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Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities: A Workshop Report

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Bureau of Safety and Environmental Enforcement
Oil Spill Preparedness Division

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A WORKSHOP REPORT

August 2023

(Photo: NOAA shoreline)

Coastal Response Research Center, NOAA Office of Response and Restoration, BSEE Oil Spill Response Division

US Department of the Interior
Bureau of Safety and Environmental Enforcement
Oil Spill Preparedness Division

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CITATION

Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities Workshop, May 9-11, 2023, NOAA's Western Regional Center, Seattle, WA; Coastal Response Research Center

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- Steven Buschang, BSEE
- Troy Baker, NOAA OR&R ARD
- Alexander Balsley, USCG Research & Development Center
- Marion Lewandowski, USCG Research & Development Center
- Lisa DiPinto, NOAA OR&R
- James Hanzalik, Clean Gulf Associates
- Nancy Kinner, CRRC
- Greg McGowan, California Oil Spill Prevention and Response (OSPR)

This summit was facilitated by Nancy Kinner (www.crrc.unh.edu). CRRC is known globally as an independent intermediary that brings all stakeholders to the table to develop and implement viable and trusted solutions to complex problems related to environmental disasters. CRRC has conducted 90+ workshops that bring together practitioners, researchers, and scientists of diverse backgrounds (e.g., industry, academia, government, NGOs) to discuss and develop solutions to marine pollution and disaster problems. We would like to thank each of the speakers for their participation in the workshop:

- Doug Helton, NOAA OR&R Emergency Response Division (ERD) Regional Operations Supervisor
- Elliott Taylor, Polaris Applied Sciences, Inc.
- Angela Vallier, National Strike Force Coordination Center (NSFCC)
- Tim Nedwed, ExxonMobil Upstream Research Company
- Ed Owens, Owens Coastal Consultants Ltd
- Lisa DiPinto, NOAA OR&R
- Michel Boufadel, New Jersey Institute of Technology (NJIT)
- Prabakar Clement, The University of Alabama, Civil, Construction & Environmental Engineering
- Chris Hall, Alaska Clean Seas
- Carl Childs, NOAA OR&R ERD
- Brent Koza, Texas General Land Office, Research & Development, State SSC
- Karolien Debusschere, Louisiana Oil Spill Coordinator's Office
- Maria Hartley, Chevron
- Elizabeth Petras, U.S. Coast Guard, ICCOPR
- LCDR Clifton Graham, U.S. Coast Guard

- Jeff Morris, Abt Associates
- Greg McGowan, California DFW, Office of Spill Prevention & Response (OSPR)
- Pauline Gerrard, IISD Experimental Lakes Area
- Charlie Henry, NOAA OR&R Disaster Preparedness Program, Gulf of Mexico Disaster Response Center
- Scott Pegau, Alaska Oil Spill Recovery Institute
- Marion Lewandowski, U.S. Coast Guard Research and Development Center (RDC)
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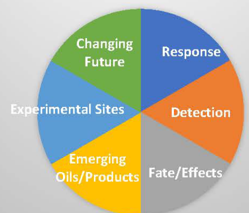
GRAPHICAL ABSTRACT

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

Topics/Participants

- Two-day workshop to identify research gaps (Federal, State, OSRO*, Industry)



- Literature review of state-of-science
- Prioritized 3 research gaps for each topic

*Oil Spill Response Organizations (OSROs)

Workshop Findings

- Focus on crude oils and dielectrics from offshore facilities
- Several North American facilities available for response research
- Clean-up in nearshore waters is best approach before spill impacts shoreline

Workshop Recommendations

- Collaborate: Among agencies and with OSROs (e.g., field test prototypes)

- Develop database on chemistry of emerging oils and contaminants
- Form working group on shoreline spill response

Report Reference: Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities Workshop, May 9-11, 2023, NOAA's Western Regional Center, Seattle, WA; Coastal Response Research Center

Coastal Response Research Center

BSEE

NOAA

EXECUTIVE SUMMARY

The Bureau of Safety and Environmental Enforcement (BSEE) partnered with NOAA's Office of Response and Restoration (OR&R) and UNH's Coastal Response Research Center (CRRC) to plan and facilitate an in-person workshop on the NOAA Sand Point Campus in Seattle, WA. This event entitled "Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities" identified knowledge gaps and opportunities regarding technologies and scientific research associated with oil spill shoreline response. This effort included the exploration of the current state of the science of oil spill research associated with impacts of crude oil to shoreline environments and identified countermeasures and response alternatives that may become part of the oil spill response toolbox. The workshop agenda is included in Appendix A. In total, there were 49 participants, including all presenters and CRRC staff and students, that attended the three-day workshop. 19 participants attended the workshop virtually. See Appendix B for the list of workshop participants.

The specific objectives of the workshop were:

1. Develop a literature review of the state of the science regarding impacts, preparedness and responses strategies and technologies associated with oil spills on shorelines (i.e., oils from offshore facilities including crude oil and dielectric fluids).
2. Identify gaps in the current state of science regarding impacts of crude oil and dielectric fluids from offshore facilities.
3. Identify operational constraints of shoreline techniques.

The workshop included plenary presentations from federal, state, and industry representatives on: response, detection, fate and effects, policy, emerging oil/products, experimental lakes, and changing future. Presentation slides can be found in Appendix C.

Table of Contents

Acronyms

ARD	NOAA Assessment and Restoration Division
BSEE	Bureau of Safety and Environmental Enforcement
CEDRE	Research Institute in France
COTS	Commercial Off-the-Shelf
CRRC	Coastal Response Research Center
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DFW	Department of Fish and Wildlife
DPP	NOAA Disaster Preparedness Program
DRC	NOAA Gulf of Mexico Disaster Response Center
ERD	NOAA OR&R Emergency Response Division
FAST	Feasibility Analysis of Shoreline Treatment
GIS	Geographic Information System
IISD	International Institute for Sustainable Development (Canada)
IR	Infrared
LiDAR	Light Detection and Ranging
MPRI	Multi-Partner Research Initiative, Fisheries and Oceans Canada
NEBA	Net Environmental Benefits Analysis
NOAA	U.S. National Oceanic and Atmospheric Administration
NJIT	New Jersey Institute of Technology
NSFCC	National Strike Force Coordination Center
OHMSETT	National Oil Spill Response Research & Renewable Energy Test Facility
OR&R	NOAA Office of Response and Restoration
OSPR	Office of Spill Prevention and Response
PAH	Polyaromatic Hydrocarbons
R&D	Research and Development
RDC	USCG Research and Development Center
ROV	Remotely Operated Vehicle
RRB	Response Research Branch
SCAT	Shoreline Cleanup and Assessment Technique
SINTEF	Research Institute in Norway
SIMA	Spill Impact Mitigation Assessment
SMART	Special Monitoring of Applied Response Technologies
SSC	Scientific Support Coordinator
UAS	Uncrewed Aerial Systems
UNH	University of New Hampshire
USCG	U.S. Coast Guard
VLSFO	Very Low Sulfur Fuel

1. Session One

The first session of the workshop was held on Tuesday May 9, 2023, and focused on the response, detection, fate and effects of shoreline oiling. A panel of experts was convened to present their views on each topic. In each of these panels, the presenters discussed knowledge gaps and opportunities for scientific research and technological improvements that related to these areas of oil spill shoreline response. A list of questions that the presenters were asked to address can be found in Appendix D. Following the panels, the in-person participants divided into breakout groups to discuss the knowledge gaps and technology needs that were noted during the plenary presentation and subsequent Q&A sessions. Other gaps and needs were added if group members identified them. Then, each group identified 2-3 knowledge gaps / needs they felt were priorities. The day concluded with all breakout groups presenting their top priorities. A vote was held among all the in person and virtual participants to select the top priorities three priorities from all the priorities identified by the breakout groups for each topic. A detailed breakdown of the prioritization can be found in Appendix E.

1.1 Plenary Panel 1: Response

Doug Helton started his presentation by discussing what the challenges are for shoreline clean-up. His list included: labor is intensive and expensive, response may further injure natural and archaeological resources, large quantities of waste are generated, it is slow, and there are health and safety concerns for the workers. Additionally, there are questions on what the efficacy is of the techniques and what is the point of diminishing return. Shoreline clean-up efforts are highly visible and may draw media and public scrutiny. Helton noted that all shoreline clean-up techniques could currently benefit from R&D to improve the efficacy as well as help understand the trade-offs.

Elliott Taylor noted that we can respond quite well for surface oiling and reasonably well for subsurface contamination, provided the response is a relatively safe working environment. The basic tools have been largely unchanged over the past 20-30 years, while there have been new developments in data management, detection, and treatment options. As for tools and technologies that could be made better, Taylor discussed opportunities to improve planning and response through adoption of shoreline segmentation efforts (i.e., Taylor described segmentation from DWH for entire GoM as part of ERMA); improved definition of expected oil behavior (i.e., field tests for potential emulsification, overwashing, and/or sinking); oil detection (mostly for subsurface oiling); and improvements in decision support tools for shoreline response. Taylor discussed the potential use of canines (detection and delineation of subsurface oil; endpoints) and knowledge exchange tools (e.g., FAST (Feasibility Analysis for Shoreline Treatment) job aid (see https://fastshores.com)). Taylor noted opportunities in knowledge sharing and decision support, such as the work initiated through the Canadian MPRI program with respect to a Shoreline Decision Support Tool that would provide users (decision makers and stakeholders) with an understanding of oil removal rates for a range of oil types, shoreline types, and treatment options (including natural attenuation). Taylor recommended creation of decision support tools to guide planners and decision makers through selecting feasible and appropriate treatment options based on the current science and in context of NEBA/SIMA considerations; the improvement of in-situ treatment options through better understanding of flushing, flooding, and in-situ treatment agents; the improvement of communications through simplified messages for stakeholders; and knowledge transfer through international exchange of research (e.g., CEDRE, CSIRO, SINTEF).

Angela Vallier started by noting that the National Strike Force's (NSF) Strike Teams capability to respond to oil spills has changed little in decades. They physically assess shorelines, which often takes a significant amount of personnel and time if the spill is large. Clean-up is done mechanically unless approval is given to use spray/flooding or surface washing agents. There is little opportunity to work with alternate means of clean-up in actual oil spill on shoreline. Currently, the OHMSETT tank is the only place they can work with oil and that is in the water. The Strike Teams use short range UAS with some IR technology, but work is being done with multiple sensor packages that would help detect oil along a shoreline. Sensors are needed to detect Class V oils that have sunk or are submerged; are under ice, or in swift water environments such as riverine areas. Additionally, sensor packages are needed that might assist in responses to oil that is burned. During an in-situ burn (ISB), the NSF deploys responders who use the SMART protocols to determine any health concerns with smoke. A UAS sensor that could find and detect concentration/ size of particulate would be helpful. The NSF would conduct some testing during dispersant use, using fluorometry equipment. This equipment is relatively old and does not interface well with new operating systems. The NSF will be getting ROVs in the 4th quarter of 2023. They will be helpful in finding submerged oil.

Knowledge gaps include response to oil in different types of ice, clean-up techniques of Class V oil, containment, booming, and skimming along shorelines with rapidly moving waters (e.g., riverine environment). Better field guidance is also needed that helps responders make decisions when there are numerous trade-offs to consider (e.g., oil into the air, surface of the water, water column; efficiencies of different alternate response techniques, herding agents, surface washing agents, dispersants, ISB).

As climate change increases risks, and more open water occurs in the Arctic allowing for more ship traffic, response options in those environments are a wise investment.

Using facilities like Poker Flat (AK) or the Experimental Lakes in Canada, will provide more opportunity to train and test tactics.

1.2 Plenary Panel 2: Detection

Tim Nedwed discussed the difficulty of detecting oil spills on shorelines. Traditional SCAT methods are slow, labor and time intensive (e.g., digging random holes in beaches searching for buried oil) with minimal accuracy. There are tools and technologies available to increase capabilities, (e.g., UASs, autonomous systems, IR/polarized IR cameras, UV cameras, dogs, smart booms). Nedwed recommended rapid and safer shoreline assessment methods e.g., autonomous SCAT) along with real-time communication of shoreline and better tools for subsurface detection. R&D spending should focus on development of autonomous systems, protocol for qualifying technologies including consistent field verification, and commercial ready prototypes that could be loaned to OSROs for real world testing and training.

Ed Owens began his discussion by highlighting the basic questions of shoreline oil detection: What are we looking for? How do we detect and delineate? What is the timing? The initial information needed is a map of how to get there, tide tables to know the water levels, and a radio for the weather. Owens noted that except for dark oil in moderate amounts on the shoreline surface, detection is very difficult. He recommended creation of training tools using existing knowledge and experience, improved detection using canines, use of robotic "K9s", and improved aerial surveys. The proven capabilities and attributes of canines for oil detection include the ability to detect all oil types, surface and subsurface oils up to 5-meters-deep, and sunken oil in shallow water. More development is needed on under -ice detection and the use of "RoboK9s". Aerial observation for oil on the shoreline is much more complex than oil on water due to the variation in colors, textures, presence of background materials, and false positives from factors such as black mineral sands, debris, and shadows. A key opportunity exists in developing job aids for training, interpretation, and communication.

Lisa DiPinto discussed factors that affect how well we can detect oil spills on shorelines, including shoreline type, nature of the oiling including extent, and the type of oil. She discussed various tools and technologies for detection that are under further development, including faster workflows for data processing and easy to read data products needed to meet rapid response timeframe information needs. She emphasized the importance of advancing our use of commercial off the shelf (COTS) tools, and how we could work to optimize the use of tools we already have available and that are likely to be used on-scene now. She highlighted some of the ongoing work with the USCG to further develop platforms such as sUAS systems and COTS remotely operated vehicles (ROVs). There are opportunities to collaborate to further develop newly emerging sensors such as multispectral/thermal IR, hyperspectral, LiDAR, polarized IR and laser fluorometry, including from various remote platforms. Research and development in areas such as use of automated or semi-automated data processing to more rapidly process large volumes of data, controlled testing to calibrate emerging sensors, testing in challenging conditions such as in ice or with newly emerging products, and detecting oil in sensitive habitats.

1.3 Plenary Panel 3: Fate and Effects

Michel Boufadel addressed beach hydrodynamics, oil persistence, and remediation. He presented data from laboratory beaches and from detailed modeling. He gave examples based on his work on Prince William Sound beaches with lingering Exxon Valdez oil on some of the beaches. He emphasized that beaches should not be treated as monolithic units, but rather multiple compartments. For oil biodegradation within the pores of beaches, the upper intertidal zone tends to be nutrient limited, and the lower intertidal zone tends to be oxygen limited. Boufadel also addressed the biodegradation of oil within the pores of the supratidal zone of beaches (landward of the high tide line). He presented data from the beaches in the Gulf of Mexico where the porewater salinity was larger than 200g/L, which is likely a main limiting factor on oil biodegradation within the supratidal zone. Oil biodegradation at 160g/L salinity was ~10% of that at 32 g/L salinity.

Prabhakar Clement discussed the fate and effects of oil spills on shorelines with a focus on tar balls. There are two types of tar balls: ones that are highly weathered and float, and relatively fresh ones that are found sunken near the shoreline. The conventional wisdom is that the weathered tar balls are formed when stranded oil floats over the ocean for many months/years. However, he noted that we do not understand how floating tar balls are formed and why they persist. Tar balls still exist along the Alabama shoreline 10 years after the Deepwater Horizon Spill (DWH). These are all sunken. The DWH oil has never formed highly weathered floating tar balls. The knowledge gap that needs to be addressed is to improve our understanding of the fate and effects of oil spills on shorelines. Specifically, he recommended: understanding how tar balls and tarmats are formed from oil spills, the background level of tar balls along the GOM coastline, development of a standard protocol for fingerprinting oil spill residues, research on the toxicological/ecological effects of heavy PAHs trapped in oil spill residues, and development of methods to destabilize and disperse floating mouse using less-toxic dispersants. He recommended R&D spending to improve the fundamental understanding of tar balls formation processes, and investment in developing eco-friendly, less toxic, dispersants that can disperse and destabilize mousse and prevent sinking near the shoreline.

Chris Hall discussed the difficulty in responding to oil spills in the Arctic, (e.g., remote locations, challenging logistical support, extreme weather, short open water season). He noted that Arctic temperatures increase the viscosity and film thicknesses on the water surface, and reduce oil weathering, spreading, evaporation, emulsification, and dispersion. Drift and pack ice reduce spreading and weathering of surface oil, and shore-fast ice and snow may act as natural barriers to limit shoreline oiling. There are tools and technologies that could improve our ability to determine the fate and effects of oil on shorelines, such as incorporation of "smarter" buoys and sensors for autonomous monitoring of oil in ice and near shorelines during breakup. He suggested that R&D spending should focus on improving trajectory modeling of oil and ice interactions, study the short- and long-term effects of oil stranded on Arctic shorelines, and improving small, easily deployable "smarter" tracking buoys, autonomous systems, and surveillance tools to rapidly identify and prioritize oiled shoreline segments.

Carl Childs believed we have fairly sophisticated understanding of the overall fate and effects of spilled oil on shorelines, but there are several ways in which we could improve that understanding. The largest knowledge gap is the inability to correlate the degree of shoreline oiling with ecological impacts. Oil spill response could particularly benefit from an improved understanding of how different levels of oiling, particularly small amounts of it, translate into ecological impact. This knowledge gap limits assessment of net environmental benefit of on-water response tactics, particularly dispersant use. There are tools and technologies that could improve understanding of oil degradation rates and biogeochemical pathways, particularly recent advances in genomics, transcriptomics, proteomics, and bioinformatics. These tools can identify changes in the microbial community composition and function throughout the process of oil degradation which correlate to overall ecosystem recovery. These tools also have the potential to improve our ability to locate buried oil. Ecosystem-level modeling could improve understanding of the fate and effects of oil on shorelines. He would focus R&D spending on remote sensing to identify and quantify shoreline oiling, ecological modeling to assess the impacts of response tactics and trade-off assessments, operationalization of molecular methods to monitor the microbial community response to oiling, and improved methods for replanting as a response strategy in oiled marshes.

2 Session Two

The second session of the workshop was held on Wednesday May 10, 2023, and focused on policy surrounding oiled shorelines, emerging oil/products and the Canadian experimental lakes, and the changing future. In each of these panels, the presenters discussed knowledge gaps and opportunities for scientific research and technological improvements related to oil spill shoreline response. A list of questions that the presenters were asked to address can be found in Appendix D. Following the panels, the in-person participants were released into the same breakout groups to discuss the knowledge gaps and technology needs. For every plenary topic, the groups prioritized up to three knowledge gaps / needs. The day concluded in the same was as Session I with all breakout groups presenting their top priorities and all participants voted on the top priorities. A detailed prioritization can be found in Appendix E.

2.1 Plenary Panel 4: Policy

Brent Koza discussed what policies exist in Texas and how well they are defined for oil spills on shorelines. There are some policies that would improve the ability to address oil spills on shorelines including expanded UAV authorization and use. Additionally, having polices that address using spills of opportunity to conduct research in a timely manner post spill would greatly help further shoreline response. Koza recommended using well informed stakeholders and continued public education along with science-based guidance for the response tactics. There should also be prioritization of data management tools that provide decision support policy that addresses the efficient use of resources.

When answering the question "How well-defined are our policies regarding oil spills on shorelines?", **Karolien Debusschere** discussed the breath of existing policies but also the need to make the available information more digestible and accessible and to ensure responders are trained on relevant policies. In addition, she discussed how policies are often driven by the large, significant incidents (e.g., Exxon Valdez, DWH) and recommended we not lose sight of the more common spills. Examples of policy improvements could be: 1) allowing oil to be spilled for the sake of research in the U.S.; 2) access to "classified"/"proprietary" information/data/technology; 3) mandatory policy training for responders and planners at all levels; 4) improving updates to guidance; and 5) establishing dedicated funding streams. When it comes to prioritizing the improvements, Debusschere recommended focusing first on what the workshop attendees agreed would give the biggest return on their investment.

Maria Hartley talked about the importance of coordination between different agencies and stakeholders during responses, along with adequate training in oil spill response science and equipment, and clear policy guidance and approval processes on use of alternative response technologies. Policies that promote collaboration and mutual aid agreements facilitate more robust and coordinated responses. In addition, policies that emphasize environmental monitoring and assessment before an oil spill can provide valuable data to evaluate potential impact and guide restoration. Policy frameworks may face challenges in keeping pace with rapidly evolving technologies, (e.g., surveillance, sampling techniques, data collection), along with alternative fuel products (e.g., biofuels, hydrogen), and new extraction methods. Being able to rapidly get

UAS emergency permits/approvals, the ability to fly beyond visual line of sight, and stay on location for 24 hours could improve situational awareness and increase response effectiveness. She recommended carefully controlled source control tests in-situ to benefit development of new response technology and improve existing ones.

2.2 Plenary Panel 5: Emerging Oil/Products and Experimental Lakes

Clifton Graham discussed M/V Wakashio accident on July 25, 2020, which involved a fuel tank breach spilling ~300,000 gal. of Very Low Sulfur Fuel Oil (VLSFO) in Mauritius. He noted that in January 2020 a Global Sulfur Cap regulation was implemented, reducing sulfur content in fuels from 3.5% to 0.5%. VLSFOs are replacing the traditional intermediate and heavy fuel oils, but little is known about the characteristics of these oils. Graham also noted that GIS has been used during response, but not always in the timeframe needed by responders. Being able to get a real-time picture of the spill would improve the response to emerging fuel spills. Additionally, the use of UAS is improving, but transmitting a large volume of data into a usable format is still difficult. Graham noted the need for better mapping and interface/product development, improved detection for the presence of oil on shorelines with UAS, and a better understanding of the behavior of new fuels and the threat they pose to the safety of responders.

Jeff Morris discussed the lack of information regarding the toxic components in many petroleum products including emerging fuels that are currently being transported via rail and pipeline indicating data on how these products weather and behave under natural conditions. He also discussed the need to collect and bank samples during and after response activities to characterize concentrations and compositions of toxic constituents and how these change with time. He recommended conducting comprehensive toxicity testing of emerging fuels for different weathering states and in the presence of other stressors (e.g., UV light) to build a catalog of toxic sublethal thresholds to relevant taxa and life stages.

Greg McGowan discussed response, detection, fate, and effects of emerging fuel spills on shorelines. For most renewable fuels, the response is well understood and is consistent with its petroleum counterpart. Ethanol is an outlier due to its solubility in water. For ethanol spills in water, response may be more focused on addressing secondary impacts such as a dissolved oxygen depletion that can lead to a sudden and significant fish kill. Visual detection of renewables on shorelines is more difficult due to their lower color contrast. Fate is broadly understood; renewables are expected to persist in the environment for a shorter time and with lower ecological consequences than their petroleum counterparts. Additional study regarding the speed of natural attenuation and the reduced ecological impacts of the fuels while in the environment is warranted to develop a defensible basis for clean-up endpoints. Renewables do not persist as long in the environment and pose reduced ecological threats, so it may be that higher residual concentrations can remain in the environment after mechanical recovery because biodegradation will occur. Effects are generally understood, and the mechanical impacts (e.g., coating of fur/feathers, smothering) would be the same as petroleum counterparts. McGowan discussed the tools and technologies that could improve response to emerging fuel spills on shorelines such as testing of various sensors for detection, mechanical equipment settings/refinements, solvent considerations for gear, and tools to predict biodegradation rates based on product and environmental conditions.

McGowan prioritized R&D spending on the following knowledge gaps in oil spill science for emerging fuels: the ability to reasonably forecast biodegradation rates, spill response benefit analysis for clean-up endpoints, wildlife response protocols for stabilization, washing, and reconditioning to ensure that renewable fuels do not pose different challenges for care. McGowan questioned whether natural attenuation in high energy wave activity should be considered a primary response technique. Additional fate and transport information for on-water spreading and shoreline substrate penetration and adhesion would be helpful for response planning and implementation.

Pauline Gerrard discussed the unique and beneficial existence of International Institute for Sustainable Development (IISD) Experimental Lakes Area, a freshwater research facility comprised of 58 small lakes in Ontario, Canada. The facility was originally established to address the challenge of large algal blooms in the Great Lakes. In use since 1968, some of the research conducted at the lakes has included microplastics, pharmaceuticals, climate change, endocrine disruption, acid rain impacts and recovery, and eutrophication. The Experimental Lakes are used for ecosystem-scale research. Provincial and federal laws contain provisions that allow pollutants to be used. The goal of the lake's research facility is to mimic real life pollution scenarios in order to help return systems to their pre-impact conditions. Gerrard discussed three recent oil studies conducted at the lakes that examined the: (1) fate, behavior, and effects of oil spills on freshwater systems, (2) effectiveness of minimally invasive shoreline clean-up methods, and (3) efficacy of engineered floating wetlands as a remediation method.

2.3 Plenary Panel 6: Changing Future

Charlie Henry discussed the problem of cleaning up oiled boulder/cobble beaches and riprap, using an example of a spill in New Orleans. He described techniques such as the omni boom, a large flushing barge like the M/V Winchester, shoreline cleaning agents, bioremediation, berm relocation, and flushing with header hoses. Most techniques did not work, so there is still need for better solutions to clean-up boulder and cobble beaches and riprap. Ultimately, the riprap along the river walk in New Orleans that was oiled was cleaned by a hurricane.

Scott Pegau focused his presentation on the needs associated with remote locations and the potential for increased vessel traffic in the Arctic. The increased traffic will lead to new routes and spills at different times throughout the year. For remote locations, the personnel and equipment necessary to respond to oil on a beach must be minimized because of the lack of logistical bases. Natural attenuation may be an important response option in many cases, but it is not well understood. Impacts on wildlife need to be considered when responding. Pegau also examined the potential of remote sensing techniques to map oil distribution.

M. J. "Lew" Lewandowski discussed prevention and response activity in terms of climate change. He noted the USCG R&D Center has started an effort to examine vessel use and transportation of alternative fuels (e.g., ammonia, hydrogen, methanol). Incident response may need a different approach, particularly for more volatile or gaseous fuels whose containment might be neither safe nor practical. In areas where subsidence is up to 2.6 cm/year, a multi-agency and industry effort could identify the most vulnerable infrastructure and develop mitigation or resilience strategies. Climate change impacts petroleum-related infrastructures (e.g., subsidence, permafrost melting). In areas prone to increasingly intense storms and associated water-level surge, regulators need to examine existing petroleum-related infrastructure and determine whether as-built piping, manifolds, control systems, and containment may be subject to inundation. There is a need to model the storm-driven extent of spill transport, including how surge-related inundation could increase the geographic extent of preventive and response activity. Lewandowski mentioned that abandoned, unplugged wells could present future problems.

Jacqui Michel discussed the expansion of mangroves in the northern Gulf of Mexico that make SCAT assessments difficult. There are limited options for effective shoreline treatment of mangroves, and they have a longer recovery time compared to marshes. Nurdles pose another problem because they can leak and sorb toxic chemicals (e.g., PAHs, mercury), complicating clean-up and waste disposal. Mapping buried oil after a spill is also an emerging field of study. UAS imagery or LiDAR can be used to assess changes in beach elevation post oil stranding. The presence of Sargassum during an oil spill greatly increases the volume of oil waste for removal and can pose a hazard to clean-up workers. Another emerging issue is the higher risk of oil transport via wash overs.

3 Session Three

The third session of the workshop was held on Thursday May 11, 2023. For this session, the breakout groups were asked to take the previously selected priorities for each of the research areas and develop a research project to address each of the knowledge gaps and technology needs. Participants were asked to: (1) decide which 2-3 research projects were the top priorities, and (2) determine its objectives and outcomes for each one. For example, under *Detection,* one of the priorities was detecting ice under challenging conditions. Participants could then design a research project to test the best methods to detect oil under ice near shore and another project on use of canines to detect oil under shoreline sands. Again, the results of each breakout group's prioritization are located in Appendix E.

3.1 Priorities, Knowledge Gaps, and Research Ideas

The workshop fostered a productive discussion about current technology needs and knowledge gaps and potential research to address them. After each individual breakout group presented their top priorities for the plenary session, all participants voted for their top three. Policy knowledge gaps were not used for the overall prioritization during Session III.

The research priorities chosen by the participants are shown in Table 1. Appendix E contains the suggested objectives/outcomes for these projects where they were delineated. The Experimental Lakes was separated from the Emerging Oil/Products topics and discussed on its own. To ensure that all topics got discussed across the breakout groups, each team started with a different topic area.

3.2 Table 1: Prioritized Research Needs for Shoreline Oil Spill Response

Response	Response technologies (crewed/uncrewed) should be developed/repurposed, specifically for clean-up	Set asides, monitoring, longitudinal studies. Assessing risk for residual oil/clean-up endpoints that may generate controversy	Research on how best to communicate shoreline response technologies to the public
Detection	Platform/sensor type evaluations for shoreline detection and rapid image processing and interpretation by SMEs	Detection of oil in challenging conditions	Development of job aids/training tools for oil detection on shorelines
Fate & Effects	Determine toxicity/risks of tar balls (e.g., how/where formed) including GIS hindcasting/fingerprinting	Develop tools so that ecosystem modeling can be used for communication with a quick turnaround time during an event, including information from specialists (e.g., biologists) and trajectory modeling	Long-term monitoring/modeling of fate and effects to help prioritize shoreline types to protect
Emerging Oils / Products	Detection, response, fate, effects, and risks of emerging products	Realistic conditions and environmentally relevant toxicity testing of emerging products	
Experimental Lakes	Oil under ice nearshore	Remote Sensing/Detection of oil on shorelines and nearshore	Shoreline Efficacy Testing of Techniques (e.g., surface washing agents, herders, set asides, in-situ burning)
Changing Future	Think Tank/incubator for new ideas on specific shoreline topics	Emerging shoreline protection technologies	Challenges with climate change and impacts to infrastructure, loss of permafrost, and changes in exposure routes and habitats

4 Workshop Findings and Recommendations

1) **Finding:** Several facilities exist in North America that could be used to conduct experimental work related to shoreline oil spill response.
   a) **Recommendation:** Develop a guide to these facilities, including locations, affiliation, capabilities, requirements, and limitations.
2) **Finding:** Data on the chemistry of emerging oils and contaminants is not located in one readily accessible location that could be used by responders.
   a) **Recommendation:** Develop a database of existing data and chemical profiles of emerging oil and contaminants.
3) **Finding:** The need to do collaborative research must be recognized and pursued.
   a) **Recommendation:** Encourage and facilitate multiple agencies working together on projects.
4) **Finding:** This workshop was successful at identifying knowledge gaps and technology development opportunities for shorelines by targeting one specific area and generating concise outcomes.
   a) **Recommendation:** Repeating this approach for other response areas (e.g., mechanical recovery, dispersants).
5) **Finding:** There is a need for field scale testing of technologies that OSROs are well positioned to achieve.
   a) **Recommendation:** Provide mechanisms to enable OSROs to use prototype technologies during actual responses.
   b) A summary of selected shoreline response literature compiled during the workshop planning process can be found here. Some of the technologies identified in the literature review and by workshop participants could support discussions with OSROs about testing prototype technologies.
6) **Finding:** Clean-up of oil in the nearshore is the best method to prevent shoreline impacts.
   a) **Recommendation:** Prioritize research that removes oil while it is in the nearshore which prevents it from reaching shorelines.
7) **Finding:** Transition of research and technology development is often not funded/pursued so that promising results are not operationalized.
   a) **Recommendation:** Facilitate regular collaboration on technology development between industry and government. This is best accomplished by in-person interactions.
8) **Finding:** For the full value of this workshop to be realized, further discussion and interaction must occur.
   a) **Recommendation:** Form and facilitate a working group on shoreline oil spill response. [N.B., The CRRC offered to facilitate this working group starting in Fall 2023 in conjunction with the Clean Gulf Conference.]

5 Appendices

Appendix A: Workshop Agenda

Appendix B: Workshop Participants

Appendix C: Workshop Presentations

Appendix D: Panelist Questions

Appendix E: Detailed Prioritization Notes

Appendix F: Literature Review

Appendix G: Post Workshop Summary Overview

Appendix H: Technical Summary