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Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources
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ARCTIC OIL SPILL RESPONSE OVERVIEW

Prepared for the
Technology & Operations Subgroup

On March 27, 2015, the National Petroleum Council (NPC) in approving its report, *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Technology & Operations Subgroup. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 46 such working documents used in the study analyses. Appendix D of the final NPC report provides a complete list of the 46 Topic Papers. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Topic Paper (Prepared for the National Petroleum Council Study on Research to Facilitate Prudent Arctic Development)	
8-7	**Arctic Oil Spill Response Overview**
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Reviewers	
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SUMMARY

Remote Sensing (RS), together with aerial observations by trained observers is required to find oil, map its extent and, track its movement. This is particularly important in the Arctic environment due to potentially limited response assets and logistical challenges. The topic paper summarizes the current techniques and capabilities for detecting oil on, among and in/under ice, mapping the extent of the oil, and monitoring the oiled ice movements.

Introduction

The purpose of this document is to summarize the current techniques and capabilities for detecting oil on, among and in/under ice, mapping the extent of the oil, and monitoring the oiled ice movements. Remote Sensing (RS), together with aerial observations by trained observers capabilities plays a vital role in oil spill response in terms of finding oil, delineating the area of the spilled oil, tracking it's movement and providing input for trajectory modeling of the spill. RS is also a key element in providing a common operating picture of the location and extent of the spill response operations.

To successfully conduct an oil spill response in any environment it is critical to locate, map and track oil as it moves away from the source of the spill. This is particularly important in the Arctic environment due to potentially limited response assets and logistical challenges. This data can be presented as a map product in a common operating picture that is immediately useable by responders in the field and decision makers in the Unified Command.

Some of the RS and survey challenges that must be overcome for winter Arctic conditions are:

- Visibility - Sensors and visual observations can be negatively impacted by blowing snow, low cloud, fog and darkness
- Weather conditions – low temperature and wind
- Ice/snow cover – detecting oil trapped under ice and snow or trapped within ice, and
- Remoteness – offshore operations could be far from shore support

The additional challenges of dealing with Arctic offshore and ice conditions will likely require a mix of remote sensors operating in different parts of the electromagnetic spectrum. Assessments of remote sensing system capabilities for oil spills in ice have drawn upon practical detection experiences of spills in open water environments (Dickins and Andersen, 2009; Fingas and Brown, 2011).

A wide range of sensor types have been tested through analytical, bench and basin tests and field trials for use in spill detection in ice: acoustics, sonar, radar, ultraviolet fluorescence, infrared (IR), gamma ray, microwave radiometer, resonance scattering theory, gas sniffers, and ground penetrating radar (GPR) (e.g., Dickins, 2000; Goodman, 2008). Beginning in 2004, projects sponsored by the Minerals Management Service (now the Bureau of Safety and Environmental Enforcement, BSEE) and industry (including the SINTEF Oil in Ice JIP that concluded in 2010) evaluated and tested a variety of sensors currently used to detect oil on open water to evaluate their potential for detecting oil in ice. In addition to the sensors above, these projects looked at side-looking airborne radar, synthetic aperture radar (SAR) satellites, forward-looking infrared (FLIR), trained dogs, and sonar (Bradford et al., 2010; Dickins et al., 2010). The current Arctic Response Technology JIP (2012-2015) is examining a range of these and other airborne, surface, and subsurface technologies in order to assign priorities for future development and testing (Puestow et al., 2013; Wilkinson et al., 2013).Table 1 compares the capabilities of different sensors for remote sensing of oil spills in ice according to the platform and the oil/ice configuration over a range of ice environments (Dickins and Andersen, 2009). The SINTEF JIP field experiments in 2008 and 2009 attempted to evaluate some of these technologies in close pack ice but the small sizes of the offshore experimental spills and effective localized containment by the ice precluded successful detection in most cases.. Expected capabilities of different systems are based on conclusions from that work and other experiments and from results of previous trials, not necessarily in the Arctic.

Dickins and Andersen (2009) concluded that current airborne systems are useful for detecting and mapping large spills in open ice but have less potential as the ice concentration increases. Many of the non-radar sensors on airborne systems do not work well under Arctic conditions of darkness, cloudiness, fogginess, and rain for much of the year. A quantum leap in all-weather capability was realized in the late 1990s with the advent of commercially available, high-resolution SAR satellite systems, which are unaffected by darkness or cloud cover and can now resolve targets of a few meters (e.g., Radarsat, ERS-1, TerraSAR-X, COSMO-Skymed). First-generation SAR satellites mapped several large marine oil spills, including the *Prestige*, *Nakodka*, and *Sea Empress* (Hodgins et al., 1996; Lunel et al., 1997). The ability of SAR satellites to detect and map oils slicks in the ocean with moderate wind conditions is likely to be practical for well-defined oil spills that spread in very open to open pack ice, where capillary waves can develop on the surface (Babiker et al., 2010). Satellites are expected to have less utility for detecting oil in concentrated ice and oil trapped under ice and snow.

The *Deepwater Horizon* oil spill provided an opportunity to utilize many of the latest detection technologies. Leifer et al. (2012) summarized how passive and active satellite and airborne marine remote sensing were applied to the spill. The Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data allowed for detection of the total slick and was used to produce maps of estimated oil thickness. Airborne and satellite SAR provided synoptic data under all-sky conditions; however, SAR typically is not able to discriminate between thick oil slicks and thin sheens (0.1 mm or less) and SAR data can be used more as a strategic response planning tool rather than a real-time tactical tool. The Jet Propulsion Laboratory's Uninhabited Aerial Vehicle SAR's higher spatial resolution and signal-to-noise ratio led to better pattern discrimination.

Sensors and Platforms – Current Capabilities

Detection and mapping of oil in ice will likely require a mix of sensors operating in different spectral bands, both passive and active. Figure 1 shows a montage of platforms and sensors ranging from AUVs sonar, and Synthetic Aperture Radar satellites.

Included in the mix is the human observer, perhaps still the most reliable "sensor", in spite of the limitations of darkness and adverse weather.

Figure 1. The challenge of oil in ice detection portrayed by the broad mix of different sensors required to achieve successful detection under a wide range of oil and ice conditions. Source: D. Dickins

Much of the early research on spill detection in ice took place over a ten-year period beginning in the late 1970s, motivated by offshore drilling programs in the Canadian Beaufort Sea. Since that time researchers carried out analytical, bench, and basin tests and field trials using a wide range of sensor types—acoustics, radar, ultraviolet fluorescence, infrared (IR), gamma ray, microwave radiometer, resonance scattering, gas sniffers, and ground penetrating radar (GPR) (e.g., Dickins, 2000; Goodman 2008).

At present, our knowledge of which sensors are most likely to succeed in different oil in ice scenarios is based largely on experiences in temperate spills supported by a small number of field tests and tank/basin experiments. A number of researchers have summarised the present state of knowledge (For example: Dickins and Andersen, 2009; Fingas and Brown, 2011).

Overall conclusions from this work were that the current generation of airborne systems have a high potential for detecting and mapping large spills in very open ice, but less potential as the ice concentration increases. Many non-radar sensors are blocked by darkness, cloud, fog, and precipitation, all of which are common over Arctic waters for much of the year.