websites. Using RRT V as an example (https://www.rrt5.org/RCPACPTools/Overview.aspx), interactive mapping includes regional preparedness and planning, inland sensitivity atlas, county fact sheets, state mapping tools, and spill site maps. These maps are representative of EPAs response teams' adoption of using ArcGIS online and Enterprise, Survey123, and Collector for ArcGIS for communication and increased response capabilities among EPA and local, State, Federal, and Tribal stakeholders. The EPA's Ohio Mapping Stakeholder Project (https://response.epa.gov/site/site_profile.aspx?site_id=14361) and Western Lake Erie Area Contingency Plan contain interactive mapping with application widgets, and GIS overlays of floodplain and containment strategies, municipal water and wastewater information, inland sensitivity data, air plume mapping, and physical features of interest.

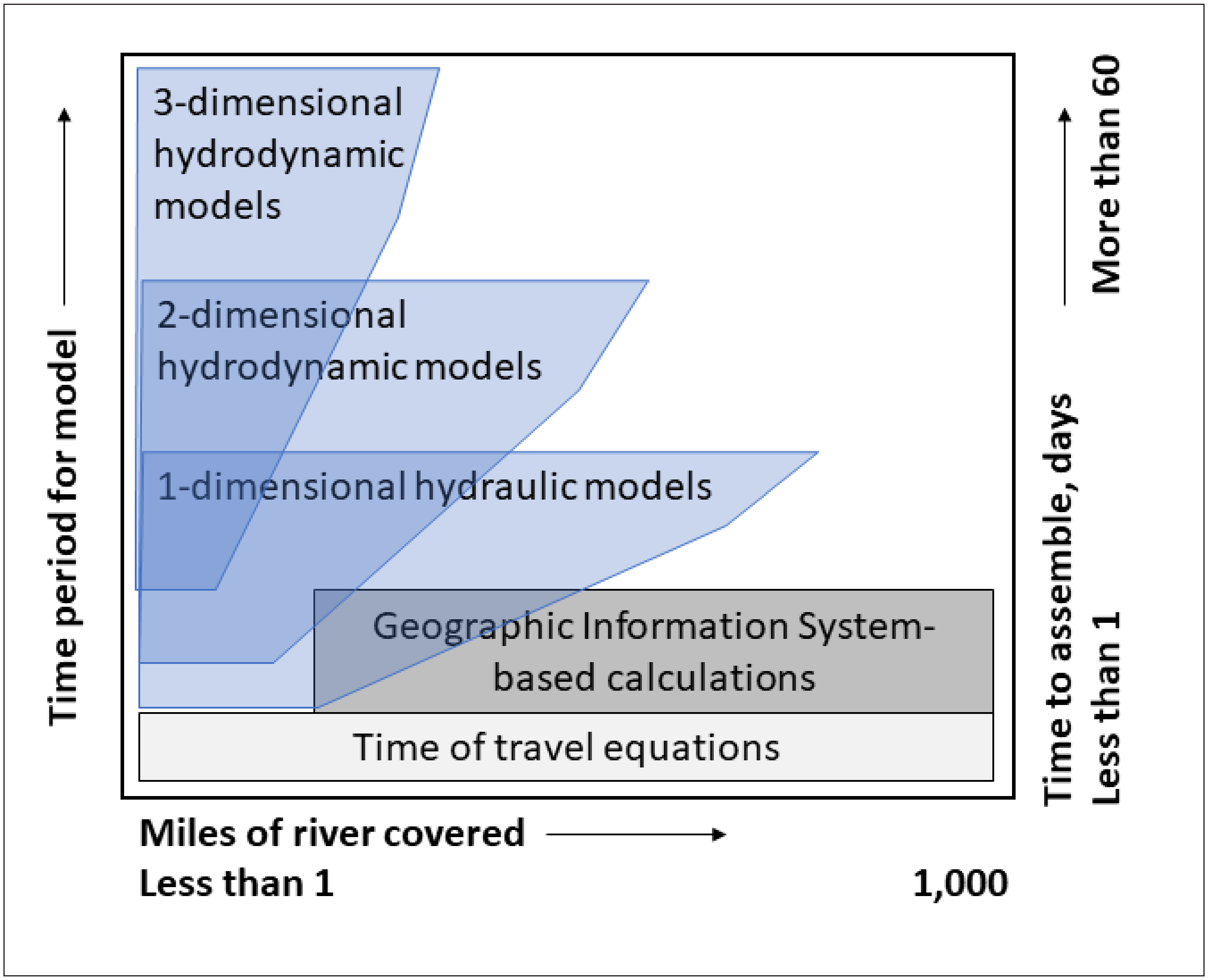


Figure 4. Fate and behavior tools cover a range of temporal and spatial scales.

Table 1. Applicability and limitations of National Oceanic and Atmospheric Administration fate and transport tools for spill response.

[NOAA, National Oceanic and Atmospheric Administration]

Question	Use	Tool	Limitations
Fate	Floating oil spills	Automated Data Inquiry for Oil Spills (ADIOS)	Designed for ocean wave energy, needs to be hand adjusted for rivers.
Transport	Floating oil spills	General NOAA Operational Modeling Environment (GNOME)	Need 2-dimensional bathymetry; scale to flow rate.
Time and distance	Chemical spill concentration (toxicity) and pH	River Dilution Model	Flow parameter is most difficult part—Plan is to use U.S. Geological Survey streamgage data for time of travel along with Jobson equations (Jobson, 1996).

Incident Command Tool for Drinking Water Protection River Plume Travel and Dispersion

The Incident Command Tool for Drinking Water Protection (ICWater) is an EPA-supported model that provides real-time assessments of the travel and dispersion of contaminants in streams and rivers (Samuels and others, 2014). It is a 1-dimensional longitudinal dispersion model based on the ArcGIS platform (fig. 5).

ICWater is designed to help responders answer these questions:

1. Where is the contaminant going?
2. Is there a drinking water intake in the plume's path?
3. When will the plume reach a drinking water intake?
4. Are contaminant concentrations high enough to be a threat to human health?

ICWater is structured around the RiverSpill model, which has been enhanced to make use of the 1:100,000-scale NHD Plus, version 1.0 (NHDPlusV1; https://nhdplus.com/NHDPlus/NHDPlusV1_home.php). NHDPlusV1 is a hydrologically connected river network that contains more than 3 million reach segments in the United States. This allows for downstream and upstream tracing (which serves in forensic analysis). Mean flow and velocity have been calculated by the USGS and EPA for each reach. These mean values are updated by flow from web-accessible, real-time streamgages. Example databases available within ICWater include dams, reservoirs, water supplies, streamgages, municipal and industrial dischargers, and transportation networks. A contaminant database is also included, which identifies biological, chemical, and radiological contaminants and their toxicities. Navigating the river network upstream coupled with mass-balance calculations from breakthrough curves allows for backtracking of the contamination to determine the origin and source strength.

Ohio River Valley Water Sanitation Commission Spill Monitoring and Modeling

ORSANCO's Organics Detection System is an effort among major Ohio River water users including water utilities to monitor volatile organic compounds (VOCs) in the river (ORSANCO, 2020). The cooperative program is designed to protect public water supplies by monitoring for and detecting low-level concentrations of VOCs at water intakes on the Ohio River and certain tributaries. In total, 17 gas chromatographs are operated daily to ensure that unreported releases or spills of VOCs do not compromise drinking-water intakes.

The Riverine Spill Modeling System (RSMS; http://rsms.orsanco.org/)—updated in 2016 after the Elk River spill—is a time-of-travel model based on the USACE's Hydrologic Engineering Center's River Analysis System model (https://www.hec.usace.army.mil/software/hec-ras/) coordinated among agencies in the basin to inform water utilities and sampling crews. ORSANCO scientists continue to validate the model and add features of 21 tributaries to the Ohio River; currently only 7 are in the model, but plans include adding more. The RSMS was originally developed in 2000 and 2001 and became a web-based application in 2016 with a simplified user interface and expanded geographic extent. In addition, EPA is seeking to test RSMS on other river systems.

Spill-Related Plumes in Aquifers

A 1979 pipeline spill release of 10,500 barrels of light crude near Bemidji, Minn., has led to long-term research on crude oil degradation in groundwater (Smith and Hult, 1993). Since 1983, researchers from the USGS Toxic Substances Hydrology Program have studied the site. About 75 percent of the initial spill was cleaned up, leaving 25 percent to percolate into groundwater. Of that, about 15 percent has degraded, leaving a plume that contains about 14,000 compounds. Although much has been accomplished at the site, it is anticipated that ongoing research will continue for the foreseeable future. In 2008 and 2009, the "National Crude Oil Spill Research Site in Bemidji, Minn." was formally established through a series of agreements between the Minnesota Pollution Control Agency, Enbridge Energy LLC, the USGS, and Beltrami County (USGS, 2017; Minnesota Pollution Control Agency, 2020). The result was a self-sustaining research facility that connects academic researchers and practitioners (consultants, petroleum and pipeline industry representatives, and regulators) to link novel ideas to practical, on-the-ground applications. Research done at the site is primarily to improve the understanding of the mobilization, attenuation, transport, remediation, and fate of petroleum hydrocarbons in the subsurface.

Spill Fate and Transport in Karst Environments

Several transportation routes run adjacent to and through Mammoth Cave National Park in Kentucky. Accidental spills threaten park resources including the groundwater, surface water, and biology of the park. The geology and geography of the area has resulted in a variety of karst basins, which have become the most thoroughly understood conduit-flow aquifer in the world (National Park Service, 2018). There is a history of spills along the transportation corridors near the park, as well as local incidents in the park itself (for example, sewer breaks).

A Spill-Response Tool has been developed by USGS researchers to protect the park and its resources. Before development of the tool, spill response required examining paper maps to predict flow paths. It is available to managers and responders and could be modified for use in other karst environments as well. About 40 percent of the U.S. population relies upon karst aquifers for drinking water.

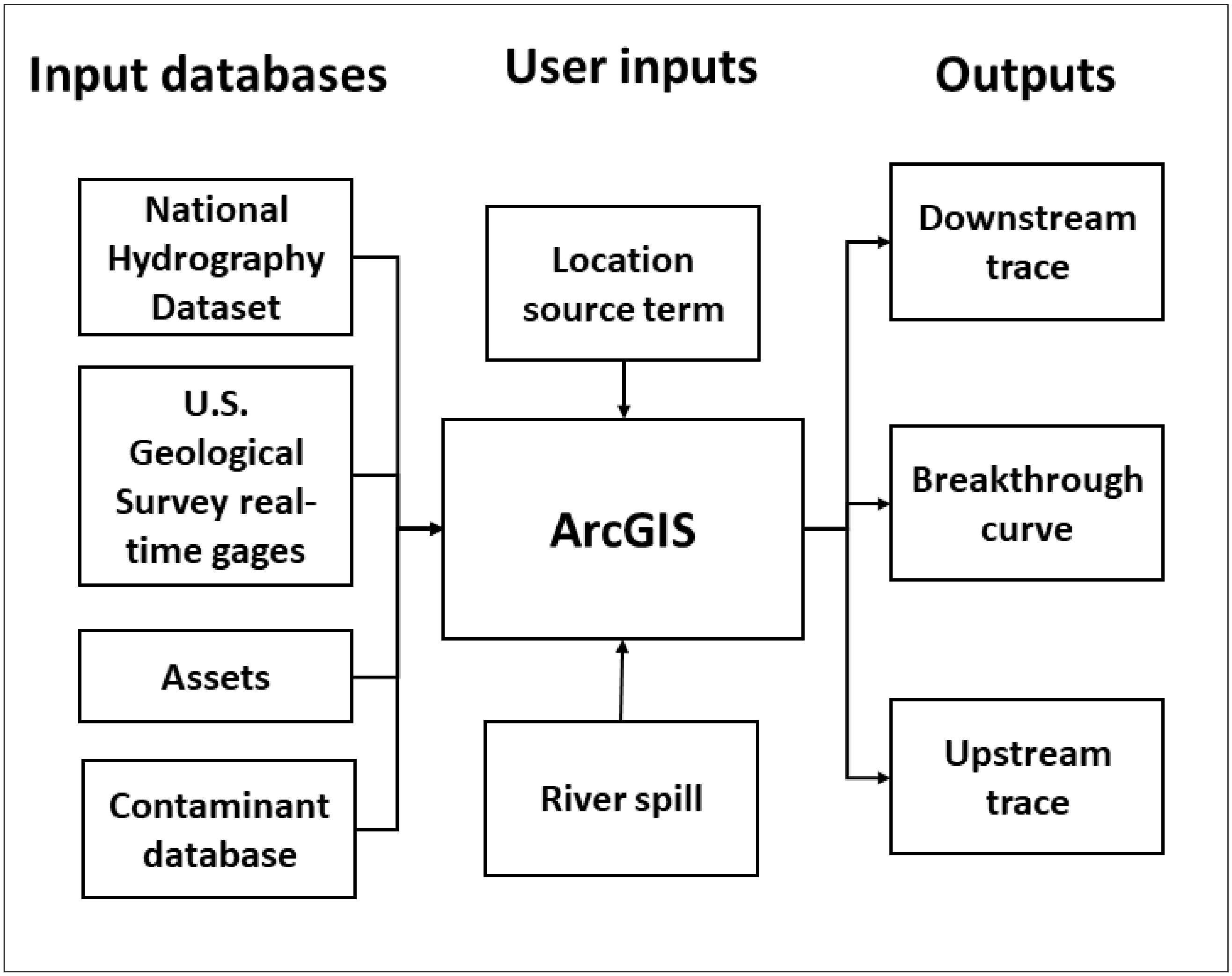


Figure 5. Incident Command Tool for Drinking Water Protection inputs and outputs.

Mapping Applications

Computer-based georeferenced maps of data that represent how water and topography interact on the Earth's surface are basic parts of inland spill fate and behavior tools and models. The USGS's NHD (https://nhdplus.com/NHDPlus/NHDPlusV1_home.php) is used in multiple tools and rapid response models described earlier. Overlays of other natural and human features are also important for spill response. As part of the workshop mapping resources from EPA and NOAA were described.

Interactive Mapping Resources

Interactive mapping resources for inland spills are available through EPA and the Regional Response Team structure (ex. https://www.rrt5.org/InteractiveMapping.aspx) and NOAA Office of Response and Restoration's Environmental Response Management Application (https://erma.noaa.gov/greatlakes/erma.html#/). Both mapping resources have environmental sensitivity maps that provide the context for spill fate and behavior tools and include EPA's Inland Sensitivity Index (https://response.epa.gov/site/site_profile.aspx?site_id=14441) and NOAA's coastal Environmental Sensitivity Index (ESI) maps (https://response.restoration.noaa.gov/resources/environmental-sensitivity-index-esi-maps). In addition to ESI maps, EPA has been developing and training response operations on an easy-to-use, standardized methods for the display and collection of data during an emergency response (Esri, 2018). The application uses a web-based common operating picture usable on handheld phones and other devices.

NOAA's ESIs cover the coast, 5 miles inland and seaward (or lakeward). Examples of at-risk resources include biological resources (such as birds and shellfish beds), sensitive shorelines (such as marshes and tidal flats), and human-use resources (such as public beaches and parks).

Maps that contain detailed coastal geomorphology, and ESI maps are publicly available at https://response.restoration.noaa.gov/esi. Most recently, updates were made to Alaska and Arctic maps. The common operating picture contains maps and common forms that help to collect, organize, integrate, and interpret data quickly from field to office in near real time.

Behavior and Risk Research

The question of how to monitor and predict how oil will behave in the environment, and the risks posed to the environment by exposure to spilled substances, are science-support activities that have applications for rapid response and longer-term response and planning. Two research areas are highlighted with special consideration to inland oil development: fate and transport of oil-particle aggregates (OPAs) from bitumen and Bakken shale oil development.

Oil-Particle Interactions

Fate and transport simulations for OPAs became one of six multiple lines of evidence for creating cleanup endpoints for the 2010 Line 6B spill into the Kalamazoo River (Dollhopf and others, 2014). After the response ended, modeling efforts continued among EPA's National Risk Management Research Lab in Ada, Oklahoma, the USGS, and two universities (Fitzpatrick and others, 2015). A team of researchers from Government and academia have further tested the interaction between Kalamazoo River sediment and Cold Lake Blend crude and modeled it using a 2-dimensional Environmental Fluid Dynamics/Sediment Transport model, a sediment transport model modified to simulate resuspension and settling of oil pollutant aggregates, and a 3-dimensional hydrodynamic/Lagrangian particle model to simulate the impounded section of the Kalamazoo River (Fitzpatrick and others, 2015; Hayter and others, 2015; LimnoTech, 2015; Zhu and others, 2018).

An understanding of the behavior of overland flow of spilled oils was presented as an area of research need. Because models for simulating overland flow of oil are few, early overland flow models were based on the modelers' experience of the local landscape in evaluating pipeline applications. One of the assumptions of these models is that the land surface is flat; development of a multifeatured overland-flow model and integrate with GIS to account for topography is planned.

Bakken Formation/Williston Basin Crude Oil Research Needs

Transport of Bakken Formation/Williston Basin (hereafter "Bakken") crude primarily from North Dakota reveals science issues that need to be addressed to protect critical habitats. Research on behavior in different seasons was identified after a West Virginia spill in winter in which there was no way to confirm the fate of the oil that spilled on ice (https://response.restoration.noaa.gov/about/media/noaa-assists-response-bakken-oil-train-derailment-and-fire-west-virginia.html). Other work needed is how spills might affect endangered fish and mussels, as well as toxicity studies for exposure to oil spills. Of special interest is spills from wastewater produced from hydraulic fracturing.

Predicting where and when the leading edge of spills reach critical stream reaches is viewed as crucial information that is missing. Being able to predict this would, for example, give fish and wildlife managers time to move critically endangered populations of mussels out of harm's way. Responders would like to have a tool such as StreamStats or ICWater to be able to make these predictions.

Bakken Formation studies are of high importance to DOI because of the large areas of DOI and Tribal lands in the Bakken production area and Williston Basin, and because a major part of the Central Flyway (a bird migration route) crosses the area as well. Most oil production in the last 10–15 years in the Bakken is from fracking (McShane and others, 2020). Oil is transported mainly by pipeline; in the past, most was shipped by railcar. Large quantities of "produced water" (highly brackish water that is pumped along with the extracted oil) is of concern in the Bakken. This produced water is an order of magnitude saltier than seawater and, thus, creates a major disposal and transportation issue of its own.

The USGS has been involved in several recent studies in the Bakken. The Science Team about Energy and Plains and Potholes Environments (https://www.usgs.gov/centers/wy-mt-water/science/science-team-about-energy-and-plains-and-potholes-environments-steppe?qt-science_center_objects=0#qt-science_center_objects) project seeks to investigate the impacts of brine waters that leach from oil well reserve pits, injection wells, and transport lines into the critical wetland and grassland habitats of importance to breeding, nesting, and migrating waterfowl, and wetland and grassland birds in the Prairie Pothole Region. Previous studies have identified contamination of wetlands and groundwater resources, including drinking water aquifers, located on U.S. Fish and Wildlife Service, Tribal, and public lands, and numerous groups have expressed concern over the potential risk of contamination (Preston and Ray, 2017; Peterman and others, 2010). Currently, the extent of such contamination across the Williston Basin is unknown, and there is a need for scientific-based information to assess this threat.

Other Research Needs

Because many spills happen on land and land is never perfectly flat and often very hilly, there is a need for a multifeatured model that considers offgassing, infiltration, and changes in viscosity, among other things, for modeling overland flow of oil. Results from multiple models can give widely different results; therefore, uncertainty analysis is needed in future efforts.

Many spill plume models lack a sediment component and researchers are investigating nationally available stream hydrologic models, such as ICWater, to link a rapid OPA transport tool. A promising model that is being developed is based on the Fluvial Egg Drift Simulator (FluEgg), a 3-dimensional egg transport and dispersal model, that utilizes a few river hydraulic parameters (width, depth, mean channel velocity, shear velocity) as model input to simulate the transport and dispersal of an egg plume (Garcia and others, 2015). This model was developed to evaluate tributaries where invasive species, such as several species of Asian carp, could find conditions suitable for successful spawning and reproduction. The transport and dispersal elements of the FluEgg Model are being morphed into what is being called FluOil (Soong and others, 2019), with the goal to have an easy-to-use decision support tool that shows the transport and dispersal of a contaminant plume and the distribution of deposition.

Workshop Findings and the U.S. Geological Survey's Role in Spill Response

The workshop findings and the USGS role in spill response that are presented here as the summary, and possible next steps were identified in discussions that took place during the workshop and in subsequent discussions after the workshop. Based on these discussions, a set of possible next steps related to the needs of the spill-responder community, the gaps in knowledges and abilities, and perhaps how can USGS better contribute science support to spill responders have been identified.

The workshop succeeded in providing an overview of existing fate and behavior tools by multiple partners. The workshop itself succeeded in improving communication between the USGS and all the spill response agencies present by providing a forum to specifically talk as a group about fate and transport tools. The USGS's participation in multiple projects under the IOSPP has furthered communication with sister DOI agencies that participate in spill response, as well as other agencies such as the EPA, the USCG, and NOAA. Since the workshop was commenced, the USGS has been added to the NRT and RRT5 science and technology committees. This has improved communication between USGS and other science-support personal among Federal, regional, State, local, and Tribal representatives on the RRTs. The USGS plans to continue to expand upon and strengthen efforts to communicate and collaborate with other response agencies, and this is our first area of findings and possible next steps.

The USGS science-support role in spill response could be strengthened by improving internal and external communication. An important aspect of communication is a consistent and ongoing contact among response agencies. For example, USGS participation in RRTs and EPA subarea meetings is crucial and would be best accomplished by having a USGS employees with knowledge of the EPA subarea attend these. Of special note for USGS science support is with the EPA Science and Technology Subcommittees. The same is true in coastal regions where the USCG has lead authority in spill response. The USGS would benefit having a representative at the following team meetings, calls, or both, when possible: NRT, RRTs, EPA subareas, State hazard-mitigation teams, ORSANCO, and UMBRA (table 2).

The following are possible next steps from discussions during and after the workshop:

- An established spill response structure within the USGS hierarchy with roles and responsibilities clearly defined at a national and regional level would be helpful in integrating USGS science with spill response efforts. A logical option would be to designate a spill response coordinator(s) at the regional, national, or both levels. This coordinator(s) would be responsible for aligning the roles of the USGS, providing linkages within USGS mission areas, and determining where and how they fit within the ICS and spill-response framework to bring USGS expertise to support function within the framework of ICS. This coordinator would need to be available within quick notice and have direct communication links with DOI, EPA, and NOAA SSCs that are part of the 24/7 response community.

- In addition, cross-mission area coordination within the USGS as well as with other Federal, State and Tribal partners would help marshal spill response resources. The spill response coordinator(s) would be tasked with bringing internal and external partners together.

- More communication is needed to identify linkages among the capabilities and expertise in various mission areas in the USGS to the greater response community. Workshops like this one, supported by USGS Midcontinent Region Flex Funds, are a start. Another example is a capability inventory that was started as part of a 2015 water-quality, flood-response internal report. The spreadsheet, updated annually, includes technical expertise and available equipment organized by WSC. Adding spill-response capabilities to this inventory is a next logical step.

- USGS participation in EPA subarea meetings is crucial and would be best accomplished by having USGS employees with knowledge of the EPA subarea attend these. Because of this workshop, there is now a USGS representative on the RRT V and NRT Science and Technology Subcommittees.

Table 2. Spill-related meetings.

[USGS, U.S. Geological Survey; RRT, regional response team; NRT, National Response Team; ICCOPR, Interagency Coordinating Committee on Oil Pollution Research; EPA, U.S. Environmental Protection Agency; NOAA, National Oceanic and Atmospheric Administration; USACE, U.S. Army Corps of Engineers; ORSANCO, Ohio River Valley Water Sanitation Commission; UMBRA, Upper Mississippi River Basin Association]

Meeting	Current attendees	Focus	Need for USGS attendance?
RRTs	Federal, State, local, and Tribal representatives	Planning, science and technology, training, exercises, worker health and safety	Yes. RRT science and technology subcommittee—USGS person added to RRT V.
NRT	Federal, State, local, and Tribal representatives	Overall tools, public/private relations. ICCOPR	NRT science subcommittee—USGS person added.
EPA Subarea	EPA managers	Size and attendance at meetings varies by region	USGS is welcome by the EPA.
State Hazard Mitigation Team	Emergency managers from a range of Government levels, including NOAA and USACE also Silverjackets	Emergency management issues for a range of topics	Usually there is a USGS representative for floods and streamflow.
ORSANCO	Regional members	Multi-State Ohio River management	Could use a USGS representative; not currently in spill contact list.
UMBRA hazardous spills coordination group	Basin-wide local to Federal representatives	Hazards, response strategies, planning, exercises, mapping	Yes. USGS welcome to attend and has given multiple presentations.

- Communication between the USGS and the Federal Emergency Management Agency could be improved for spill-response planning by establishing communication linkages through the Hazards and Water Programs at the USGS. All external communications would need to be done in coordination with the USGS emergency management coordinator.

- For subsurface tools, more communication between the USGS and other agencies is needed to bring attention to the research results from the Bemidji Crude-Oil Research Project in the areas of mobilization, transport, and fate of crude oil in the shallow subsurface. There is also an opportunity in filling a gap in surface water-groundwater relations and plume modeling in previously glaciated landscapes. Lastly, karst areas are important in unglaciated landscapes, and the USGS has developed some time-of-travel tools for karst areas.

Realtime mapping and rapid modeling of plumes and associated time-of-travel estimation for streams across the United States at a national level is a need that USGS can address. As mentioned in the previous section, numerous approaches use data at different scales. For example, ICWater is based on USGS time-of-travel studies using conservative tracers (only) and is for a limited range of flow regimes. Although researchers tend to develop the "best" model for a situation, regardless of complexity, spill responders often just need a simple model that accesses readily available data, oftentimes in the field on a handheld device. The following are possible next steps from discussions during and after the workshop:

- Time of travel is a central area of USGS expertise that can be applied to spill response. Planned updates to the USGS StreamStats program provided by the IOSPP will have wide application to spill planning and response communities. Nearly all models would benefit from better linkages to real-time velocity, stream morphology, and slope data, most of which is or could be available in StreamStats or as part of the NHD. The USGS velocity data, including index velocity, channel cross sections, and under-ice measurements collected at streamgages are underutilized and unknown to many spill preparedness planners and responders. Future efforts could continue to integrate these data into available web-based tools.

- There is a need for time-of-travel information under different flow conditions and for nonconservative substances (particles like sediment or pathogens, floating substances, and so on). It would be beneficial to modify ICWater to include nonconservative substances and a wider range of potential flow regimes. Even though ICWater does not have a contaminated sediment-transport component built in yet, it is currently the only national rapid response model that uses NHDPlus as its base along with the contaminant-in-water dispersion algorithms. Improvements to make ICWater more readily available for use in rapid-response situations would be beneficial.

- Although continued development of sophisticated models is needed, simple applications that can be run by responders in the field on a tablet or other portable device also are needed. Applications to display, for example, time-of-travel information and estimates of plume extent are vital to assisting field responders.
- The NOAA National Water Model (https://water.noaa.gov/about/nwm), which simulates look-back, observed, and forecasted streamflow, is an untapped resource for inland spill fate and transport tools. The model uses data from 8,000 USGS streamgages plus NOAA's atmospheric models and is mainly used for flood- and drought-related emergencies and planning. More exploration of the model for spills is needed among NOAA's spill-response group, the National Weather Service, the USGS, and other agencies and perhaps universities.
- Once available, these tools would benefit from better linkage into existing mapping and response tools already available to OSCs during a spill response.
- A nationally available, easy-to-use tool to predict the leading edge of the plume is needed.

Linking and explaining existing plume models and fate and transport models for different scenarios and applications is another critical need within the spill response community. Existing models operate at a variety of scales, which adds confusion. There is a need to identify/describe what is the best model(s) for a given situation, including the desired end product; the spatial extent and temporal scale called for by the circumstances of the spill; and whether it is near-term prediction (that is, plume direction and speed) or long-term prediction (that is, weathering, transformation, and so on). The following are possible next steps from discussions during and after the workshop:

- Drinking-water and water-authority source protection plans (sources upstream) and emergency response (knowing what is downstream) have separate pathways toward the same goal: protecting the resource. The Ohio River provides an example case where attempts are being made to more closely integrate between two groups with common goals. This possible next step could be addressed with the science and technology subcommittees of the NRT and RRTs. Existing RRT websites (for example, https://www.rrt5.org/RRTHome.aspx) could be used as a landing place for spill fate and transport models.
- The USACE has models and data sources for large rivers that may be applicable to spills. More communication is needed among Federal agencies to communicate with USACE districts that have existing hydraulic models for navigational purposes or floods that may be of use in spill fate and transport models.

Continued research into the **long-term fate and behavior of materials such as bitumen and Bakken crude and byproducts**, which in some cases are not well understood, would be beneficial. Without this information, it will be difficult to assess the success of cleanup efforts, as well as the threat that remaining deposits of spill pose to long-term ecological and human health. The following are possible next steps from discussions during and after the workshop:

- It would be beneficial for USGS to continue to work on IOSPP-funded research and applications, especially those that span multiple disciplines, product types, and environmental components.
- Spill forecasting could be improved with the National Weather Service precipitation predictions incorporated and should be added to flow models.

A **common conceptual model for spill response planning** is needed to organize tools and responders. The following are possible next steps from discussions during and after the workshop:

- Develop a conceptual model of spill response where the axis shows the progress of oil transformation from an oil spill to oil droplets to the OPA process, in time scale for different types of crudes. Place available models along that axis and determine where the gaps are and when to invoke specific model(s). Define the purpose of models and what level of expertise is needed (anyone from the public to a specialist).
- Include land-water interaction.
- Identify ownership of tools as well as applicability.
- Include contact information.

Of importance to inland spills is **linking stream models to other components of the environment** (land/overland/groundwater/air); in other words, go beyond the stream network to forecast or affirm effects on the greater environment. This is critical, for example, when documenting the impacts of diluted bitumen crude, parts of which sink and can have long-term effects. The following are possible next steps from discussions during and after the workshop:

- Supplement stream network with underground conduits: storm sewers and karst. NOAA's big-river models could be linked to models of inland tributaries with bathymetry added.

- The EPA maintains an interactive mapping tool for emergency environmental response (https://www.rrt5.org/InteractiveMapping.aspx) that provides layers of geospatial information for emergency responders. Linking this system with StreamStats would link critical time-of-travel information to infrastructure data. This link is important to guide responders' efforts at spill containment to protect lives and property.
- Existing symbiotic relationships among USGS hydrologists and ecologists that clarify the interactions of aquatic ecosystems with hydrology and hydrochemistry could be expanded and applied to spill response. USGS spill response coordinators would benefit from work across mission areas to identify expertise appropriate to the situation at hand. In addition, the U.S. Department of Agriculture Animal and Plant Health Inspection Service warrants further inclusion for inland wildlife issues.

The greatest potential for the USGS may be in having developed tools that can be deployed to assist responders once an event occurs, such as the ability to predict time of travel in a given stream reach downstream from a spill. USGS needs to continue, and expand upon, nascent efforts to be involved at the regional level with the RRTs, with the long-term goal of having a recognized position within the roles of response (ICS; fig. 2) by working with response agencies to help them understand the knowledge and application gaps that can be filled by its science capabilities.

To ensure the USGS effectively engages in spill response, the Bureau could develop an established structure within its hierarchy with roles and responsibilities clearly defined at a national and regional level.

Although not a point of discussion for this workshop, there remains a role for the USGS in assisting OSCs in monitoring physical, chemical, and biological conditions associated with spills. This aspect could be developed further with communication between the USGS and the Natural Hazards mission area.

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Appendix 1. Workshop Agenda and Attendees

The workshop was held at the Upper Midwest Water Science Center in Middleton, Wisconsin, on December 12–13, 2017. The workshop agenda is shown in table 1.1, and the list of attendees is in table 1.2.

Table 1.1. Workshop agenda, December 12–13, 2017, U.S. Geological Survey Upper Midwest Water Science Center, Middleton, Wisconsin.

Time	Agenda item
	Tuesday, December 12, 2017—Spill response and plumes
1:00–1:20 p.m.	Introductions and meeting goals (Faith Fitzpatrick, USGS UMid WSC; JC Nelson, USGS UMESC; Dan Sullivan, USGS UMid WSC) •USGS Midwest Science Support (Scott Morlock, USGS)
1:20–2:30 p.m.	Federal spill planning and response • Overview of DOI IOSPP and USGS connection (Lindy Nelson, DOI; Jo Hinck, USGS) • USGS Hazards and spill response (Jo Hinck, USGS) • Overview of NOAA SSC, ESI, ERMA (Adam Davis, NOAA SSC) • Overview of EPA inland spill response (Jacob Hassan and Jon Gulch, EPA) • USGS science support for EPA Kalamazoo River spill (Chris Hoard, USGS UMid WSC) • Discussion
2:30–2:45 p.m.	Break
2:45–4:30 p.m.	Time of travel/plumes • StreamStats application (Peter McCarthy, USGS StreamStats) • WiM/StreamStats applications (Jeremy Newson, USGS Web Informatics and Mapping) • NOAA fate and behavior models (Chris Barker and Amy McFadyen, NOAA response/restoration) • ICWater spill models (Bill Samuels, Leidos) • Ohio River Valley ORSANCO time of travel application (Sam Dinkins, ORSANCO) • Groundwater plumes (Jared Trost, USGS Bemidji research lab) • Karst environments, spill tracking (Randy Bayless, USGS) • Discussion
4:30–5:00 p.m.	Recap of afternoon's discussion and identify science gaps
6:00–8:00 p.m.	Group dinner and discussion
	Wednesday, December 13, 2017—Behavior and risk
8:00–8:30 a.m.	Tuesday recap and overnight thoughts from the group
8:30–10:30 a.m.	Behavior and risk • EPA laboratory/modeling (Jim Weaver, EPA National Risk Management Research Laboratory) • Lab experiments and modeling for oil particle aggregates (Faith Fitzpatrick and David Soong, USGS) • Bakken science needs (Susan Lingenfelser, USFWS) • Bakken/Williston Basin studies (Greg Delzer, USGS Dakota WSC) • Upper Mississippi River Basin planning (JC Nelson, USGS UMESC) • Mississippi River issues (Adam Davis, NOAA) • Great Lakes ESI updates (Annie Gibbs, NOAA) • Other studies? • Discussion
10:30–10:45 a.m.	Break
10:45–11:45 a.m.	Discussion • What knowledge gaps are there in spill behavior and fate • What gaps are there in the tools needed for current planning and response needs? • What expertise can be provided from USGS? For example, time of travel, hydrologic setting, fate/behavior, ecological sensitivity, and toxicity? • Feedback from other agencies • Integrated approaches and avenues for collaboration across agencies • Emerging issues
11:45 a.m.–12:00 p.m.	Next steps and Wrap-up • Workshop products • Future communication and collaboration
12:00 p.m.	Wrap-up

Table 1.2. Workshop attendees, December 12–13, 2017, U.S. Geological Survey Upper Midwest Water Science Center, Middleton, Wisconsin.

[USGS, U.S. Geological Survey; --, not applicable; MCR, Midcontinent Region; DOI, U.S. Department of the Interior; NRDAR, Natural Resource Damage Assessment and Restoration; IOSPP, Inland Oil Spill Preparedness Project; USFWS, U.S. Fish and Wildlife Service; NOAA, National Oceanic and Atmospheric Administration; SSC, science-support coordinator; ESI, Environmental Sensitivity Index; EPA, U.S. Environmental Protection Agency; FOSC, Federal On-Scene Coordinator; ORSANCO, Ohio River Valley Water Sanitation Commission; ICWater, Incident Command Tool for Drinking Water Protection]

Name	Agency	Available	Notes	Meeting in person	Teleconference
Faith Fitzpatrick	USGS	Yes	Chair	1	--
Dan Sullivan	USGS	Yes	Co-chair/spills/water-quality monitoring	1	--
Scott Morlock	USGS	Yes/part	MCR lead	--	1
Peter McCarthy	USGS	Yes	StreamStats	1	--
Jeremy Newson	USGS	Yes	Web mapping app	1	--
Jo Ellen Hinck	DOI/USGS	Yes	USGS/NRDAR coordination	1	--
Lindy Nelson	DOI	Yes	IOSPP	1	--
Susan Lingenfelser	USFWS	Yes	Bakken science needs	1	--
Jared Trost	USGS	Yes	Groundwater plume, emerging issues, toxics	--	1
Chris Hoard	USGS	Yes	Kalamazoo overview, water science center perspective	1	--
Greg Delzer	USGS	Yes	Williston Basin/Bakken and emerging issues	1	--
Randy Bayless	USGS	Yes	Karst/underground to surface spill tracking	--	1
David Soong	USGS	Yes	FluOil modeling	1	--
Gary Latzke	USGS	Yes	Web mapping	1	--
Laura Hubbard	USGS	Yes	Water quality	1	--
Adam Davis	NOAA	No	NOAA SSC overview	--	1
Amy MacFadyen	NOAA	Yes	NOAA modeling	--	1
Chris Barker	NOAA	Yes	NOAA modeling	--	1
Annie Gibbs	NOAA	Yes	ESI Great Lakes update	--	1
Jacob Hassan	EPA	Yes	Region V FOSC	1	--
Ann Whelan	EPA	Yes/part	Science needs	--	1
Jon Gulch	EPA	Yes	EPA modeling	--	1
Jim Weaver	EPA	Yes	EPA lab/modeling	--	1
Susan Mravik	EPA	Part	EPA lab/modeling	--	1
Sam Dinkins	ORSANCO	Yes	Ohio River travel time	1	--
Bill Samuels	Leicos/ICWater	Yes	ICWater	--	1
Katie Skalak	USGS	Yes	North Dakota spills, toxics	--	1
Jason Rohweder	USGS	Yes		--	1
--	--	--	Total	14	14

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For additional information, visit: https://www.usgs.gov/centers/umid-water

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