Acquisition Directorate
Research & Development Center

Federal On-scene Coordinator (FOSC) Guide for Oil in Ice

Distribution Statement A: Approved for public release; distribution is unlimited.

March 2017

Homeland Security

N O T I C E

This document is disseminated under the sponsorship of the Department of Homeland Security in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

This report does not constitute a standard, specification, or regulation.

Mr. Timothy R. Girton
Technical Director
United States Coast Guard
Research & Development Center
1 Chelsea Street
New London, CT 06320

Technical Report Documentation Page

1. Report No.	2. Government Accession Number	3. Recipient's Catalog No.
4. Title and Subtitle Federal On-scene Coordinator (FOSC) Guide for Oil in Ice		5. Report Date March 2017
		6. Performing Organization Code Project No. 4701
7. Author(s) Kurt A. Hansen and Dr. Michele Fitzpatrick		8. Performing Report No. RDC UDI # 1567
9. Performing Organization Name and Address Shearwater Systems, LLC Contractor for USCG Research and Development Center 1 Chelsea Street New London, CT 06320	U.S. Coast Guard Research and Development Center 1 Chelsea Street New London, CT 06320	10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Task Order #HSCG32-16-J-500019
12. Sponsoring Organization Name and Address COMMANDANT (CG-MER) US COAST GUARD STOP 7516 2703 MARTIN LUTHER KING JR AVE SE WASHINGTON, DC 20593		13. Type of Report & Period Covered Final
		14. Sponsoring Agency Code Commandant (CG-MER) US Coast Guard Washington, DC 20593
15. Supplementary Notes The R&D Center's technical point of contact is Kurt Hansen, 860-271-2865, email: Kurt.A.Hansen@uscg.mil.		

16. Abstract (MAXIMUM 200 WORDS)

In the northern climates of the United States, the Coast Guard (CG) and Environmental Protection Agency are required to respond to oil spills during the winter months. The majority of the spills are tank leaks and gasoline truck accidents that may occur near waterways; thus, the oil can reach navigational waters, such as harbors and rivers, requiring CG response. The reduced ice during some seasons may increase vessel and barge traffic and increase the potential for more accidents. In addition, the aging petroleum pipeline infrastructure is a cause for concern.

While response issues have historically been addressed, the changing environmental conditions are requiring responders in these areas to re-evaluate the equipment and techniques that were recommended. Over the past seven years, the CG Research and Development Center has conducted a number of demonstrations of new technologies, approaches, and tactics to detect, track, and remove oil in ice-infested water in all conditions in the Great Lakes and Alaska. The objective of this report is to summarize the findings of these demonstrations in a format that provides input for useful guidance to the Federal On-scene Coordinator (FOSC) in responding to lake and marine spills where ice is a factor.

17. Key Words	18. Distribution Statement		
Oil spills in ice, Great Lakes oil spill response, Arctic oil spill response, oil spill response demonstrations	Distribution Statement A: Approved for public release; distribution is unlimited.		
19. Security Class (This Report) UNCLAS//Public	20. Security Class (This Page) UNCLAS//Public	21. No of Pages 64	22. Price

(This page intentionally left blank.)

EXECUTIVE SUMMARY

In the northern climates of the United States, the Coast Guard (CG) and U.S. Environmental Protection Agency are required to respond to oil spills during the winter months. The majority of the spills are tank leaks and gasoline truck accidents that may occur near waterways; thus, oil can reach navigational waters, such as harbors and rivers, requiring CG response. The reduced ice during some seasons may increase vessel and barge traffic and could increase the potential for more accidents. In addition, the aging petroleum pipeline infrastructure is a cause for concern.

While response issues have historically been addressed, the changing environmental conditions are requiring responders in these areas to re-evaluate the equipment and techniques that are recommended. Over the past seven years, the CG Research and Development Center has conducted a number of demonstrations of new technologies, approaches, and tactics to detect, track, and remove oil in ice-infested water in all conditions in the Great Lakes and Alaska. The objective of this report is to summarize the findings of these demonstrations in a format that provides input for useful guidance to the Federal On-scene Coordinator (FOSC) in responding to lake and marine spills where ice is a factor.

This report includes the lessons learned from oil-in-ice response demonstrations in the Great Lakes and the Arctic. The demonstrations have shown that a number of the technologies, approaches, and tactics require additional development and/or demonstration before they are ready to use in the field. These include the following:

- Detection and Surveillance:
  - Aerostat.
  - Small Unmanned Aerial Systems.
  - Remotely Operated Vehicles.
- Containment and Recovery:
  - Ice Edge Conditions:
    - Skimming – Boom Vane.
    - Herding.
    - Slotting.
  - Broken Ice Conditions:
    - Skimming.
    - Ice Cage.
    - Herding and Ice Management.
- In-situ Burning.

(This page intentionally left blank.)

TABLE OF CONTENTS

(This page intentionally left blank.)

LIST OF FIGURES

LIST OF TABLES

(This page intentionally left blank.)

LIST OF ACRONYMS AND ABBREVIATIONS

ACS	Alaska Clean Seas
ADCP	Acoustic Doppler current profilers
BSEE	Bureau of Safety and Environmental Enforcement
CG	Coast Guard
CGC	Coast Guard Cutter
CGHQ	Coast Guard Headquarters
COTS	Commercial-off-the-shelf
CRRC	Coastal Response Research Center
D1	Coast Guard District One
D9	Coast Guard District Nine
D17	Coast Guard District Seventeen
DECON	Decontamination
DHS	Department of Homeland Security
DRAT	District Response Assist Team
EO	Electro-optical
EPA	Environmental Protection Agency
ERMA	Environmental Response Management Application
FOSC	Federal On-scene Coordinator
ICS	Incident Command System
IR	Infrared
JIP	Joint Industry Program
lb	Pound
LF	Laser fluorometer
LRB	Lamor Oil Recovery Bucket
MPT	Marine Portable Tanks
MSST	Coast Guard Maritime Safety and Security Team
NOAA	National Oceanic and Atmospheric Administration
NSF	National Strike Force
NSFCC	National Strike Force Coordination Center
Ohmsett	National Oil Spill Response Research and Renewable Energy Test Facility
OSRO	Oil Spill Response Organization
PPE	Personal protective equipment
PVC	Poly vinyl chloride
RDC	Research and Development Center
ROV	Remotely operated vehicle
SORS	Spilled Oil Recovery System
STAR	Spill Tactics for Alaska Responders
SUAS	Small unmanned aerial systems
T/V	Tugboat vessel
TST	Temporary storage tank
TWG	Technical working groups

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

UUV	Unmanned underwater vehicle
UV	Ultraviolet
VOO	Vessel of Opportunity
VOSS	Vessel of Opportunity Skimmer System
WHOI	Woods Hole Oceanographic Institute
WLB	Coast Guard Buoy Tender

1 INTRODUCTION

In the northern climates of the United States, the Coast Guard (CG) and Environmental Protection Agency (EPA) can be tasked to respond to oil spills during the winter months. The majority of the spills are tank leaks and gasoline truck accidents that may occur near waterways; and the oil can reach navigational waters, such as harbors and rivers, requiring CG response. The reduced ice during some seasons may increase vessel and barge traffic and could increase the potential for more accidents. In addition, the aging petroleum pipeline infrastructure is a cause for concern.

While response issues have historically been addressed, the changing environmental conditions are requiring responders in these areas to re-evaluate the equipment and techniques that were recommended. For example, CG District One (D1) had a cold-weather response workshop in 2007; and CG District Seventeen (D17) is initiating efforts to increase spill response capabilities of the North Slope of Alaska in anticipation of increased exploration, drilling, and shipping. The CG Research and Development Center (RDC) also conducted two workshops for stakeholders in Anchorage and Cleveland in 2010 to determine if lessons learned from the evaluation of equipment and tactics in the Great Lakes during the winter would be useful for the Arctic. During the workshops, a list of potential technologies and scenarios was developed for evaluation. The recommendation was to plan a series of Great Lakes demonstrations; since the costs would be significantly less for the Great Lakes and support is more easily obtained (Hansen and Lewandowski, 2011).

Over the past seven years, the RDC has conducted a number of demonstrations of the existing technologies identified in the workshops; and recently developed technologies, either by the RDC or commercial enterprises. Tactics to detect, track, and remove oil in ice-infested water in many conditions were also identified and evaluated for these technologies. This project was designed to investigate the needs and requirements in both the Arctic and the Great Lakes; in order to identify technologies, approaches, and tactics that would these needs in both environments.

1.1 Objective

The objective of this effort was to use information generated from the lessons learned during past demonstrations to identify and/or develop equipment and techniques that could be used to detect, track, and recover oil in ice-filled waters in all conditions.

This report provides a brief summary of:

- CG oil-in-ice demonstrations in the Great Lakes,
- CG oil-in-ice technical demonstrations in the Arctic,
- Other related CG efforts, and
- Related industry efforts.

It also includes lessons learned from the CG demonstrations and efforts; and recommendations for future research work. Finally, the combination of equipment development and field demonstrations was used to develop recommended inputs for Federal On-scene Coordinator (FOSC) guidance.

1.2 Background

While Great Lakes ice and Arctic ice are different, there are enough similarities during the Great Lakes winter and the Arctic summer and shoulder seasons (fall and spring). The ice edge in the Arctic is usually composed of first year ice and is not too different from the ice in the Great Lakes. With this similarity, specific spill response tactics may be applicable to both environments.

Some differences between the two environments do need to be taken into account during planning and response. The greater amount of vessel traffic in the Great Lakes creates more of a risk for spills. The elimination of the use of dispersants (due to freshwater) and the limited window in time and space for in-situ burning (ISB) in the Great Lakes focuses efforts on mechanical response under conditions when the ice may not support personnel and equipment. The position of major cities and transportation infrastructure in the Great Lakes simplifies response logistics. However, the challenge of removing oil from a broken and moving ice environment exists in both the Great Lakes and the Arctic.

2 GREAT LAKES OIL-IN-ICE DEMONSTRATIONS

A series of oil-in-ice response exercises were conducted in the Great Lakes that informed discussions about how to respond to oil in broken and loose ice conditions:

- 2011 (April): CG Sector Sault Ste. Marie operating area (open water; cool temperatures but no ice available) (Cooper and Dugery, 2011).
- 2012 (January): Straits of Mackinac on the Great Lakes in northern Michigan (rubble and sheet ice) (Yankielun et al., 2012).
- 2013 (February): CG Station St. Ignace near the Straits of Mackinac, MI (oil surrogate (e.g., peat moss, oranges) in frigid open water, under sheet ice, and in and among broken ice) (Yankielun et al., 2013).

Exercise objectives:

- Pick off-the-shelf equipment and evaluate them for use in cold temperatures.
- Identify deployment requirements for use on CG vessels.
- Identify performance gaps with respect to equipment capabilities, logistics, and support.
- Involve local Oil Spill Response Organizations (OSROs) to assess operational feasibility, including logistics and personnel requirements.

The following techniques and technologies were demonstrated in the Great Lakes:

- A newly designed grooved drum skimmer fitted with a steam/hot water hook-up (2011). This concept was designed to help reduce the viscosity of oil being collected, and minimize ice blockages.
- A fire boom (2011, 2012) was mobilized and towed in a U-configuration using two small vessels.
- A fire monitor (also called a water cannon) was used to “herd” oil into a containment boom. This demonstrated multiple logistical implications for diverting oil in broken ice. (2011, 2012, 2013)
- An older design rope-mop skimmer. (2011, 2012)

- A Boom Vane (2011), along with an additional small drum skimmer (2011, 2012). The Boom Vane, controlled from shore, utilized water current to hold a diversion boom in place while the small skimmer operated in the pocket of the boom.
- CG deployment of a Helix skimmer as a concept for cold weather use of the Spilled Oil Recovery System (SORS) (Figure 1). (2012, 2013)
- Slotting of a solid ice sheet to produce an oil collection area. (2012)
- Remotely Operated Vehicle (ROV). (2012, 2013).
- Unmanned Underwater Vehicle (UUV). (2013)
- Oil and ice detecting radar. (2013)
- Aerostat balloon with an electro-optical (EO) and infrared (IR) real-time video. (2013)
- Containment boom deployment and recovery. (2013)
- Bucket skimmer for oil recovery and ice management. (2013)

Figure 1. CG buoy tender deployment of SORS skimmer.

See Section 6 for a summary of demonstration results.

3 ARCTIC OIL-IN-ICE DEMONSTRATIONS

The oil-in-ice response exercises conducted in the Arctic included:

- Arctic Shield 2012 exercise (July 25–August 8, just off Barrow) in cooperation with CG D17 (Alaska) and the U.S. Navy Supervisor of Salvage and Diving (Hansen, 2012).
- Evaluation of equipment deployed off the *CGC Healy* as part of the Arctic Shield 2013 exercise (about 300 miles north of Barrow in 2013) (Hansen et al., 2014)
- Arctic Technology Evaluations in 2014 and 2015 (internal USCG RDC reports; contact CGD17 Incident Management Branch for information).

The objective of these exercises was to conduct a capability assessment of existing equipment; and evaluate potential techniques that could enhance the efficiency of a response. The equipment deployed varied from skimmers to small unmanned aerial systems that were provided in cooperation with multiple organizations.

The following technologies were demonstrated in the Arctic:

- Helix skimmer; concept for cold weather SORS (2012, 2013).
- High Speed Current Buster Skimmer (2012).
- Boom Vane (2012).
- Polar Bear skimmer (2012) (Figure 2).
- Small unmanned aerial systems (SUAS) (2013, 2014, 2015).
- Remotely Operated Vehicle (ROV) (2013, 2014, 2015).
- Unmanned Underwater Vehicle (UUV) (2013, 2014).
- Aerostat (2014, 2015).
- Oil and ice detecting radar. (2014, 2015).

Figure 2. Polar Bear Skimmer deployed.

See Section 6 for a summary of demonstration results.

4 RDC RESEARCH AND DEVELOPMENT EFFORTS

The RDC pursued the following technologies and techniques, identified from the previous demonstrations, as needing additional development for use on a CG buoy tender:

- Temporary Storage Tank (TST).
- Ice Cage (aka Ice Management System).
- Cold Weather Decontamination (DECON).

Logistical considerations for these technologies and techniques were evaluated during a demonstration on board the *CGC Juniper* in August 2016 (Balsley et al., 2016). While underway in the Narragansett Bay, the vessel's crewmembers deployed the ice cage, which was integrated with a DOP-Dual Helix cold-weather skimming system; and erected two TSTs of different sizes on the buoy tender deck. The DECON procedure evaluation was carried out when the ship returned to port.

4.1 Temporary Storage Tanks

4.1.1 Initial Development and Field Demonstration 1

An important and limiting factor in effective containment and recovery operations is the availability of recovered oil storage on the skimming vessel. The size of storage, in comparison to the recovery capability of some recovery systems, is a critical factor. The CG Juniper Class Seagoing WLB has space for temporary storage containers (Marine Portable Tank (MPT)). One can be seen in Figure 3 (the gray tank), deployed in 2012. Each one of these containers could hold about 4,200 gallons of liquid. A preliminary layout for four of these tanks was developed during the Deepwater Horizon Response; but detailed design was needed for on-deck or below-deck mounting and appropriate plumbing for cold weather use. This also needed to include a manifold system that could connect to multiple tanks.

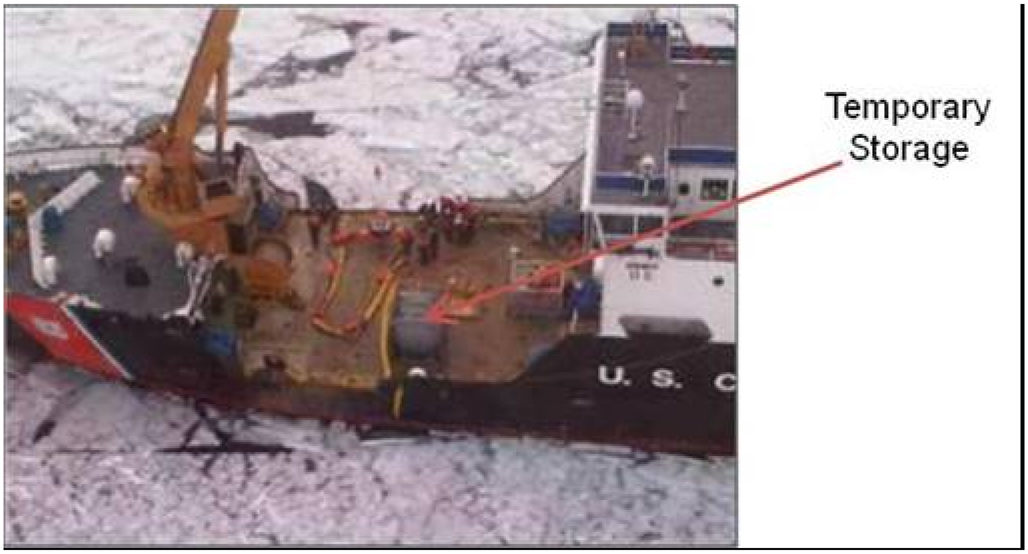


Figure 3. A temporary storage container mid-deck on a Juniper Class Seagoing WLB.

RDC worked with ELASTEC American Marine to develop a collapsible tank. One of the primary design goals was that it must fit in the storage hold of the WLB. ELASTEC designed a prototype TST and demonstrated it on *CGC Elm* in 2014 (see Figure 4). It consists of a bladder-like arrangement with internal baffles and external aluminum support poles. ELASTEC used straps to stabilize the aluminum poles. It can hold about 3,900 gallons. Multiple TSTs would be needed to meet the Lancer Barge capacity. During this demonstration, RDC and ELASTEC filled it with water to evaluate the initial strength and stability. RDC identified the following minor issues for improvement to a future system: the material used for the manhole, the survivability of the selected material in cold weather, and the correct hooks for use to connect the straps on a WLB. In general, the system met the minimum requirements.

Figure 4. Empty TST ready for service.

4.1.2 Field Demonstration 2

RDC deployed two TSTs on the deck of the *CGC Juniper* during the August 2016 demonstration (Figure 5). The first one was the system deployed in the first demonstration with minor adjustments for the access hole and tie-down arrangement. The second TST (black color in Figure 5) used a material that is better suited for colder weather and has a larger capacity of about 4,800 gallons. The deck layout with both TSTs and the ice cage (see Section 4.2.2) was a challenge that was overcome by the re-positioning the smaller TST from the far port side of the deck to the aft portion and turned sideways. The TSTs required many strap tie-downs that prohibited the placement of a DECON station at the aft door that led inside to the mess deck. The tie-downs also posed safety hazards with risks of tripping responders wearing Personal Protective Equipment (PPE) designed for cold weather oil spill response. However, the TSTs were successfully deployed on the deck of *Juniper*. The larger TST was filled halfway with fresh water and no stability issues were observed during the underway demonstration.

Figure 5. Two temporary storage tanks fully erected on the deck during the underway demonstration.

Both TSTs required many small parts that would prove to be difficult to assemble in cold weather when wearing gloves. In contrast, the equipment vendors during the August demonstration were able to use their bare hands for easier access. Both tanks were easily set up, once all the small parts were assembled. As a result, the RDC recommends that some parts come pre-assembled; to ease assembly and preclude handling small parts. Installers also determined that partially filling the tanks with air, using a leaf blower, greatly improved the ease of setup. Additionally, each TST was easily transported from the pier to the ship on a pallet using a crane. Figure 6 shows that TSTs packed and bound would take up relatively little storage space; and could be placed in the storage hold. Use of a manifold system between the skimmer and tanks would also ensure that the tank fittings are not stressed when being pulled by the skimmer hoses.

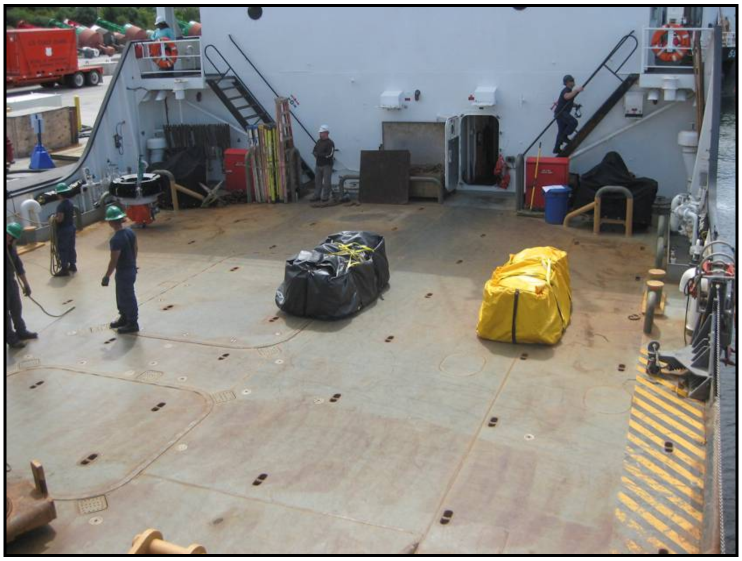


Figure 6. Temporary storage tanks packed and bound.

The size, weight and center of gravity for these systems are inside the limits for weight, size and locations approved for use of the Marine Portable Tanks (MPT) during the Deepwater Horizon spill response. Another analysis is needed, once final configurations and arrangements are determined.

Participants quickly learned that deck space was at a premium during the demonstration. Adding a third TST with a volume of approximately 4,000 gallons is unlikely. To help counter storage capacity, the higher efficiency of the DOP-Dual skimmer will greatly decrease the amount of water recovered. A full Concept of Operations (CONOPS) to keep the vessel on station and performing skimming operations as long as possible needs to be developed.

The RDC recommends that the use of temporary storage tanks be further explored for use in Arctic conditions. This needs to include how they can be secured to the deck without causing trip hazards to workers on the deck. Methods and configurations for the storage of these tanks in the ship's hold also need to be investigated.

4.2 Ice Cage

4.2.1 Initial Development and Tests in Ice

Results of the Great Lakes and Arctic demonstrations showed that lighter or vulnerable skimmers cannot be placed near ice and expected to remain intact. The RDC developed an ice cage designed to keep ice fragments from affecting skimmer performance. The design leveraged the results of Bureau of Safety and Environmental Enforcement's (BSEE) earlier "Ice Month" testing at the National Oil Spill Response Research and Renewable Energy Test Facility (Ohmsett) in 2013 (SL Ross and MAR, Inc., 2013). Those test results showed that most skimmers could not pick up oil in pack ice of over 70 percent coverage; because pieces of ice interfered at the weir, brush, or belt interface with the water and kept the oil from reaching the collection point. The RDC cooperated with the (BSEE) to evaluate the system at Ohmsett in March 2014 (Figure 7), using the Coast Guard's Helix skimmer. Test results appeared to triple the oil recovery rate in over 65 % ice coverage. (Hansen and McKinney, 2016)

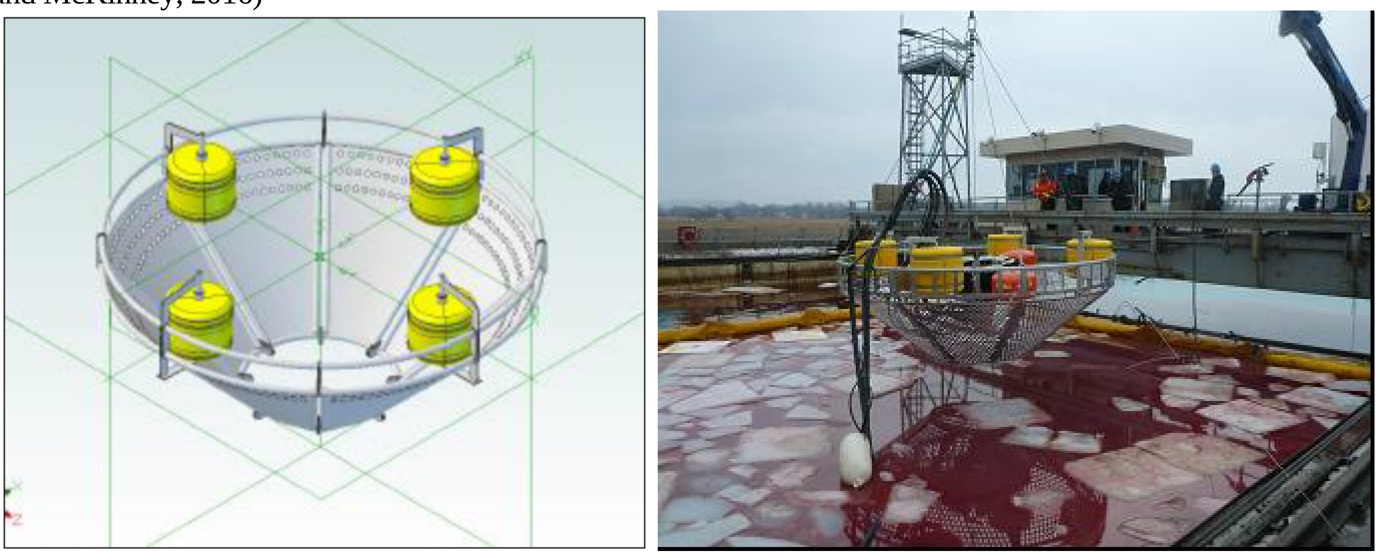


Figure 7. Ice cage drawing (left) and testing at Ohmsett (right).

4.2.2 Field Demonstration

During the August 2016 field demonstration, the ice cage was deployed with a DOP-Dual Helix skimmer provided by the CG Atlantic Strike Team (Figure 8). The ice cage required many parts and pieces; and had to be assembled in a particular order. The RDC recommends a reduction in parts and pieces to make assembly easier in cold weather and reduce the manpower required.   While a stand is required to hold the ice cage as it is being assembled, the RDC also recommends that the stand be reduced in size to create more deck space for the crew to maneuver.

Figure 8. Ice cage integrated with a DOP-Dual Helix skimmer.

Another critical aspect of the ice cage deployment is the management of the skimmer hoses. During the demonstration, it was particularly important for the crane operator to identify the location of the saddle in order to place the hoses in the correct location. This precluded the need for small adjustments by the crew. The demonstration also revealed the need for adequate deck space to maneuver the ice cage; since the first 25 feet of the hose is relatively rigid-braided stainless steel. This stainless steel, chemical resistant hose is needed for cold weather. It ensures the hose will not freeze shut when not in use. This configuration used a 6-inch diameter hose that is too large for this use. A smaller 3-inch hose is available; and needs to be evaluated for use with this skimmer. Additionally, a more compact configuration is needed to protect the hoses and wires from being damaged by ice and make them more manageable.

Once the ice cage encounters oil, it becomes critical that the contaminated equipment does not increase the amount of oil brought to the deck through dripping. The RDC recommends the use of a berm or dam around the contaminated equipment on the deck. This will contain oil brought aboard by both the IMS and hoses.

4.3 Personnel Decontamination

Decontamination (DECON) involves the removal of oil or other contaminants from personnel or equipment after they leave the Hot Zone or working area. The purpose for personnel DECON is to minimize worker contact with contaminants and prevent spread of contaminants to clean areas. In most situations, water and mild solutions can be used to wash down personnel. On smaller vessels and in cold environments, this may not be an option; due to waste storage capabilities and the potential for the solution to freeze. The preferred option is to attempt dry decontamination using clean rags or wipes to remove oil from individual's clothing.

Decontamination is conducted in the Warm Zone, which is the control point for personnel and equipment entering and leaving the Hot Zone.

4.3.1 Initial Evaluation

The Arctic and Great Lakes demonstrations showed that most vessels, especially the tugboats, would have difficulty in handling crew DECON during an actual cold weather spill. A structure would be needed on deck as a Warm Zone to disrobe from the contaminated PPE to ensure oil is not tracked into the other living and piloting spaces. A research effort to investigate vessel of opportunity (VOO) protection and personnel DECON for cold weather reached the following conclusions:

- PPE must be donned completely prior to entering the Hot Zone to minimize DECON efforts when returning to the Cold Zone.
- Dry DECON can be completed effectively aboard VOOs.
- Effectiveness depends on inspection of response personnel exiting the work zone prior to allowing them entry into the Cold Zone.
  - Spot DECON may be needed prior to allowing entry.
  - A clean set of disposable PPE (e.g., coveralls) may still be needed upon entering the Cold Zone to protect interior clean spaces.
- Disposable suits, boot covers, gloves, and spot DECON materials are needed to:
  - Protect doffers from contamination.
  - Protect interior clean areas of vessel.
- Some materials are commercial-off-the-shelf (COTS) available, such as waste receptacles, spot DECON materials, disposable suits, and gloves.
- A custom disposable boot configuration needs to be developed for donning over cold weather boots.
- A standardized shelter needs to be developed to adapt across the many VOO configurations (Figure 9 shows a recommended DECON shelter configuration).

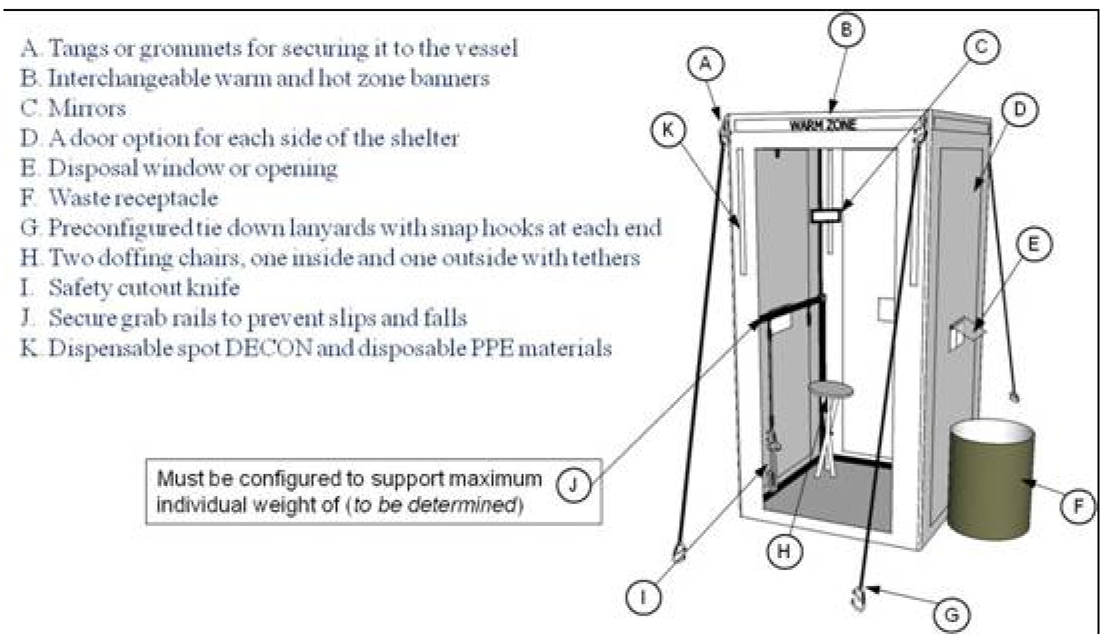


Figure 9. Recommended DECON shelter configuration.

4.3.2 Field Demonstration

From the August 2016 demonstration, the RDC noted that DECON line workers play a major role in performing efficient decontamination of responders. The NSF agreed that the original DECON procedure was effective for the most part, but needed minor revisions (see Appendix A). Instead of the coverall suit being ripped off with a knife, it was recommended that the suit be rolled off carefully by a DECON line worker. The line worker would have thin plastic gloves or garden gloves with rubber grips to enable the "roll off" method. Since the recommended gloves are not adequate in keeping their hands warm during extreme cold weather, the DECON line workers should come out to the deck on an as-needed basis only and work in 15-minute rotations. Effective DECON can take place only if the DECON line workers are kept warm, well fed, and comfortable in between their work shifts; so they remain as alert as possible.

The shelters used in this demonstration proved to be flimsy and participants agreed that the shelters would not be able to withstand strong winds and cold temperatures; or provide stable support to responders when they sit down. RDC recommends a sturdier structure, if protection from the elements is desired. However, deck space will need to be considered, if this approach is to be taken. Otherwise, DECON can be performed in the open air. Responders would have layers of warm clothing beneath the coverall that can still keep them warm during the DECON process. Since DECON line workers would be warm and alert, they will be able to work quickly and get the responder into the safety of the ship as quickly and safely as possible without contaminating the Cold Zone.

The shelters were effective in providing a clear physical barrier between the Hot Zone and the Cold Zone; providing responders awareness of the extent of their working zone. RDC recommends that a DECON line worker be stationed at each DECON station to monitor the ingress/egress of workers; and ensure that the Cold Zones remain contamination-free.

During the DECON demonstration, RDC observed that DECON waste can accumulate quickly, especially when more than four responders are involved. Although deck space is at a premium, some space will need to be available for the storage of contaminated PPE (hazardous waste) until the ship returns to port and they are properly disposed of. In addition, RDC observed that the collapsible trash cans made of thin plastic were flimsy and needed to be tied down. They were easily knocked over when heavy PPE was thrown in. RDC recommends that large, hard plastic containers (minimum 30-gallon volume) are used to store contaminated gear/PPE during the DECON process.

Overall, the DECON procedures in Appendix A were modified to include the above recommendations. DECON line workers were found to be especially helpful; since it is anticipated that responders will have limited mobility due to additional PPE to protect them from the cold weather, and be more susceptible to slips, trips, and falls. During the DECON procedure, the DECON line workers are expected to perform most of the DECON while the responders follow instructions.

5 JOINT INDUSTRY PROGRAMME EFFORTS

The oil and gas industry has made significant advances in being able to detect, contain and clean up spills in Arctic environments. To further build on existing research and improve the technologies and methodologies for Arctic oil spill response, nine oil and gas companies (BP, Chevron, ConocoPhillips, Eni, ExxonMobil, North Caspian Operating Company, Shell, Statoil, and Total) established the Arctic Oil Spill Response Technology Joint Industry Programme (JIP, www.arcticresponsetechnology.org) (Mullen, 2014). The goal of the JIP is to advance Arctic oil spill response strategies and equipment; as well as to increase understanding of potential impacts of oil on the Arctic marine environment. Officially launched in January 2012 at the Arctic Frontiers Conference in Tromsø, Norway, the JIP has six technical working groups (TWG) each focusing on a different key area of oil spill response: dispersants; environmental effects; trajectory modeling; remote sensing; mechanical recovery, and in-situ burning (ISB). There is also a field research TWG to pursue opportunities for field releases for validation of response technologies and strategies. Many of these working groups have published documents that provide the latest state-of-the-art for the technologies and some address policies. There are recommendations for techniques and methodologies for use to respond to oil spills in different ice regimes. Most working groups also report the latest tests both in the laboratory as well as intentional research spills.

JIP research efforts are currently underway that include:

- laboratory and meso-scale dispersant tank testing to advance the application and understanding of dispersant effectiveness in very cold water,
- understanding the potential environmental effects of oil spills and spill response technologies,
- ice and oil spill trajectory modeling,
- surface/subsea remote sensing,
- mechanical recovery of oil, and
- In situ burning in Arctic and ice-prone regions.

Information is available via the dedicated JIP website created specifically for this purpose (http://www.arcticresponsetechnology.org/research-projects).

6 SUMMARY AND LESSONS LEARNED

The demonstrations described in this report provide valuable information for personnel responding to oil spill in ice conditions. The techniques and equipment that need additional development and/or demonstration are discussed in this Section. The techniques and equipment that are ready for incorporation into FOSC tactics for response to oil spills in or near ice are incorporated into tactic suggestions in Appendix B.

The lessons learned are organized into five general categories: logistics, detection and surveillance, containment and recovery, in-situ burning, and decontamination.

6.1 Logistics

Responders in the Great Lakes Region are generally used to working on land. Many lessons learned and recommendations from the demonstrations reflected the lack of experience in the Great Lakes for operating in cold climates on open water. These lessons learned included how to best utilize barges; and how to perform decontamination on small boats and tugs with the inherent issues of not being able to support more than a few people on board. In addition, there are limited platforms in this region that can support operations in ice conditions and most are Coast Guard assets.

In remote areas of coastal Alaska, there is little to no infrastructure, and marine-based logistical support will be the only way to support long-term on-water oil recovery operations. Marine-based logistics are challenging and expensive. The Arctic demonstrations reinforced the main issues of remoteness and lack of support infrastructure on the North Slope of Alaska; including lack of deepwater ports, lodging for response personnel, and limited warehouses/storage and disposal facilities (Hansen, 2014).

Logistics Lessons Learned:

- Icebreakers may be necessary to assist other vessels making way through ice to the oil.
- Environmentally sound equipment de-icing methods are necessary.
- Frequent crew rotations for work on deck are necessary in cold weather.
- Shipping and loading equipment in cold climates is easier if everything is containerized.
- Barge use and tending procedures need to be developed for use in ice and emergency response.
- There are few vessels built to handle ice; so responders may need to adapt available equipment and vessels.

6.2 Detection and Surveillance

Before spill response tactics can be selected and equipment deployed; spill management personnel must first have a clear picture of the geographic extent and movement of the spilled oil. The location, thickness, and movement of the oil must accurately charted. Surveillance data can potentially be transferred to NOAA's Environmental Response Management Application (ERMA); which contributes to the development of mapping and projected spill trajectory development. This data can be used by the FOSC at the command center to deploy assets.

Current assets used as detection and surveillance platforms include fixed-wing aircraft, helicopters, and marine vessels. There are a number of unmanned aerial and underwater vehicles being tested to serve as oil spill detection, surveillance, and tracking platforms to augment the current assets. Specific platforms addressed in the demonstrations included:

- Aerostat (tethered).
- Small Unmanned Aerial System (SUAS) (un-tethered).
- Remotely Operated Vehicle (ROV) (tethered).
- Unmanned Underwater Vehicle (UUV) (un-tethered).

The two unmanned aerial sensor platforms, the tethered Aerostat and the remotely operated SUAS, were successfully demonstrated; and are included in the tactics updates. The demonstrations also included two underwater technologies, the ROV and the UUV. The ROV was successfully demonstrated and the lessons learned are also included in the tactics updates. The UUV needs additional evaluation for the oil in ice application. A fifth technology, demonstrated in both the Great Lakes and the Arctic, is a radar designed for the detection of oil and ice. It successfully found leads in the ice, but needs more development to find oil in the ice.

Demonstration results showed that with teamwork, determination, and experience, it is sometimes possible to mitigate or work around the many challenges presented by the Arctic environment. However, for effective detection, surveillance, and data collection in the air, on the surface, and underwater; the need for more robust systems is evident. As these systems are developed, they should minimize – whenever possible – the deployment of support boats, in order to minimize risks to boat crews and equipment.

6.2.1 Aerostat

A small helium balloon system called an Aerostat was deployed in both the Great Lakes and the Arctic as a possible detection and surveillance system (Figure 10). It can be equipped with sensors such as remote-controlled electro-optical (EO) visible light and infrared (IR) real-time video cameras. In the Great Lakes in 2013, the remote-control tilt/pan/zoom real-time EO and IR sensors both provided excellent situational awareness of the operational scene with receivers within line-of-sight. This was demonstrated with video being transmitted to the command center about 4 miles away. Figure 11 shows Aerostat sensor output on the *CGC Hollyhock.*

In the Arctic in 2014, the Aerostat was successfully deployed from *CGC Healy* on three occasions for an accumulated time of about 10 hours. Deployment of the system was limited by winds over 25 knots and fog. Output from EO/IR cameras was passed wirelessly to the computer lab on the ship; and then patched to the Science Network computer for ship-wide distribution. A laptop on the bridge displayed the picture in real-time.

In the Arctic in 2015, the Aerostat was launched in varying weather conditions with a wide range of payloads and mission objectives. Operational tests resulted in establishing Arctic protocols and procedures as well as safe operational parameters for Aerostat flight operations in the Arctic.

Figure 10. Aerostat being deployed from the *CGC Healy*.

Figure 11. Aerostat sensor output on *CGC Hollyhock.*

Aerostat Lessons Learned:

- Visibility and wind speed are the main limiting factors on utilizing the Aerostat capabilities.
- Wind direction, velocity, and especially turbulence/eddy effects caused by nearby structures must be considered when launching.
- Use in cold conditions can require additional helium; due to the increased density at the lower temperatures.
- Providing different camera systems and balloon options, depending on conditions, will make deploying the Aerostat system more useful.
- An instrument that can handle the moisture (ability to keep the lens clear and not frozen) would increase capability.
- Situational awareness of where the balloon and tether are located is essential due to wind shifts, crane operations, and other possible interferences on board.

6.2.2 Small Unmanned Aerial Systems

Use of a Small Unmanned Aerial System (SUAS) can enhance oil recovery by providing real-time information to the on-scene responders or back to the Incident Command Center. Types of sensors mounted in an SUAS depend upon lift capability and weather. There are several sizes of SUAS that are capable of being used. All have limitations, based on deployment packages and weather (wind and icing) in a cold environment. Most surveillance capabilities include EO and IR cameras, although use of radar and communications systems as radio links, is also possible. The nature and amount of data to be recorded and processed should be considered to ensure the appropriate receiving equipment is available.

During the Arctic Shield 2013 spill response exercise, the SUAS was launched from *CGC Healy's* deck (see Figure 12) and recovered from the water or ice sheet. Also in 2013, the temperature was in the low 20s during the day, wind speed was a constant fifteen to twenty-five knots, and there was occasional snow and icing. At times, the unmanned aircraft were grounded due to potential icing conditions, low cloud cover, or high winds that exceeded operational thresholds.

Figure 12. SUAS being deployed from the *CGC Healy*.

In 2014, a net-capture system was developed and successfully deployed on the *CGC Healy*. Also in 2014, the SUAS was used to detect and map the ice floes and oil surrogates from the air, although the amount of deployment time for the SUAS was again adversely impacted by the weather. There was fog or high wind on several days, which did not permit any launches. Additionally, the SUAS operations were restricted when the boat was needed to support other technology demonstrations. Work still needs to be done to determine optimal search parameters for unmanned aircraft in Arctic conditions.

In 2015, the SUAS accomplished several firsts that can pave the way for increased and more effective SUAS shipboard operations. They were successfully tested in beyond-line-of-sight operations; autonomous net capture onto the forecastle of the ship; and autonomous net capture onto the flight deck of the ship. They were also able to stream live video to the ship and back to shore for viewing over the internet from any location. However, the SUAS experienced some issues with making automatic net captures, which required the ship to alter course to have the correct relative winds for the SUAS to land in the nets. There were also some difficulties with hand launches.

At the time of this report, the CG RDC is the only Coast Guard organization to have purchased and flown SUASs. Once they are permitted for CG operations, the governing policy will fall under the Air Operations Manual. Appendix D of that manual is where the Scan Eagle guidance presently resides for the NSC. The FAA has three different avenues for using drones. First is a Certificate of Waiver or Authorization (COA); second, a Memorandum of Understanding used by government agencies; and third, the recently released part 107 for SUAS (this process is focused on civilian uses). The FAA regulations for SUAS can be found at the following website: https://www.federalregister.gov/documents/2016/06/28/2016-15079/operation-and-certification-of-small-unmanned-aircraft-systems.

SUAS Lessons Learned:

- Deck or net landings facilitate better use of the ship and alleviate the need for deployment of a support small boat.
- The system needs further development and testing to get to the state of operations that are more consistent and reliable.

- Link establishment to ERMA can be difficult in the Arctic. It is dependent upon a number of factors including atmospheric conditions and geographic location.
- The lack of accurate weather forecasting, combined with patterns of marine and ice fog, made launching within required FAA parameters very difficult. The restrictions on launch envelopes and landing parameters are still arbitrary. These limitations are more severe than the limitations on manned aircraft.
- One of the advertised advantages for unmanned systems is that they can keep people out of harm's way by sending in an unmanned system. That is currently not possible with the SUAS as the manned helicopters from the Forward Operating Location (FOL) were able to launch in conditions that are currently out of tolerance for the SUAS systems.

6.2.3 Remotely Operated Vehicles

Remotely Operated Vehicles (ROVs) (Figure 13) were deployed in both the Great Lakes and the Arctic as possible detection and surveillance systems. In the Great Lakes (2012), the ROV, with an ultraviolet (UV) fluorometer, showed great potential both as a means of locating oil concentrations under sheet ice and as a means of positioning and manipulating oil recovery equipment beneath the ice. In 2014, the amount of deployment time was adversely impacted by the weather. All of the ROVs encountered some difficulties in handling the water current and ice conditions.

<u>ROV Lessons Learned:</u>

- An ROV is a versatile platform that can handle many different payloads.
- ROV operations can be successful in an oil-in-ice scenario. However, challenges will include possible fouling of camera lenses and tethers.
- Cold weather may adversely impact ROV operations; including the mechanical aspects of the ROV itself, as well as exposure of the operator and control station.
- Set-up and deployment of the ROV requires a clear deck space, depending upon the size of the system.
- RDC recommends that the main propulsion of the host vessel be shut down to prevent the ROV tether and control cable from becoming fouled in the vessel's propeller.
- The operator needs situational awareness with respect to the ice, which moves constantly. Tether pull can be affected by ice and slush movement around the tether; making underwater ROV control more difficult.
- Consider protective shields or 'armoring' for sensors to prevent damage from ice or handling.
- An ROV can be deployed and recovered without a crane. However, a crane would be added safety in rough conditions.
- A light may be required on the ROV when thicker ice is present or during darkness.
- The laser fluorometer, mounted on the top of the ROV and pointing upwards, was overloaded by the sunlight when at a depth of less than 10 feet.
- Use of sophisticated sensors would require a more stable platform using either software to acquire, store, and transmit the collected data, or a larger ROV.
- Moving components (e.g., camera pan/tilt/focus mechanism) should be de-iced prior to deployment.

Figure 13. ROV deployed in a water pocket near the ice sheet edge.

6.2.4 Unmanned Underwater Vehicles (UUV)

Unmanned Underwater Vehicles (UUVs) (Figure 14) were deployed in both the Great Lakes and the Arctic as possible detection and surveillance systems. Use of a UUV can assist recovery by finding potential oil locations under the ice, gathering bathymetry data, and assessing the presence of wildlife. This technique needs more research before it's recommended as a FOSC tactic.

Figure 14. UUV being deployed.

UUV Lessons Learned:

- Vehicle did demonstrate potential for autonomous under-ice operation and data collection.
- The upward-looking capability would be useful for searching for oil under the ice where an ROV could not reach, although the data may not be available in real time.
- Systems should be easily deployable and recoverable without the use of small boats, especially in broken ice.
- Additional buoyancy adjustments are required when used in fresh water.
- Most commercial systems are not designed for a spill response operation; so may be susceptible to damage from oil and ice, cannot easily be configured, and data may take extra time to download.
- Number and weight of sensors that can be mounted in an UUV depend upon its size, lift, and battery capabilities.
- The amount of battery life also controls the length of missions; the batteries needed to be in a warm environment (over about 55°F) to charge.
- Decontamination techniques have to be determined for specialized equipment.
- Further research is needed on the selection of appropriate sensors to use. In addition, research on data usage by decision-makers is needed to determine criteria such as the data format and the refresh rate.

6.2.5 Oil Spill and Ice Detection Radar

The Rutter oil spill detection and ice detection radar was tested in both the Great Lakes and the Arctic. In the Great Lakes (2013), it clearly displayed areas of open water as well as a variety of lake ice types (e.g., solid plate, rubble, and windrow features) that were not discernible on the vessel's navigation radar (Figure 15). Because there was no actual oil spill, no demonstration of the system's ability to detect and identify oil could be performed.

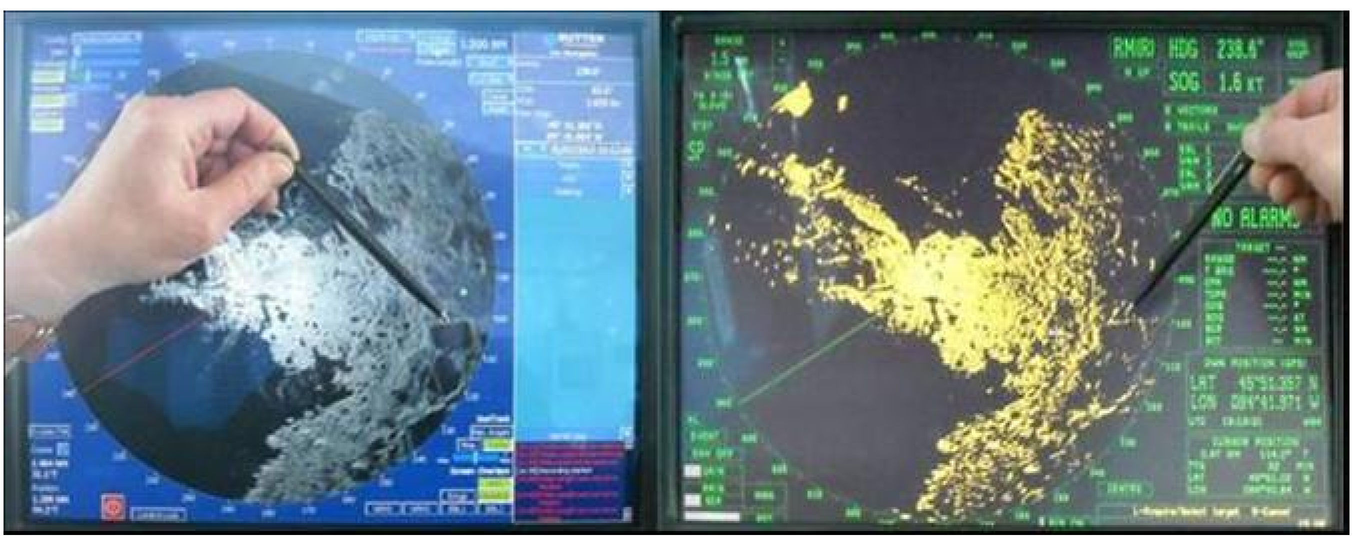


Figure 15. Comparison of ice radar (left) and standard navigation radar (right).

Hand with pencil points to same plate ice feature displayed by each system; maximum radar range displayed is 1.5 nm.

Oil and Ice Radar Lessons Learned:

- Ice radar clearly identified open water vs. ice cover up to a range of 3 nm with some additional capability up to 6 nm. The data collected indicated that the extra processing in the ice navigation radar enabled the crew to identify different types of ice and its approximate thickness as well.
- Longer range (>4 nm) capability of radar to provide clear identification of ice locations as well as displaying and identifying different ice types (i.e., plate, rubble, wind row, etc.) would be helpful.
- Rutter system provided significantly higher detail information of lake ice surface conditions than standard navigation radar for ice navigation and ice type identification.
- The radar can be used to find leads in the ice where oil could potentially be pooling.
- Additional research is needed on the use of the oil detection algorithm in ice conditions.

6.3 Containment and Recovery

Different containment and recovery systems and tactics are necessary for various environmental conditions. Performance of each piece of equipment is dependent on ice, wind, and other weather conditions. This section focuses on lessons learned associated with the ice edge and broken ice.

6.3.1 Ice Edge Conditions

For the purposes of this report, ice edge conditions are defined as places where there is a direct transition from solid or sheet ice (greater than 70% ice cover) to open water (less than 30% ice cover) with a minimal amount of broken ice in a transition zone.

6.3.1.1 Skimming – Boom Vane

Mechanical containment and recovery near the ice edge using booms and skimmers is similar to open water; except the need to account for safe operation of the equipment close to the ice. The same skimmers will be used for either open water or broken ice, depending on the conditions. A new technology to assist with boom use near the ice edge is the boom vane. This may be used to help keep the boom from colliding with the ice; and allow for oil collection when there is significant current adjacent to the ice. A boom vane uses a series of vertical plates within its structure, all of which are submerged in operation, to develop a hydrodynamic force that will pull the end of the boom into the current. By precisely establishing the length of towline with respect to the length of boom and the speed of the tow, a boom vane will position the leading end of a boom at a fixed position relative to the towing vessel or to the shore.

The boom vane was demonstrated in the Great Lakes in 2011 in ice-free waterways. A small drum skimmer was deployed in the apex of the boom to show how a skimmer would be used in conjunction with the boom and boom vane. This technique displayed a great deal of potential for oil cleanup in ice conditions. In the Arctic in 2012, it was used with the USN SUPSALV Current Buster (SK0050) system deployed from the deck of the *CGC Sycamore* (Figure 16) at current encounter rates (current plus ship speed) of up to 3 knots. The boom vane permitted control of the opening of the system during skimming operations. The boom opening can be closed by pulling the control line to stall the vanes before ice is encountered. This can done to minimize damage to the boom or when skimming has ceased. Releasing the control line permits the vane to pull open the boom.

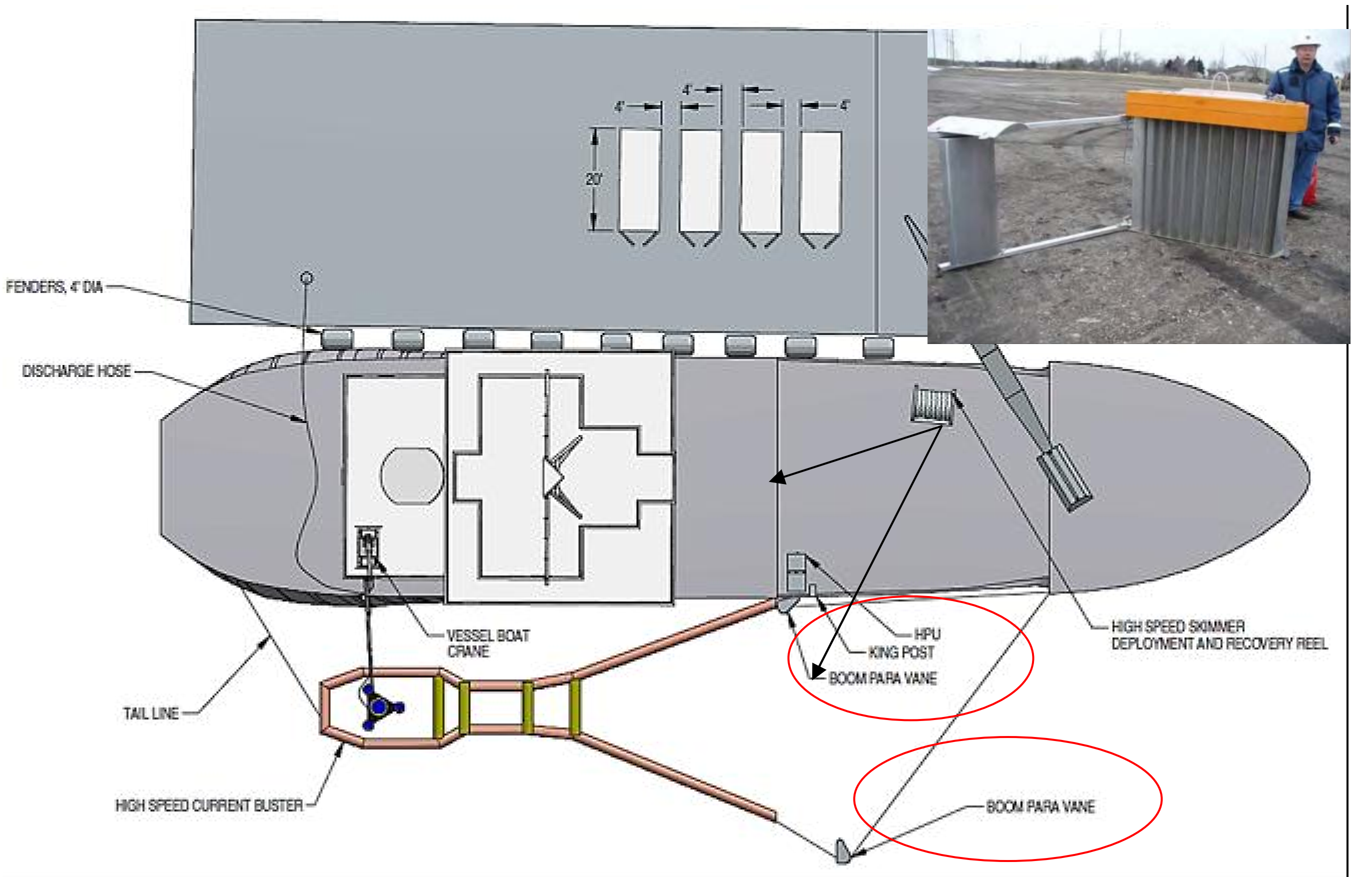


Figure 16. Overhead layout of current buster with boom vanes.

Boom Vane Lessons Learned:

- It displayed a great deal of potential in oil cleanup in ice conditions.
- The boom could be deployed using the vane to divert oil to a clean-up area. When broken ice threatens the boom; it could be moved out of the path of the ice.
- The vane can also be used in selected areas where a vessel is not available for fast boom deployment.
- The Boom Vane requires currents greater than 1 knot to operate; and a loss of precise steering control will result from slower currents.
- It can be used in current or towing conditions up to 6 knots.
- This device would probably not be very useful in medium to heavy ice conditions.

6.3.1.2 *Herding*

The tactic of using a high pressure water stream or jet from a fire monitor/water cannon can be effective for herding both oil and broken ice (Figure 17). The fire monitor can be either self-contained or integral to the vessel. This technique has been used in open (ice-free) water environments to aid in collecting oil. In an ice-covered or partially ice-covered waterway conditions, the method should be quite successful in moving the surface oil towards containment devices or skimmers from a floating or fixed location. An additional use is to aid in the herding of broken ice on the water surface, keeping the ice from interfering in oil recovery operations.

Figure 17. Herding of oil substitute.

This tactic was successfully demonstrated a number of ways in the Great Lakes using an oil substitute to simulate the surface movement of the oil. In 2013, a self-contained fire monitor was demonstrated as a means of guiding or directing an oil spill surrogate consisting of peat moss and oranges towards the bucket skimmer on the barge deck. While slow and a bit tedious, this method appeared to work; however, moving larger pieces of plate ice with the water jet was difficult. This concept appeared to function best when the water jet from the fire monitor had a wide area of surface impact. For this demonstration, the fire monitor was stern-mounted. Bow-mounting the water cannon may facilitate easier positioning and handling of the vessel. Use of this technique along an ice edge would be beneficial.

Herding Lessons Learned:

- Using the two smaller side cannons on a tug did not seem to work as well as using the single center large water cannon for herding in open water.
- The stern-mounted water cannon provided a challenge for the skipper to maneuver the tugboat because of the obstructed view from the bridge to the tugboat stern. The consensus was that a bow-mounted fire monitor configuration would improve efficiency of herding operations.
- Multiple vessels with monitors would be much better for herding oil in the open water.
- Use of a boom on the outboard side of the barge could help concentrate any oil that is herded.
- Booms may be placed parallel to the ice edge if the edge is not well defined and deep enough.
- Herding towards an ice edge facilitates oil collection. Arching spray from fire monitors appeared to be more effective for herding than a strong, directed steady stream.
- One drawback to the fire monitor pack demonstrated in 2013 was its 3450 lb weight, which limits it to larger vessels and requires a crane to maneuver the package. Fire monitors and hoses already installed on vessels should generate similar results. Any vessel using such a system would require adequate displacement to counter the thrust imposed by the water stream.

6.3.1.3 Slotting

Maneuvering a vessel bow or stern into the edge of an ice sheet creates an ice/vessel 'pocket' for herding and skimmer recovery of oil. In the Great Lakes, the CGC *Hollyhock* experimented with its ice-breaking capabilities to cut channels and pockets into the ice for oil collection. Single- and multi-pass channels were created. Figure 18 shows a channel cut into the sheet ice and a side pocket running at an acute angle to the main channel. This ice-breaking effort produced an area of open water into which the skimmer was deployed (Figure 19).

Figure 18. Channel or 'slot' created in sheet ice to facilitate oil skimmer deployment.

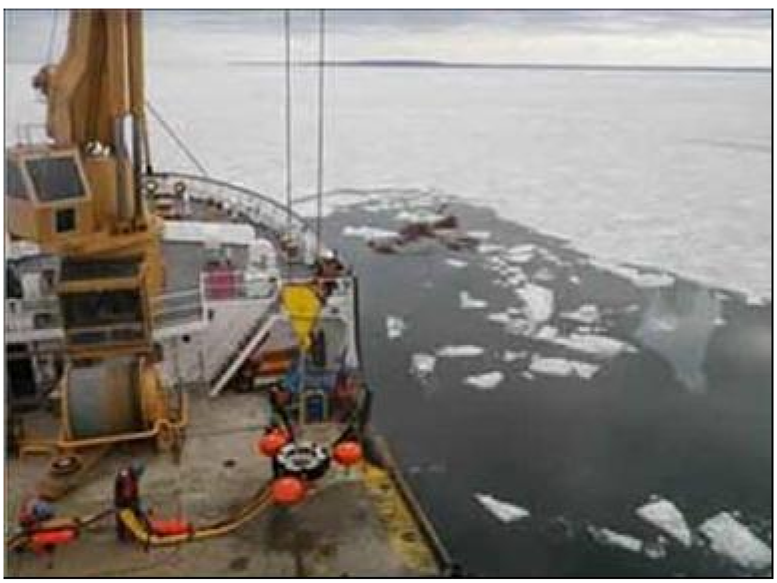


Figure 19. Helix skimmer being prepared for deployment in open water pocket.

Slotting Lessons Learned:

- An ice-capable vessel can utilize slotting tactics adapted from solid ice techniques if the ice mass is relatively stable.
- Changes in direction of wind and current must be monitored and adjustments made as needed, as the slot may open or close depending upon conditions.

6.3.2 Broken Ice Conditions

Containment and recovery systems may be useful in the broken ice environment, where the ice serves to contain and concentrate oil in leads. For the purpose of this report, broken ice conditions include ice coverage between 30% and 70%. According to Hansen and McKinney (2016), in 30% concentration, ice is not a significant impediment for most skimmers, although ice can interfere with the flow of oil periodically even in this coverage. However, in 70% concentration, ice is a significant impediment to skimming with most skimmers having dramatically lower rates and efficiencies in the denser ice compared with the 30% ice.

An icebreaker may be necessary to assist other vessels to make their way through ice and to the oil. Overall, there are a limited number of vessels capable of safely responding to spills in an ice environment within the United States. Trade-off on the use of the vessels for ice-management versus equipment deployment will have to be made, depending upon resources used during a spill (Mullen, 2014).

6.3.2.1 Skimming in Broken Ice

Equipment for oil recovery in broken ice may be difficult to deploy and operate because of ice interfering with the boom and skimming system. Oil recovery systems deployed in broken ice should be highly maneuverable, utilizing vessels that can safely operate in ice. Sometimes ice leads can act to contain and concentrate oil so that a recovery system can be used for collection. Skimming system efficiency is generally reduced in broken ice.

In addition to skimmers discussed as part of other tactics (boom vane, ice cage, and herding and ice management), the following types and models of skimmers were used in the Great Lakes (GL) and/or Arctic (AR) demonstrations. Demonstration location and years are included for future reference.

- Rope Mop:
  - Oil Mop, Inc. model OM-01 (GL 2011).
  - DESMI (GL 2012).
- Heated grooved drum (Elastec TDS136) (GL 2011, GL 2012).
- Brush:
  - Desmi DOP DualHelix (GL 2012, GL 2013, AR 2012, AR 2013).
  - Desmi Polar Bear (GL 2012, AR 2012).

Rope Mop Skimmer

Rope mop skimmers can be used under some conditions. This technology has historically proven successful in collecting oil along slots cut in solid ice, when oil has migrated under ice sheets. An older rope mop skimmer with only one rope assembly was deployed in the Great Lakes in 2011 in water without ice. Some concern was noted about how messy the collection could be; given the design of the rope-squeezing mechanism and the integrated collection tray under the motor. A different rope mop skimmer with multiple mop ropes was briefly deployed in the Great Lakes in 2012 (Figure 20). While it appeared to operate successfully, it should be deployed in more open water for maximum efficiency. High winds made it difficult to deploy the rope mop and have it fully engage with the water.

Figure 20. Rope mop skimmer deployed in open water pocket.

Rope Mop Lessons Learned:

- Deploying the rope mop in high winds is difficult and possibly results in suboptimal performance due to ‘sail effect’ deflecting the exposed portion of the mop belt.
- The rope mops should have a breakaway device or weak-link point to prevent the system from being damaged or pulled into the water if a rope mop gets hung up on a large piece of ice.
- The rope mops can get tangled; and untangling them safely and quickly is important.

Heated Grooved Drum Skimmer

A grooved drum skimmer with a steam/hot water hook-up was briefly deployed in water without ice in the Great Lakes in 2011. Without ice in the water, it was not possible to evaluate its use; although the use of steam appeared to be a good idea. It was briefly deployed again in 2012 in and among broken rubble ice (Figure 21). This device worked well in Ohmsett’s ice month (SL Ross and MAR, 2013), but had problems during these demonstrations with the steam line freezing over night. It also did not have enough weight to displace the surrounding ice rubble to have the drum surface sufficiently contact the water surface. Additionally, the device did not appear rugged enough to stand up to a continual pounding contact with ice.

This device may be useful under certain conditions, such as in open water or quiet pools. It was also not as useful within the ice cage design when tested in ice at Ohmsett (Hansen and McKinney 2016).

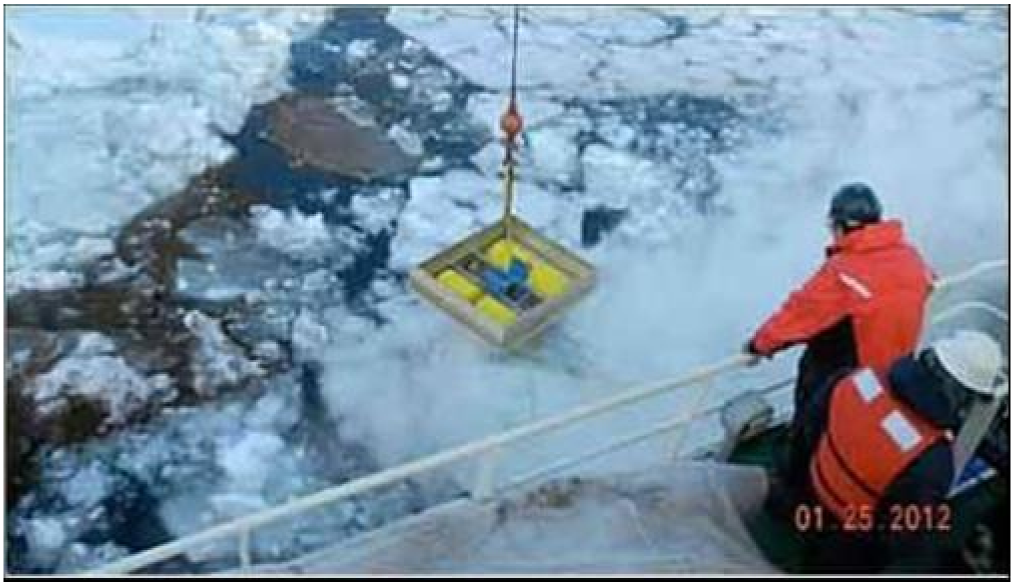


Figure 21. Drum skimmer deployed in rubble ice.

<u>Drum Skimmer Lessons Learned:</u>

- Drum skimmer may be too light to properly settle into a field of rubble ice and efficiently function.
- The drum skimmer may not be sufficiently armored for use in heavy rubble ice conditions.
- The pumps need to be fully primed to remove air bubbles from the water and steam lines.
- When using the ice cage, the drum skimmer does not create enough current to draw in the oil from the perimeter of the cage. A smaller, better defined cage might help.

<u>DESMI Helix Brush Skimmer</u>

The DESMI Helix skimmer, which is currently part of the CG's Spilled Oil Recovery System (SORS) inventory, was successfully deployed in the Great Lakes and the Arctic in 2012 and 2013, under a variety of conditions including rubble and sheet ice. The Arctic demonstration in 2013 included an improved hose recovery system that reduced the size and weight; did not permit the hose to drop onto the ice; and prevented the hose from collapsing and freezing up (Figure 22).

Figure 22. CGC Healy deploying Helix skimmer.

Helix Skimmer Lessons Learned:

- Manipulation and positioning of this skimmer worked best when slung from the vessel's bow-mounted 750-pound crane block.
- The Helix fittings, hoses, and moving parts should be ruggedized or armored to protect against impacting rubble ice. Specifically consider armored hoses and hydraulic line sections where direct contact with rubble ice may cause puncture or severing.
- In addition, a sling or festoon configuration might help suspend and support the hoses to prevent contact and damage from floating ice.
- An ice cage would help to keep ice away from the skimmer.

DESMI Polar Bear Brush Skimmer

The DESMI Polar Bear skimmer was briefly deployed in the Great Lakes in 2012. It appears to be rugged and is designed to withstand the broken ice conditions encountered. A safety concern with this skimmer was that personnel needed to climb on top of its frame to complete connections, which could be hazardous in icy conditions.

In the Arctic in 2012, the Polar Bear skimmer was deployed over the side of the *CGC Sycamore* among some variable sized drifting ice. This provided experience for the buoy tender crew in executing this type of deployment. It demonstrated that Coast Guard personnel could get equipment into the water, if a spill occurred; although the CG would potentially need help from the Department of Defense or other organizations with additional barges or vessels.

Lamor Oil Recovery Bucket

The Lamor Oil Recovery Bucket (LRB) is a brush-wheel skimmer operated from an excavator or from an on-board crane (Figure 23). For this demonstration, it was operated from fixed mounts on the deck of the barge. From its hard-mount tie-down position at the bow of the barge, the skimmer demonstrated operation by recovering peat moss used as an oil simulant from a pool of open water surrounded by broken ice.

Figure 23. Lamor oil recovery bucket.

6.3.2.2 Herding and Ice Management

As discussed earlier, herding using fire monitors may aid in the movement of broken ice on the water surface, keeping the ice from interfering in oil recovery operations.

In the Great Lakes in 2013, the LRB demonstrated the ability to use the articulated arm to move small plates of ice out of the way to create an open water pool for collection of the peat moss oil stimulant in conjunction with herding techniques (Figure 24). The tactic selected for this system would depend upon the location of the skimmer on the barge.

Figure 24. LRB demonstrating ability to push ice out of way.

6.3.2.3 Ice Cage

Skimmer performance in broken ice conditions may be improved by the addition of an ice cage to deflect the ice away from the skimmer while letting the oil through. The ice cage has demonstrated that it enhances the oil recovery rate, when used in broken ice up to about 65% ice coverage, when used with the CG's DOP Dual Helix skimmer (Hansen and McKinney 2016). Figure 25 shows the ice cage with the Helix skimmer as deployed from a USCG buoy tender.

Figure 25. Ice Cage being deployed with DOP Dual Helix skimmer.

<u>Ice Cage Lessons Learned:</u>

- The vessel chosen should have the appropriate ice classification and manning to perform this operation. The vessel should also be able to handle temporary storage of collected oil.
- Skimmer deployment may be difficult. Hydraulic hoses and recovery hoses may be susceptible to damage, if dragged over or through ice.
- Pieces of ice can block the oil from reaching the cage inlets.
- Adequate water supply tanks, hoses, and heating systems may be needed for certain skimmer configurations.
- Long lengths of hose running over the deck may need to be heated to prevent freezing.
- The use of an oil recovery bucket/boom assembly securely mounted to the deck of a towed barge, works well in these circumstances in terms of maneuverability while providing deck space and storage.
- Comparatively, skimmers that use a tether system from the vessel; and that are deployed over the side may present challenges in terms of maneuverability.

6.4 In-situ Burning

In-situ Burning (ISB) is a technique to remove oil from the surface of the water before it reaches the shoreline in offshore operations. Vessels must capture the oil and tow it to a safe location while moving at less than 1 kt to avoid losing the oil from the boom. It may also be used in sea ice under certain conditions.

In circumstances where the ice is concentrating the oil and preventing it from spreading (usually in ice concentrations greater than 70%), burning may be able to remove a high percentage of the slick. Solid ice may also slow the evaporative loss process. However, broken ice conditions may complicate vessel operations and fire boom deployment if booming is necessary to concentrate the oil.

Demonstrations were conducted in the Great Lakes to see if booms designed for ISB (generally called fire booms) could be successfully deployed in broken ice conditions. While no actual burns were conducted, previous tests have shown that oil will burn in the presence of broken ice.

Several approaches were made into a broken ice field using a fire boom in various configurations to determine which technique would be the most effective. The traditional 'U' shape did succeed in collecting some broken ice. However, the additional maneuvering by the two tugs to maintain the configuration, resulted in much of the broken ice being lost; and any potential oil collected would have been minimal. Additionally, the prop wash from the vessels could have pushed any oil at the surface farther under the ice, making recovery increasingly difficult.

Another method explored used a 'J' configuration; where one vessel is slightly ahead of the other (Figure 26). During several attempts to use this method, RDC observed that of the initial "bite" of oil and broken ice the boom removed from the broken ice pack; between 70 percent and 85 percent of the initial volume stayed in the boom once the ice pack was cleared. RDC also observed the amount of broken ice and size of the ice pieces play a role in the success of the boom. During the demonstration, RDC observed that in the broken ice field of 60-75 percent ice coverage, ice pieces encountered were 4 ft in size or less. Less ice concentration with smaller pieces would improve the collection and effectiveness for ISB.

Figure 26. PyroBoom deployed and towed by two tugboats to simulate collection of oil in rubble ice.

<u>ISB Lessons Learned:</u>

- Fire-resistant boom appeared to hold up well while gathering and towing ice.
- Close coordination between both vessels is important to successful deployment and entry of boom into the ice.
- Two vessels of sufficient horsepower with ice-breaking capability are required for effective deployment and manipulation of the boom.
- Boom can be deployed by allowing it to slide off the vessel deck, or it can be deployed in sections, if the vessel has an onboard crane.

- Forty to fifty percent broken ice coverage with floes no larger than 5 feet (1.5 meters) appears to be the limit for carving out a sufficient oil/ice mixture for in-situ burn. Thicker concentrations of broken ice and larger floes caused the fire-resistant boom to override the ice.
- Use of a ‘J’ formation, rather than the straight ‘U’, with the boom, appears to make it easier for the vessels to control the amount of ice captured.
- To maintain ice in the ‘pocket’ of the boom, towing speed had to be kept to a minimum. The ability of the tugboat to operate at a slow speed makes it ideal for the process, as opposed to a vessel that must continually clutch its prop in and out to limit headway.
- Any type of boom used with this tactic must be extremely robust and should be deployed and retrieved in open water.

6.5 Decontamination

The Great Lakes and Arctic demonstrations showed that most vessels would have difficulty in handling crew decontamination during an actual spill. A structure would be needed on deck as a warm zone to disrobe from the Personal Protective Equipment (PPE) to ensure oil is not tracked into the other spaces.

From the August 2016 demonstration, it was noted that DECON line workers play a major role in performing efficient decontamination of responders. The original DECON procedure was modified to reflect this issue (see Appendix A).

7 FUTURE RESEARCH WORK

The equipment deployed in the demonstrations exhibited varying utility for spill clean-up under various ice conditions, with performance dependent on ice, wind, and weather conditions. Some of the tactics attempted in these demonstrations need to be refined and adapted to existing equipment and vessels. Consideration should be given to the potential need for getting specialized equipment into place when reviewing contingency plans. Issues that still need research:

- Cold weather Personnel Protection Equipment (PPE) adapted for easy decontamination.
- Develop a concept of operations for UAS, UUV, and ROV efforts.

Additional exercises under extreme cold and harsh weather (e.g. higher waves and wind) conditions will further improve and build upon lessons learned; operational and tactical protocols; and equipment deployment, application, and design. These exercises also benefit response personnel in obtaining experience using the equipment and tactics under these extreme conditions.

A number of the systems demonstrated in the Great Lakes and the Arctic have the potential for use during an oil spill response; but require more research and/or additional demonstrations. Specifically, the detection and surveillance technologies requiring more research include:

- UUV – Need further research on the selection of appropriate sensors to use. In addition, need to research how decision-makers will use data, to determine the proper data format, the refresh rate, and other specifications.
- Ice and oil radar – Need additional research to identify any specific environmental conditions where the oil detection algorithm in ice conditions can be effective.

- ROV – Need to demonstrate ROV operation with manufacturer-specified 200 foot to 5000 foot tethers to evaluate full utility of the system.

7.1 Skimmer Concerns

An important consideration for future research and development is preventing a long length of hose in extreme cold from freezing during skimmer operations. Need to develop techniques that can clear a hose, if pumping is halted, the flow of liquid is intermittent, or a large amount of water gets into the system. Use of water-annulus systems to pump highly viscous oil requires a significant amount of water. This can become trapped in the hose or the skimmer; and would have to be cleared to keep from freezing and disabling the flow.

7.2 Under Ice Retrieval

Another technique that needs research is collection of oil under ice. Most current techniques assume that equipment and personnel can be deployed onto the ice; but additional options are needed to deploy from vessels, if the ice is not strong enough to hold personnel. Techniques that can permit an ROV or other mechanism to reach under and recover oil that is under the ice need to be researched.

8 FOSC TACTICS RECOMMENDATIONS

There are multiple commercial, state, and international manuals, which describe tactics that can be used in cold weather. These recommendations vary depending upon weather conditions, ice conditions, the oil spill size, weathering, and movement. They are generally written for solid ice where personnel and equipment can be placed safely on the ice; and broken ice which cannot support personnel and equipment. There is also a category of open water; but operating when ice is serving as a barrier and the oil is sitting against it. The focus of this effort was to identify and recommend spill response tactics that can be safely used in broken ice and near the ice edge by CG and supporting local Oil Spill Response Organizations (OSROs) vessels.

The recommended tactics detailed in Appendix B are intended as input to supplement the Spill Tactics for Alaska Responders (STAR) manual for the Arctic and equivalent guidance for the Great Lakes. The STAR manual provides standardized oil spill response tactics specific to the State of Alaska. The manual is a standard tactical reference for oil spill planning and response activities in Alaska. It is available for use by the spill response community, including federal, state, local, industry, and spill response organizations throughout Alaska (STAR, 2014).

9 REFERENCES

ACS (2015). *Alaska Clean Seas Technical Manual, Volume 1, Tactics Descriptions*. Revision 12, January 2015. http://www.alaskacleanseas.org/tech-manual/.

Balsley, A., Elam, D.E., and Hansen, K. (2016). *Oil-in-Ice IV Demonstration Quick Look Report*, USCG Research and Development Center, October 2016.

Cooper, D. and Dugery, D.J. (2011). "Final Great Lakes Exercise 1 Report," Report CG-D-09-11, USCG Acquisition Directorate, Research and Development Center, July 2011.

CRRC (2010). U.S. Coast Guard Arctic Response Workshop: April 23, 2010, report by CRRC submitted to the United States Coast Guard, http://www.crrc.unh.edu/workshops/arctic_response/index.html.

Elastec (2014). Contract HSCG32-14-C-R00010, Temporary Oil Containment System for Coast Guard Buoy Tender (WLB), Periodic Deliverable 4 (SOW reference 2.5.1), Progress Report, December 2014.

GPC (2012). "Final Report Operation Arctic Shield Barrow/Prudhoe Bay, Alaska, July 25-August 8, 2012," Prepared for Naval Sea Systems Command (NAVSEA), October 9, 2012.

Hansen, K.A. (2012). "Quick Look Trip Report Oil Spill Response Equipment Deployment on CCG Sycamore Arctic Shield 2012," July 31-August 2, 2012.

Hansen, K.A. (2013). "Results for Oil-in-Ice response Demonstration in the Great Lakes," Proceedings of the Thirty-sixth technical Seminar on Environmental Contamination and Response" June 4-6, 2013, Halifax, Nova Scotia.

Hansen, K.A. (2014). "Responding to Oil Spills in Ice," *2014 International Oil Spill Conference*, May 2014.

Hansen, K.A. and Lewandowski, M. (2011), "Using Exercises to Advance Approaches to Response for Oil in Ice Environments," Arctic Technology Conference 2011, Houston, TX, February 7-9, 2011.

Hansen, K.A. and McKinney, K. (2016). "Evaluation of an Ice Management System," Arctic and Marine Oil spill Program (AMOP). 2016, in preparation.

Hansen, K.A., Tripp, S.T., and Hansen, R.L. (2014). "Evaluating Equipment for Responding to Oil Spills in Ice," Arctic and Marine Oil Spill Program (AMOP), June 2014.

Marine Pollution Control (2015). Drawings, Calculations, User Manual: Static Ice Management System for Recovery of Oil in Ice, SOW Reference: Paragraph 2.2, Task 2 - Deliverable No. 2 – REVISION 2 (FINAL), Date: July 12, 2015.

Mullin, J. V. (2014). "Advancing Oil Spill Response in Arctic Conditions: The Arctic Oil Spill Response Technology - Joint Industry Programme," *2014 International Oil Spill Conference*, May 2014.

Potter, S., Buist, I., Trudel, K., Dickins, D., and Owens, E. (2012). "Spill Response in the Arctic Offshore," prepared for the American Petroleum Institute and the Joint Industry Programme on Oil Spill Recovery in Ice, February 2, 2012.

RDC (2012). Quick-Look Assessment Report: Lessons Learned and Observations for Oil Recovery from Ice-Infested Waters, January 22 – 27 2012, St. Ignace, Michigan, February, 2012.

RDC (2015). Quick-Look Assessment Report, Task Order 51: Vessel of Opportunity (VOO) Protection and Personnel Decontamination (DECON) for Cold Weather, January, 2015

SL Ross Environmental Research Limited and MAR, Inc (2013). Skimmer Tests in Drift Ice: Ice Month 2013 at Ohmsett, prepared for: Bureau of Safety and Environmental Enforcement, August 2013.

Spill Tactics for Alaska Responders (STAR) (2006). Alaska Division of Spill Prevention and Response, http://www.dec.state.ak.us/spar/perp/star/index.htm.

Softye, Richard, George Comfort, 2010. "Oil-in-Ice Workshop for the Great Lakes", BMT Designers and Planners for USCG R&D Center, October 2010.

Yankielun, N.E., Dugery, D.J., Sundberg, R.D., and Wilson, K. (2012). "Great Lakes Demonstration 2 Final Report," Report CG-D-8-12, Department of Homeland Security, Coast Guard Research and Development Center, June 2012.

Yankielun, N.E., Barone, R., Cables, E., Locklear, C., and Wilson, K. (2013). "Great Lakes Oil-In-Ice Demonstration 3 Final Report," Report CG-D-08-13, Department of Homeland Security, Coast Guard Research and Development Center, October 2013.

APPENDIX A. COLD WEATHER DECONTAMINATION PROCEDURE

A.1 Cold Weather Personal Protection and Decontamination Equipment

Table A-1 shows the dry DECON equipment that should be assembled for multiple responders transitioning out of a HOT zone and into a WARM zone. Table A-2 shows the typical cold weather PPE that a responder is expected to wear; in addition to a life jacket and inner layers necessary for working with oil spills in a cold weather environment on a ship. A station should be placed near a hatch that the responder is expected to enter in order to leave the HOT zone.

Table A-1. Dry DECON equipment for one location.

Quantity	Item
1	Grayling 77" D-CON shelter (36" x 36" x 77") or 81" D-CON shelter (48" x 48" x 81") (Figure A-1) (Note: Other equivalent systems exist and should be chosen based on vessel arrangements and environmental conditions.)
1	77" or 81" Grayling D-CON pole set (8 poles)
1	Collapsible canvas stool (Figure 1)
2	Collapsible waste receptacles
3	Extreme duty bags, 73” x 36”
3	PCXM 55" x 45" x 73" plastic bags
2	Multiple large clear plastic zip-lock bags (Figures A-2-and A-3)
1	Misc. parachute cord
3	Misc. snap hooks
1	5/16” 15ft black polyline w/ snap hooks
5	Hook & loop fabric cable ties
2	Green bungee cords
8	Terry cloth rags
1	Pair scissors
1	Talon rescue knife
1	Triangular red safety LED lights
1	Hand-held mirror
6	Chem lights
6	Pairs disposable green vinyl gloves

Table A-2. Cold weather PPE for one responder.

Quantity	Item
1	Size XL/XXL Kleenguard coveralls w/ hood & boot
1	Hard hat
1	Hard-hat windsock, ear/face
1	Clear plastic safety glasses
1	3M disposable ear plugs
1	Disposable respirator
1	Pair cotton utility gloves
1	Pair PVC coated orange rubber (lined) work gloves
1	Pair Safety Boots
1	Pair non-skid boot/shoe covers, gray

Figure A-1. Prototype station.

Figure A-2. Equipment secured.

Figure A-3. Hanging equipment.

A.2 SETUP PROCEDURES

In addition to all the equipment listed in Tables B-1 and B-2, responders will be aided by PPE managers and other responders as they proceed with the DECON procedure. At least one manager is needed inside the cold zone to monitor and inspect individuals who pass through.

Table A-3. Setup procedures.

Step	Setup Procedures
Step 1	Carefully consider safety, available deck space, visibility, and crew movement during cleanup operations and decide upon locations of the HOT zone, WARM zone, COLD zone, and DECON stations.
Mark Contamination Control Zone	
Step 2	1. Using the contamination control zone marking tape, mark off the HOT, WARM, and COLD zone boundaries. 2. Ensure that DECON shelter entry is clearly identified with lighting and/or taped pathway. 3. Determine the best foot traffic flow to prevent cross contamination.
Establish Station No. 1 - Gear Drop	
Step 3	Designate a location for responders to place contaminated gear, such as hand-held tools or PPE, as they begin the dry DECON process. 1. Place sturdy, 30-gallon hard plastic receptacles with sealable lids near shelter entry.
Erect the DECON shelter at Station No. 2 - Dry DECON	
Step 4	1. Erect the DECON shelter at Station No. 2 - Dry DECON, on a boundary line between the HOT and WARM zones. a. Sweep and clear the area where the units will be setup, then cut and lay a protective layer of plastic sheeting on the deck. b. Unfold the shelter and stand it vertically by lifting the top panel. c. Position and tension the poles into the corners in the recessed slots on the base and top panels. d. Ensure that shelter entry is completely open but shelter exit has a flap that only the DECON line worker can open for the responders' admittance to the COLD zone. 2. Place disposable gloves, sorbent pads, and terry cloth rags in open plastic bags and attach to the outside walls of the shelter with Velcro strips within reach of DECON line workers. 3. Tie down shelter and all equipment.
Set up Station No. 3 - Redress and Monitoring	
Step 5	Establish Station No. 3 at the exit of the DECON shelter: 1. Set up portable lights. 2. Place a raised platform between shelter and the COLD zone to minimize oil tracking.
Set up Station No. 4 - COLD Zone	
Step 6	Establish Station No. 4 at the entrance to the clean area: 1. Set up portable lights. 2. Place sturdy, 30-gallon hard plastic receptacles with sealable lids near shelter exit.

A.3 DECONTAMINATION PROCEDURES

Table A-4. Decontamination procedures.

Station	Procedure
Station No. 1 - Gear Drop	1. Place handheld contaminated tools or equipment in the designated gear drop receptacle or area for re-use (e.g. unneeded load bearing equipment, wrenches, screwdrivers).
Station No. 2 - Dry DECON	1. Before stepping inside the DECON shelter, request a DECON line worker for assistance. The DECON line worker will perform the following functions: a. Remove gross contamination on the surface of outer clothing and body worn PPE with Simple Green cleaner/equivalent or sorbent pads. Dispose of sorbent pads and any expended items in waste receptacle. b. Remove responder's hardhat and outer gloves; place them in designated receptacle. (Figure A-4) c. Using thin gloves for maximum finger agility, roll off the coverall. Start at the head of the responder and roll down to the shoulders. Direct responder to pull one arm out of the coverall sleeve and raise his/her arm up high. Roll the coverall sleeve down to the waist level. Repeat for the other arm. (Figure A-5) d. With responder's both arms raised and the coverall now rolled down to slightly below the waist level, direct the responder to sit on the stool inside the shelter. e. Direct responder to raise his/her leg and remove the first boot cover. Proceed to roll the coverall off the leg. Direct responder to place clean leg inside the shelter and away from the HOT zone. Repeat for the other leg and dispose of the coverall into waste receptacle.
Station No. 3 - Redress/Monitoring	1. If necessary, put on clean disposable gloves and use sorbent pads/terry cloth rags to carry out spot cleaning on own body. DECON line worker stationed in the HOT zone will inspect responder and point out remaining contamination spots, if any.
Station No. 4 - COLD zone	1. Before taking the shelter exit: a. Request final inspection from a DECON line worker stationed in the COLD zone. b. Remove remaining contamination using terry cloth rags/sorbent pads, if any. Dispose of rags/sorbent pads into waste receptacle outside of shelter exit. c. Upon approval from DECON line worker, dispose of temporary gloves and footwear (if necessary) into waste receptacle outside of shelter exit. d. Step through the flap at the shelter exit and enter the COLD zone.
System Disposal	Place all contaminated materials and system components in the hard plastic receptacles with sealable lids and move them to a safe location for further waste processing upon arrival ashore.

Note: Special thanks to National Strike Force and Crew of CGC Juniper (WLB 201)

Figure A-4. Initial clothing removal.

Figure A-5. Using roll technique (2 views).

APPENDIX B. RECOMMENDED TACTICS UPDATES

Each tactic sheet includes a summary of the tactic objectives and strategies that may be utilized, a picture or pictographic tactic description of a typical deployment configuration; and deployment considerations and limitations. The tactic sheet also contains resource information that summarizes the types and quantities of personnel and equipment recommended to implement the tactic as described. The equipment and personnel tables can be used to determine typical equipment and personnel needs; although actual equipment and personnel needs will be site and situation specific. The tables include the following information:

- “Equipment” is the list of equipment needed to execute the tactic.
- “Function” describes how the equipment will be used.
- “Pieces” is the amount or number of each piece/item.
- “No. Staff/ Shift” indicated the number of personnel needed per shift.
- “Set-up Time” is the time to make the equipment operational for its intended use at the spill site.

B.1 DETECTION AND SURVEILLANCE

B.1.1 Aerostat

Use of an Aerostat or similar tethered balloon can enhance oil recovery by providing almost continuous surveillance, especially visual, capability. It adds an aerial observation advantage to an on-scene response vessel. It is useful to have correlated aerial and marine observations taken at the same time and place.

Aerostat systems are not limited by duration but sometimes by weather. They also do not require full Federal Aviation Administration (FAA) approval for air space. In general, they must be kept at altitudes lower than 500 feet and not within 5 miles of airports. CFR PART 101 - Moored Balloons, Kites, Unmanned Rockets and Unmanned Free Balloons covers the requirements.

Aerostat on Flight Deck

Deployment Considerations and Limitations

- The method of data format and supporting documentation is critical.
- Video streams can be passed to line-of-sight receivers.
- Power and control are usually located on board a vessel.
- Type and number of sensors mounted in an Aerostat depend upon it's lift capability, weather, and surveillance needs. Visual and infrared cameras are usually mounted; but radars and communication systems may be possible.
- Use in cold conditions can require additional helium; due to the increased density at the lower temperatures.
- Several sizes of Aerostat are well suited for oil spill surveillance. All have limitations for system payload and vessels that can utilize them. Smaller systems deployed directly on the skimming vessel may identify oil locations and enhance recovery.
- Cost effective lightweight packages for visual cameras have difficulty seeing a person more than one mile away. Other systems, especially larger ones, can coordinate the movement of several ships when deployed from a command vessel. . Higher resolution systems are needed if the multiple ships are spread out.
- Weights of deployment packages range from 800-1800 pounds, not including helium tanks.
- Systems can generally work in winds up to 50 knots; but control of the system is better at wind speeds less than 25 knots.
- Situational awareness of where the balloon and tether are located is essential due to wind shifts, crane operations, and other possible interferences on board.

Equipment and Personnel

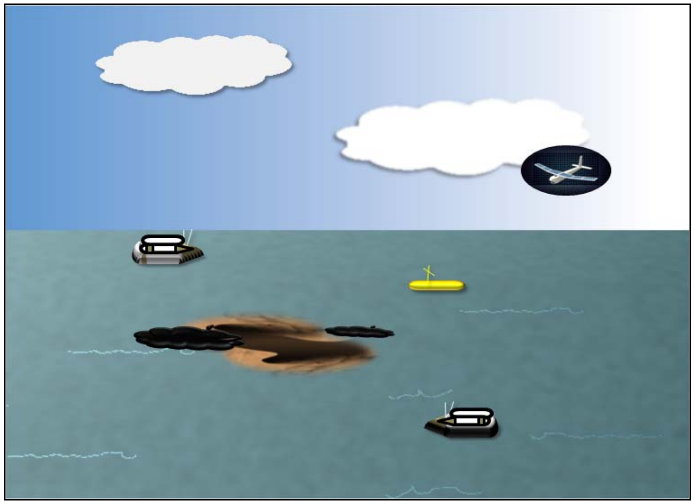
EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Command Vessel	Surveillance Platform	1	1-2	6 hours
Aerostat	Surveillance	1	3-4	2-3hours

B.1.2 Small Unmanned Aerial Systems

Use of a Small Unmanned Aerial Systems (SUAS) can enhance oil recovery by providing real-time information on oil location and concentration to the responders on-scene or back to the incident commander. Sensors mounted in an SUAS depend upon lift capability and weather. The FAA regulations for SUAS are found at the following website:

https://www.federalregister.gov/documents/2016/06/28/2016-15079/operation-and-certification-of-small-unmanned-aircraft-systems

SUAS Tactic



SUAS Ready for Launch

<u>Deployment Considerations and Limitations</u>

- Several sizes of SUASs are capable of being used. All have limitations for system payload and weather (wind and icing) in a cold environment.
- Sensors may include cameras, infrared devices, and radar; as well as communications systems, such as radio links.
- Deployment of SUASs is weather dependent. Potential icing conditions, low cloud cover, or high winds that exceed operational thresholds can ground these systems.
- The method of data format and supporting documentation is critical.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Operational Vessel	Working platform	1	2-4	1-2 hours
SUAS	Surveillance	1-2	3	1-2 hours#

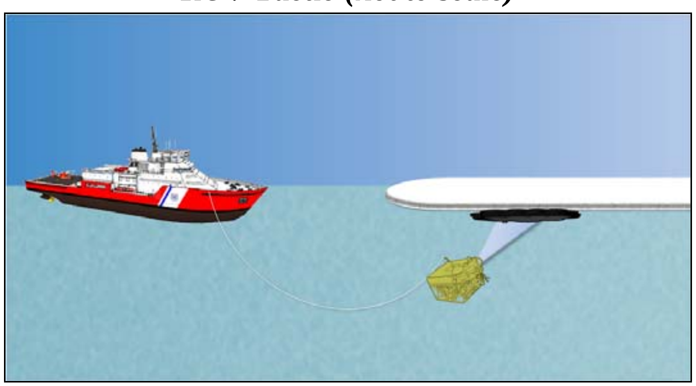
depends upon SUAS and conditions

B.1.3 Remotely Operated Vehicle

This technique deploys a Remotely Operated Vehicle (ROV) near the ice edge to search for oil under the ice. It can also be used down a hole through the ice, if the ice is solid enough for personnel to be deployed on the ice. Potential sensors used include cameras, sonar, or fluorometers. Most are configured in a looking-up position.

ROV in Process of Being Deployed

ROV Tactic (not to scale)



Deployment Considerations and Limitations

- Use of an ROV means that open water must be available during the full timeframe of the deployment to ensure successful recovery.
- Care needs to be taken to ensure that cables do not get tangled into propellers or bow thrusters. Cables may also be susceptible to damage from the ice. . The cable should not be dragged on the bottom in shallow water.
- Bright sunlight can help or hinder upward-looking sensors, depending on the conditions. For thin ice, the ROV may need to be deployed at a deeper depth to reduce glare. Lights may be needed on overcast days and at night.
- The weight of the system may necessitate the use of a crane; so the vessel selected should have this capability.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Vessel	Working platform	1	2	#
ROV	Search	1	2	<30 minutes

depends upon location

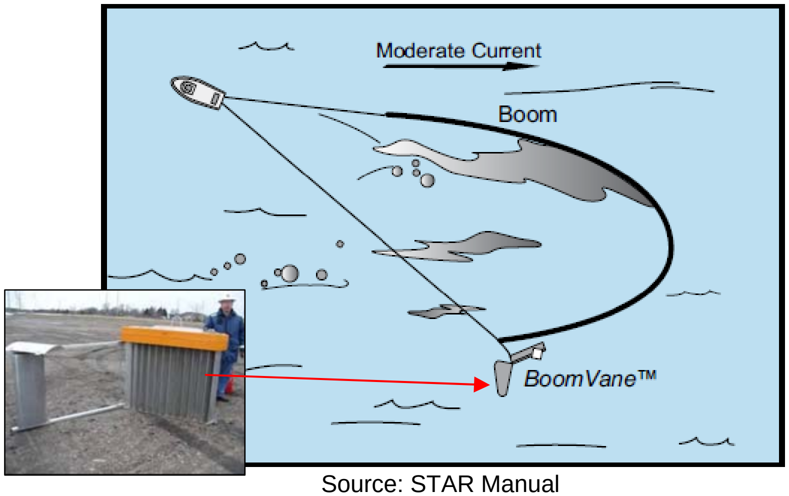
B.2 CONTAINMENT AND RECOVERY

B.2.1 Ice Edge Conditions

Ice Edge – Skimming

Mechanical containment and recovery near the ice edge requires safe and efficient operation of the equipment close to the ice. This tactic may involve skimmers deployed from a cutter or large vessel using a single davit or crane, deck-mounted excavator oil bucket/ boom assemblies, or similar configuration. The skimmers used will be the same as those for either open water or broken ice, depending on the conditions. Containment booms are deployed, when feasible, to intercept, control, and concentrate the oil. Most tactics usually focus on the use of two towing vessels; which permits maneuvering around ice floes. If the oil is in relatively open water but close to the ice edge, a boom vane may be used to control the end of the boom and help keep the boom from connecting with the ice without the use of a second vessel.

Tactic Diagram



Source: STAR Manual

Deployment Considerations and Limitations

- The boom vane technology may suffer limitations if there is broken ice near the ice edge and/or ice coverage increases past a limiting point of boom vulnerability.
- Collisions with smaller pieces of ice in fast-moving waters may not be an immediate issue; but over time, they may accumulate in the containment system. This accumulation of ice within the boomed area would impart additional stresses on the system and may accelerate a failure mode.
- Operators should take special care in broken ice conditions as impacts by chunks of ice may damage, block, or interfere with the vanes; affecting control of the device and requiring suspension of operations until ice can be cleared.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Operational Vessel	Working platform	1-2	2-4	1-2 hours#
Tugboat	Working platform	1	2-3	<1 hour
Boom and boom vane	Containment	1-2	2-4	< 1 hour
Skimmer	Recovery	1-2	2-4	< 1 hour

depends upon equipment and conditions

Ice Edge – Herding

Herding moves the oil towards or along the ice edge to a collection point and/or help concentrate the oil near a skimmer. A fire monitor or water cannon moves oil into a preferred area.

Deployment Considerations and Limitations

- Care should be taken not to send water directly into the ice or with too much force that can push the oil under the ice. Direct the stream at least 10-20 feet from the oil so that the induced surface current and not the direct water stream itself moves the oil.
- Care to prevent freeze-up of the monitor/water cannon is needed when the system is off.

Herding Oil into Ice Pockets

- Equipment placed over the side can be exposed to ice that can damage or disable the equipment.
- If the ice is not clearly defined and the weather is reasonable, deploy boom alongside the ice edge. Deploy traditional boom from the collection vessel or barge to help concentrate the oil.
- One drawback to a self-contained fire monitor pack is its weight, which limits it to larger vessels and requires a crane to maneuver the package.
- Use of fire monitors and hoses already installed on vessels should generate similar results.
- Bow mounting the water cannon may make vessel handling and positioning easier.
- Moving larger pieces of rubble ice with the water jet may be difficult.
- Multiple vessels with monitors would be much better than one vessel for herding oil in the open water.
- Use of a boom on the outboard side of the vessel could help concentrate any oil.

Equipment and Personnel

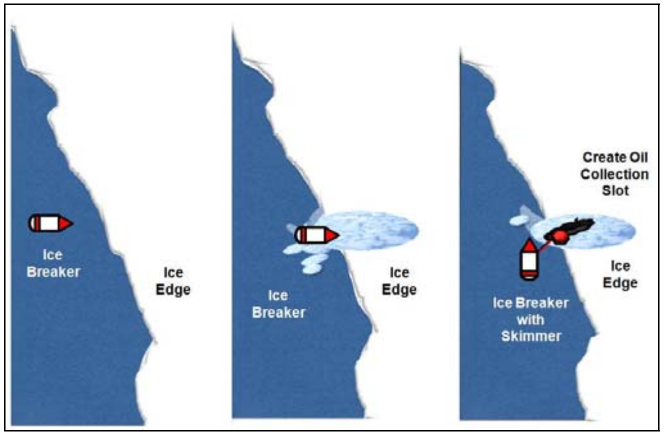
EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Vessel	Working platform	1	2	#
Fire Monitor	Herd oil	1	2	<1 hour

depends upon location

Ice Edge – Slotting

There may be many instances when the ice can be managed using an icebreaker to gain access to the oil or to keep ice away from the oil. Where the oil is moving towards a solid ice sheet, it may be possible to trap the oil by using the icebreaker to create a slot in the ice to isolate the oil from wind and current. Once the slot is produced, a skimmer can be deployed to recover the oil from the slot.

Tactic Diagram – Vessel Being Used to Create Collection Slot Allowing Oil to Concentrate



Deployment Considerations and Limitations

- In broken ice conditions, ice that is moved aside may shift back into place depending upon wind and wave conditions.
- The window of operations may be limited. Shifting ice can easily entrain the oil under the ice; so caution should be taken not to disturb the ice.
- Potential tactics include using vessels to move or deflect ice and creating collection slots for oil to surface. Consider how the ice and currents are moving so that any oil is deflected into the slot.
- The vessel used must have the correct ice classification and operator expertise before using this technique. Multiple vessels could be involved in this tactic, some of which may not have skimming capability.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Ice-capable Vessel	Working platform	1	2	#
Skimmer	Oil recovery	1	2	<10 minutes

depends upon location

B.2.2 Broken Ice Conditions

Broken Ice – Skimming

Mechanical recovery in broken ice is limited by the ability of the skimmer to encounter and remove spilled oil in the presence of broken ice and to function effectively under extremely low temperatures.

This tactic may involve skimmers deployed from a cutter or large vessel using a single boom or crane, excavator oil bucket/boom assemblies, or similar configuration. The vessel must try to get as close to an area of collected oil as possible and use the boom/crane to place the skimmer in an area not occupied by ice. It must be carefully monitored so that it is not crushed by the bigger ice floes. If the oil is in pools separated by ice, the skimmer may need to be lifted from the surface and repositioned to new oil.

Skimmer Deployed in Broken Ice

Deployment Considerations and Limitations

- The vessel chosen should have the appropriate ice classification and staffing to perform operations in broken ice.
- The vessel should be able to handle temporary storage.
- Hydraulic hoses and recovery hoses may be susceptible to damage if dragged over or through ice.
- Long lengths of hose running over the deck may need to be heated to prevent freezing even when using non-collapsable hose.
- Pieces of ice can block the oil from reaching the skimmer inlet.
- Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs.
- The use of an oil recovery bucket/boom assembly securely mounted to the deck of a barge and pushed by a towboat works well in these circumstances in terms of maneuverability.
- Comparatively, skimmers that use a tether system and that are deployed over the side may present challenges in terms of maneuverability.
- In greater than 70% concentration, ice is a significant impediment to skimming, with most skimmers having dramatically lower rates and efficiencies in the denser ice.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Operational Vessel	Working platform	1	2	#	1-2 hours
Tugboat	Maneuvering platform	Optional	#	#	#
Skimmer	Recovery	1-2	2-4	#	<30 minutes

depends upon location

Broken Ice – Ice Cage

Skimmer performance in broken ice conditions may be improved by the addition of an ice cage to deflect the ice away from the skimmer while letting the oil through. The figure below shows the ice cage designed to work with the DOP-Dual Helix skimmer as deployed from a USCG buoy tender.

Deployment Considerations and Limitations

- The vessel chosen should have the appropriate ice classification and manning level to perform this. The vessel should also be able to handle temporary storage of collected oil.
- Skimmer deployment may be difficult. Hydraulic hoses and recovery hoses may be susceptible to damage if dragged over or through ice.

Skimmer with Ice Cage Being Deployed from a Buoy Tender

- Pieces of ice can block the oil from reaching the inlet.
- Adequate water supply tanks, hoses, and heating systems may be needed on certain configurations.
- Long lengths of hose running over the deck may need to be heated to prevent freezing.
- Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs.
- The use of an oil recovery bucket/boom assembly securely mounted to the deck of a barge that is pushed by a towboat works well in these circumstances in terms of maneuverability while providing deck space and storage.
- Comparatively, skimmers that use a tether system from the vessel and that are deployed over the side may present challenges in terms of maneuverability.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Operational Vessel	Working platform	1	2	1-2 hours
Tugboat	Maneuvering platform	Optional	#	#
Skimmer	Recovery	1-2	2-4	<30 minutes

depends upon location

Broken Ice – Herding and Ice Management

Herding is designed to move the oil slick into an area where it can be burned, contained, or recovered. The herding process in broken ice is similar to herding at the ice edge. The main difference is that ice may be herded along with the oil. An additional use is to aid in the movement of broken ice on the water surface, keeping the ice from interfering in oil recovery operations.

Herding is usually done with a fire monitor that can move oil from a fixed location into a preferred area. Oil can be trapped in small spaces between bits of rubble ice, making it inaccessible for burning or collection by oil skimmers. Ideally, oil should be herded towards a more open area that is reachable by responders to conduct their recovery operations. Use of a robust skimmer is needed at the collection point.

Certain types of skimmers can also be used to manage the ice, as shown in the figure below.

Skimmer Maneuvering a Piece of Ice

Deployment Considerations and Limitations

- Care should be taken not to send water directly into the ice or with too much force that can push the oil under or onto the ice. The water stream should be directed at least 10-20 feet from the ice so that the induced surface current and not the direct water stream itself moves the oil. A direct water stream will disperse and/or emulsify the oil.
- Care for preventing freeze-up should also be taken if the system is off.

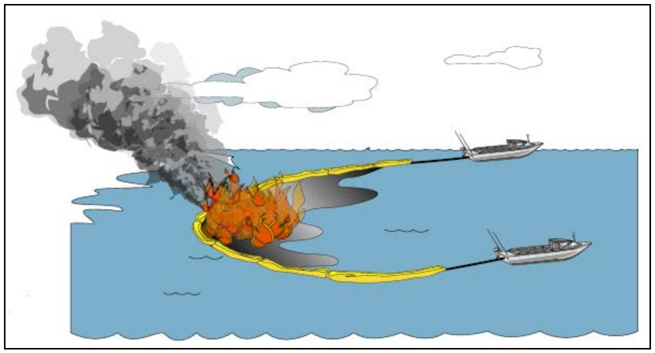
Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Vessel	Working platform	1	2	#
Fire Monitor	Herd oil	1	2	<1 hour

depends upon location

B.3 IN-SITU BURNING

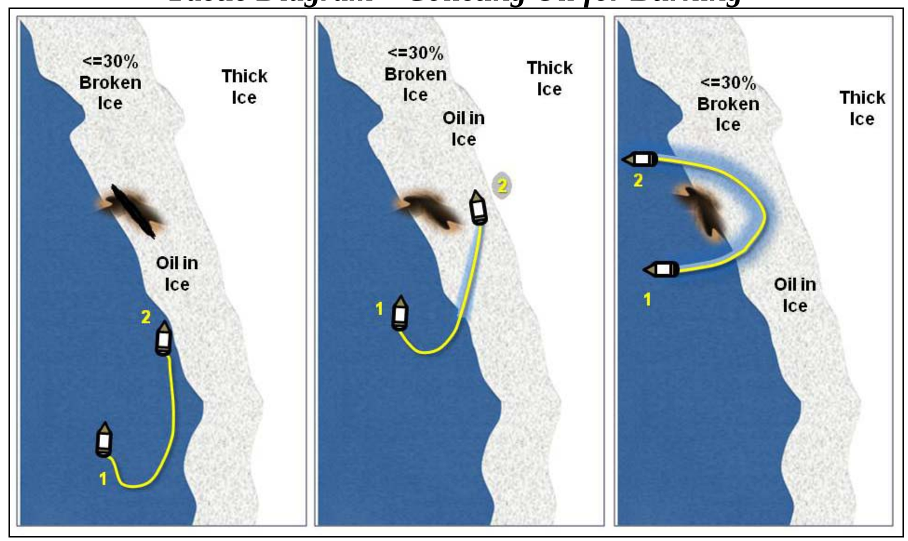
In-situ Burning (ISB) is a technique to remove oil from the surface of the water before it reaches the shoreline. Vessels must capture the oil and tow it to a safe location (defined by the FOSC with respect to water depth, smoke plume, and distance from population and other responders) while moving at less than 1 kt. In open water, two response vessels are recommended to tow the fire boom between them in a “U” configuration (see figure below from STAR; B/W version available from ACS).



In-situ burning may also be used in broken sea ice under certain conditions. In circumstances where higher ice concentrations isolate the oil and prevent it from spreading (usually in ice concentrations greater than 70%), burning may be able to remove a high percentage of the slick (potentially up to 90 %). However, broken ice conditions may complicate vessel operations and fire boom deployment if booming is necessary to concentrate the oil. During spring break-up, oil may accumulate in melt pools, while subsurface oil slowly migrates to the surface through brine channels and cracks. At break-up, this pooled oil will spread into the broken ice. During freeze-up, spilled oil may be contained by new thin or slush ice.

When collecting oil in broken or brash ice, ice may be collected along with the oil. Vessels should do their best to avoid amassing a large number of ice pieces. Use of a “J” formation in deploying the boom may make it easier for the vessels to control the amount of ice captured (see figure below) by allowing for quicker release of oil from the boom. The boom can be converted to a “U”, once free of the ice field.

Tactic Diagram – Colleting Oil for Burning



The general tactics and safety precautions for ISB on open water apply to ISB in broken ice. That is, ISB can only be used if the wind is blowing away from populated areas and if the collected oil forms a thick enough layer to allow for ignition. Oil that gathers inside the boom is moved to a location away from the main spill slick where it is ignited. By controlling the speed of the vessels, the rate of the burn can be increased, decreased, or even extinguished. Any residues left in the boom after the burn must be recovered by conventional means.

Deployment Considerations and Limitations

- The deployment, logistics, and safety considerations for ISB on open water generally apply to ISB in broken ice.
- The boom may be deployed from either a staging platform, such as a barge, or the towing vessels. However, in either case a very large deck space is necessary to stow the boom before deployment.
- Deployment typically involves towing the length of faked-out boom into the water from the deck and then to the start position, where another tug retrieves the other end of the boom.
- Depending upon boom weight, environmental conditions, and staffing levels, a crane or lifting boom is typically necessary in order to recover the boom not otherwise destroyed in the ISB process.
- Hand tools and heating devices are needed to assemble and disassemble mechanical or frozen fittings.
- Two vessels of sufficient horsepower with ice-breaking capability are required for effective deployment and manipulation of the boom.
- Forty to fifty percent broken ice coverage with floes no larger than 5 feet (1.5 meters) appears to be the limit for carving out a sufficient oil/ice mixture for in-situ burn.

Collecting Ice which could Potentially Include Oil

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Control vessel	Boom deployment and retrieval	1	2	1-2 hours
Tugboat	Tow and manage boom	1	2	1-2 hours
Crane	Recover boom	1	1	1-2 hours
Fire Boom	Containment, ISB	1	2-4	1-2 hours
Ignition system	Burn collected oil	10	1	1 hour
Fire suppression system	Control burn if necessary	2		

depends upon location