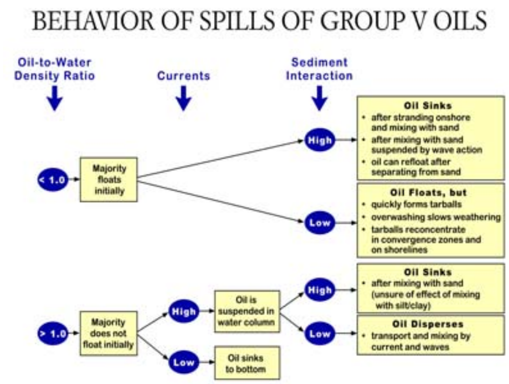

Submerged Oil – State of the Practice and Research Needs

Coastal Response Research Center
Durham, New Hampshire
December 12-13, 2006

Report Issued: July, 2007

Coastal Response Research Center

UNIVERSITY OF NEW HAMPSHIRE

Forward

With increased reliance on heavier crude oils and refined products to fill the current energy demands, the proportion of oil spills involving subsurface oil is also on the rise. Submerged oils provide unique response challenges in oil detection, tracking, remobilization, fate and transport modeling, containment, and recovery. In 1996, the U.S. Coast Guard (USCG) was directed to assess the risk of such spills to evaluate the existing cleanup technologies and identify potential technological and financial impediments to timely response activities. The National Academy of Science (NAS), on behalf of USCG, published Spills of Nonfloating Oils: Risk and Response (1999), which provided recommendations of critical research needs relevant to subsurface oils in the environment. Since the release of this report, little advancement has been made in addressing these persistent issues. In light of these ongoing challenges, the Coastal Response Research Center, the National Oceanic and Atmospheric Administration (NOAA) and USCG have partnered to address the detection, monitoring, modeling and recovery of submerged oil and are committed to coordinating programs and leveraging resources to better address these issues.

The Coastal Response Research Center, a partnership between NOAA Office of Response and Restoration (ORR) and the University of New Hampshire (UNH), develops new approaches to spill response, assessment, and restoration through research and the synthesis of information. The Center's mission requires it to serve as a hub for research, development, technology transfer to the oil spill community. To better guide future efforts, the Center hosted a workshop to evaluate the state of the practice and identify research needs to improve response to and restoration of spills of submerged oil. The December 2006 workshop entitled "Submerged Oil – State of the Practice," was held in Durham, NH. Dr. Jacqueline Michel (Research Planning, Inc.) served as workshop facilitator and authored this report, which provides a synthesis of the research priorities identified by the many dedicated workshop participants. This report will be a resource of submerged oil priority topics for funding entities and a tool to inform the oil spill response community.

We hope you enjoy reading the report and exploring the priority research topics for submerged oil. If you have questions or comments, please contact the Center. We look forward our continuing our involvement in the submerged oil discussion and serving the oil spill community, and the nation.

Sincerely,

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Acknowledgements

The Coastal Response Research Center gratefully acknowledges Jacqueline Michel of Research Planning, Inc., the author of this report. The Coastal Response Research Center acknowledges the time and effort provided by the participants in the workshop, whose contributions have been synthesized into this report. The Coastal Response Research Center also acknowledges the thoughtful input and comments received by the members of the Submerged Oil Working Group on the concept of the workshop and the draft report.

Citation:

Coastal Response Research Center. 2007. Submerged Oil – State of the Practice and Research Needs. Prepared by the Coastal Response Research Center, Durham, New Hampshire, 29 pp + appendix.

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Submerged Oil – State of the Practice and Research Needs

I. Introduction

Most oil spill response strategies, tactics, and equipment are based on the simple principle that oil floats. However, oil does not always float. Sometimes it suspends in the water column; sometimes it sinks to the seafloor. Sometimes it does all three: floats, suspends, and sinks. Furthermore, oil that has sunk to the seafloor can become re-suspended and spread by currents. Terminology to describe these various behaviors can be confusing. The NRC (1999) used the term “nonfloating oil” in the report Spills of Nonfloating Oils: Risk and Response, but its vagueness has caused some consternation. The term “submerged oil” is used in this report to describe any oil that is not floating at or near the surface. Thus, it should not be confused with oil that has become temporarily submerged by wave action, which should be called “overwashed oil.”

There are several types of submerged oil. Submerged oil can be suspended in the water, either throughout the water column or just above the bottom. Sunken oil is appropriate to describe the accumulation of bulk oil on the seafloor. Sunken oil can, and often will, contain some sediment, but it is described more as sediment-contaminated oil rather than oil-contaminated sediments.

Oil becomes submerged when the density of the oil is greater than the density of the receiving water. The “oil” can be any combination of petroleum products, water, and sediments. Figure 1 shows this relationship. In full-strength seawater with a salinity of 35 parts per thousand, oil with an API gravity above 6.5 will still be lighter than the seawater and is likely to float. Very few crude oils or refined products (other than asphalt) are this heavy, although the amounts of very heavy refined products are increasing as refineries modify their processes to produce as much gasoline as possible out of each barrel of oil.

Michel (2006) summarized 26 oil spill cases where the oil became submerged. In thirteen of these cases, the initial density of the oil was higher than the receiving waters and the oil submerged shortly after release; of these, eight were spills to fresh water and five were spills to seawater.

It is important to note that for half of the cases discussed by Michel (2006), the oil initially floated then became submerged, mostly after picking up sand. Thus, a floating oil can become heavier than the receiving water by either of two processes: 1) stranding on a sedimentary shoreline, picking up sand, then being eroded from the shoreline; or 2) by mixing with sand suspended in the water column by wave action (Michel and Galt, 1995). In either case, depending on the amount of sediment mixed into the oil, the oil-sediment mixture can become slightly negatively buoyant and become suspended in the water column by currents, or it can be dense enough to sink to the bottom. It is important to note that, in these cases, the oil itself is still buoyant and, if the oil separates from the sediment, it can refloat, as happened at the T/B Morris J. Berman spill in Puerto Rico (Burns et al., 1995).

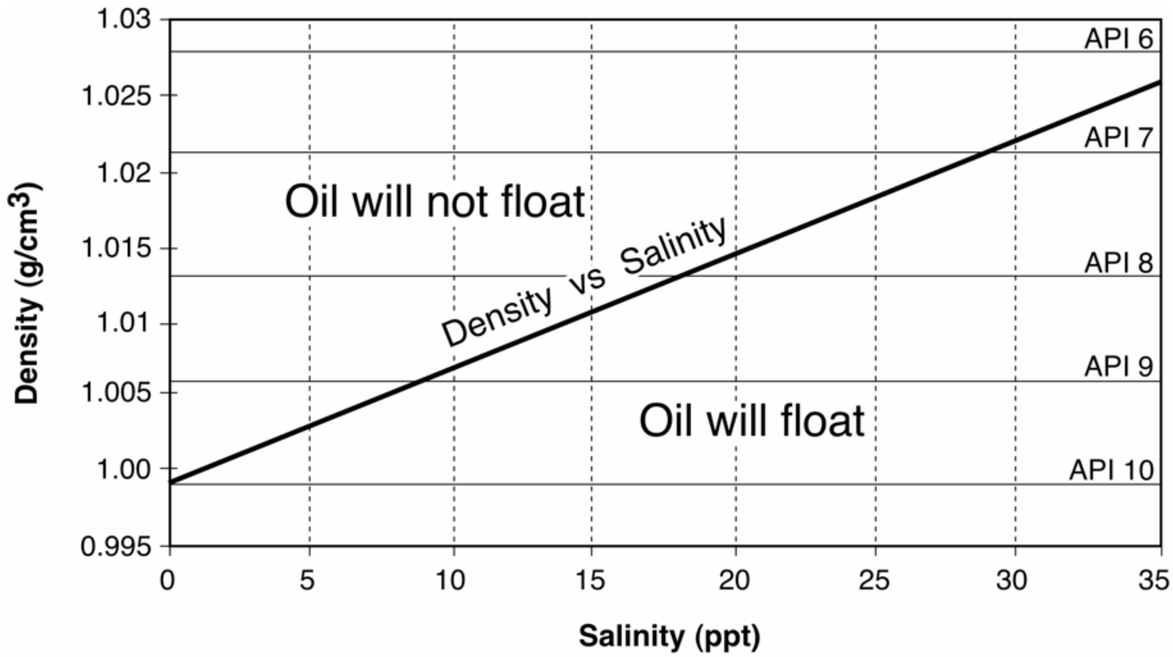

Figure 1. Diagram showing the relationship among water salinity, density, and API gravity. Oils above the line will be heavier than the receiving water and will not float. Those below the line will be lighter than the receiving water and will float.

Currents are another key factor in determining the behavior of submerged oil, both initially and over time. In strong currents, the oil can remain suspended in the water column and transported over long distances, as in the case of several spills of denser-than-water oil into the Mississippi River and Puget Sound (Weems et al., 1997; Yaroch and Reiter, 1989). If currents are weak, the oil can settle to the bottom, as did the T/B DBL-152 (Michel, 2006).

It is clear from the above discussions that submerged oil poses many response challenges. Submerged oil is very difficult to detect, both when it is suspended in the water and sunk to the seafloor. Oil suspended in the water column and moving with the currents is difficult to track using standard visual survey methods. Oil that has accumulated on the seafloor can be mobilized by changing bottom energy resulting from events such as floods and storms. Trajectory models traditionally used to predict floating oil movements and fate are not applicable to submerged oil. Weathering processes of submerged oil are slow and poorly understood, so it is difficult to assess the ultimate fate of the oil. There are no proven methods for containment of submerged oil, and methods for recovery of submerged oil have limited effectiveness. With low recovery rates and slow natural weathering processes, it becomes even more important to understand the short- and long-term effects of submerged oil that remains in the environment.

The National Research Council (NRC, 1999) published a report on the risk and response concerns of nonfloating oil spills and made specific recommendations for further research. There has been little follow-up since that report. However, the issues of submerged oil were raised at two recent spills where all or part of the oil became submerged. The spill of 264,000 gallons of a heavy Venezuelan crude oil (API = 13.6) from the M/T Athos into the Delaware River in November 2004 threatened water intakes (including a nuclear power plant) and shellfish beds. The total response costs for the M/T Athos incident were $267 million (USCG, 2007). In

November 2005, the DBL-152 spill released 2.7 million gallons of a heavy slurry oil (API ~ 4) 55 kilometers off the coast of Louisiana where about 5 percent of the spilled oil was recovered at an estimated cost of $50 million (USCG, 2007).

Because of these many challenges, the U.S. Coast Guard (USCG), National Oceanic and Atmospheric Administration (NOAA), and Coastal Response Research Center (CRRC) initiated a partnership to address detection, monitoring, modeling, and recovery of submerged oil. Each organization has been working on submerged oil issues. The USCG Research & Development Center (RDC) sponsored several reports that reviewed the current state of the recovery of submerged oil (Michel, 2006) or viscous oil on the surface (Cooper, 2006). Their findings indicate that there is a lack of capability to respond to these situations. The USCG plans to release a request for proposals to address these issues. NOAA is investigating the revision of rapidly re-locatable hydrodynamic models to account for subsurface flow and integrating these models into the fate and transport models for submerged pollutants. CRRC is coordinating its funding decisions with USCG and Minerals Management Service (MMS) on new methods to detect submerged oil, specification of conditions that will lead to its remobilization, formulas that will predict its mechanical characteristics and particle size distributions, and its expected interactions with near-shore sediments.

To better coordinate and direct these research efforts, CRRC hosted a workshop on December 12-13, 2006 to evaluate the state of the practice and identify research needs to improve response to and restoration of spills of submerged oil. The workshop participants were selected by the Submerged Oil Working Group and consisted of a diverse group from all sectors, including academia, industry, international, national and state governments, and non-governmental agencies (See Appendix A for the list of participants). The overall workshop goal was to work together to identify research needs information on submerged oil pertaining to the following response and restoration topics:

- Detection and Monitoring
- Fate and Transport
- Containment and Recovery (including Protection of Water Intakes)
- Effects and Restoration

This report serves as a synthesis of the research priorities identified at the workshop, a working document for funding entities to use to sponsor future research, and an information dissemination tool for the oil spill response community. The objective of the workshop was to provide language for the preparation of study plans for future funding mechanisms or research proposals.

II. Workshop Organization and Structure

The CRRC submerged oil workshop was organized along the four response and restoration topics identified above as “breakout” discussion themes. Prior to the workshop, the participants were selected to establish balanced representation of expertise in all four topics. There was also a concerted effort to distribute affiliations and expertise across breakout groups to maximize exchange and reduce parochialism. During the workshop, the groups were subdivided again so there were two groups addressing each topic during the breakout sessions. This duplication was used to determine that a range of priorities was truly identified. After each breakout session, all groups were reconvened. Each group reported on their discussions and priorities for the given topic. For each major research idea or need presented, each group was asked to provide comments in the following headings:

- Research Need
- Objectives
- Guidelines
- Potential Impediments or Enhancements to Success
- Application to the Decision-making Process

The main body of this report reflects this format.

This report is the result of a multi-stakeholder effort and provides the participating agencies with a prioritized template of potential research topics to more effectively use the limited funds available for research. The results also provide an integrated research planning tool to improve understanding of submerged oil behavior, fate, effects, and response options. This report provides the spill response community with an abbreviated work plan to inform the development of requests for proposals and other funding mechanisms. It also provides the research community with information to facilitate proposal writing, develop experimental designs, and improve the efficiency and relevance of future research.

III. Workshop Results

The workshop results are organized into tables for each of the four major topics. There are eleven tables organized as follows:

Detection and Monitoring:	Table 1 – Group A
	Table 2 – Group C
Fate and Transport:	Table 3 – Group D
	Table 4 – Group E: Pre-spill Planning Activities
	Table 5 – Group E: Observation and Monitoring Activities
	Table 6 – Group E: Modeling and Prediction Activities
	Table 7 – Group E: Chronic Releases from Contaminated Sediments
Containment and Recovery:	Table 8 – Group F
	Table 9 – Group G
Effects and Restoration:	Table 10 – Group H
	Table 11 – Group I

Table 1. Group A: Detection and monitoring research needs.

A1. Research Need	Ability to calibrate the degree of oiling on snare sampling systems with the amount of oil on the seafloor or in the water column.
Objectives	Provide data on which to evaluate the oil uptake and retention on snares under various conditions (chain drags, in stationary pots, suspended in the water column).
Guidelines	Develop methods for and conduct bench-scale lab tests using flow-through systems and different oils, temperatures, and flow velocities to provide relative uptake rates. Should include assessment of oil washoff. Conduct multiple tests to determine ranges of uncertainty. Based on lessons learned during lab testing, develop protocols for on-scene tests to be performed at actual spills.
Potential Impediments or Enhancements to Research	There is much concern about how realistic laboratory testing would be; underwater video of actual deployment of snare sampling systems would improve design of test flow conditions. Will not address the issue of if the snares encountered one large patch during deployment or multiple small patches.
Application to the Decision-Making Process	Would provide estimate of ability to correlate visual descriptions of oiling on snares to the amount of oil present. Would provide some indication of optimal oil uptake and oil quantity present to support risk assessment. Would indicate potential for snares as oil recovery method.

A2. Research Need	Evaluation of the potential of acoustic systems and LiDAR, both individually and as packaged suites, to detect submerged oil on the seafloor and in the water column
Objectives	Identify the conditions under which such remotely sensing systems are likely to be effective. Identify system configurations and operating conditions to maximize performance; must be able to generate products that are easily interpreted and generated in a timely manner to support operations.
Guidelines	Involve operational oil spill experts to make sure that the system meets their needs and reflects realistic conditions. Need to be able to estimate oil volume. Should include analysis of error in terms of false positives and negatives
Potential Impediments or Enhancements to Research	Development costs will be high. Will only be able to confirm performance at actual spills; spill conditions will vary so what works in one case may not work the next time. Submerged oil spills are infrequent so such systems may not be used often, making it difficult to justify equipment and software development and maintain operational expertise.
Application to the Decision-Making Process	Would provide initial assessment of amount, location of oil to support decision for and design of recovery options, monitoring for changes over time, and effectiveness of recovery methods.

Table. 1. Continued

A3. Research Need	Improved confidence in ability to estimate the areal extent and amount of submerged oil since actual locations and amounts are not visible
Objectives	Develop statistically rigorous sampling designs for methods used to determine the spatial extent of submerged oil.
Guidelines	Plans need to be applicable to the different sampling methods (e.g., snare sentinels, chain drags, ROV, acoustic systems).
Potential Impediments or Enhancements to Research	Field conditions are highly variable in terms of scale, habitat, physical conditions, oil distribution pattern, and rate of change. Each spill will be very different; general guidelines are likely to be of limited value and detailed guidelines are likely not to apply to a specific spill. It is particularly difficult when the oil is mobile and the scale is constantly expanding. The patchiness and size of individual oil accumulations will often vary over space and time.
Application to the Decision-Making Process	Would improve the basis and confidence of strategic and tactical response decisions on if and how to recover the oil. Would provide basis for exposure assessment over space and time.

A4. Research Need	Understanding of when and which in-water chemical sensors would be useful for detecting submerged oil.
Objectives	Identify the sensors and conditions under which they might be useful to detect submerged oil (both in the water column and on the seafloor) and provide estimates of oil quantities. Provide real-time data on oil concentrations at key points, such as water intakes.
Guidelines	Developers need a clear and accurate understanding of the likely range of spill conditions, oil types and behavior, and transport processes. Oil could be in the form of suspended particles (which can quickly lose their already low water-soluble fractions) or thick accumulations on the seafloor (from which there would be very slow dissolution). Should consider different deployment strategies (e.g., at a water intake, at a buoy, on a ROV).
Potential Impediments or Enhancements to Research	The sensor technology is rapidly evolving so there may be solutions in development. The oil in the water column may be present as both dissolved and particulate fractions, and the particulate fractions can vary widely in size. Submerged particulate oil is likely to be viscous and sticky, thus fouling of sampling systems and/or sensors is of concern.
Application to the Decision-Making Process	Would provide real-time monitoring of oil concentrations at water intakes to determine when to shut down/start up. Would provide data to support transport modeling and prediction during response operations. Would provide exposure data for injury assessment.

Table 2. Group C: Detection and monitoring research needs.

C1. Research Need	Capability to determine the presence or absence of submerged oil over a large area (on the seafloor or in the water column) on a coarse scale. (Although focus was on sonar and laser fluorosensor technologies, all potential technologies across the spectral range should be considered.)
Objectives	To cover a large area quickly and provide data to confirm the presence or absence of submerged oil and an initial indication of the oil quantity.
Guidelines	Data analysis must be completed within the operational planning cycle. Results need to be easily understood and usable within the command center. Will need analysis of the level of resolution for the appropriate scale of coarse detection. Minimum detection capability needs to be expressed in terms of X barrels of oil over Y area, Z percent of areal coverage at some minimal thickness, or no patches larger than some pre-determined size. Include uncertainty (false positives are more acceptable than false negatives), depth, and clarity limitations.
Potential Impediments or Enhancements to Research	The lack of the ability to test and evaluate concepts in a controlled environment. Actual spills with submerged oil are few, and emergency conditions are not conducive for testing concepts. Systems should be easy to deploy and mobile so they can be readily re-positioned as the spill conditions change. Should be compatible with the fine-scale detection systems (see C2).
Application to the Decision-Making Process	The location, quantity, and movement of oil are the basis for all other operational decisions.

C2. Research Need	Capability to confirm and refine the location and quantity of submerged oil detected on a coarse scale.
Objectives	Provide information on the presence, location, distribution, and quantity on a scale fine enough to support decisions about removal at individual locations.
Guidelines	Data analysis must be completed within the operational planning cycle. Results need to be easily understood and usable within the command center. The fine-scale detection has to be able to closely follow (in both terms of time and location) the coarse-scale detection to provide confirmation.
Potential Impediments or Enhancements to Research	The lack of the ability to test and evaluate concepts in a controlled environment. Actual spills with submerged oil are few, and emergency conditions are not conducive for testing concepts. Systems should be easy to deploy and mobile so they can be readily re-positioned as the spill conditions change. Should be compatible with the coarse-scale detection systems (see C1).
Application to the Decision-Making Process	The location, quantity, and movement of oil are the basis for all other operational decisions.

Table 3. Group D: Fate and transport research needs.

D1. Research Need	Decision template or conceptual model of the conditions under which oil might become submerged that includes oil properties and environmental characteristics.
Objectives	Provide better guidance to be able to predict how much of a spilled oil will be a subsurface issue, both initially and over time after weathering, sediment interactions, etc.
Guidelines	Start with the NRC (1999) report. Include factors such as oil viscosity, pour point, etc. Identify research needs to fill data gaps. Should include special cases such as burn residue and emulsified fuels.
Potential Impediments or Enhancements to Research	Some basic research is needed to better understand oil:sediment interactions; energy thresholds for oil particle remobilization and breakup.
Application to the Decision-Making Process	Allows decision makers to identify the potential for submerged oil at an spill incident and make appropriate response plans. Key questions to be answered include: if, when, and how the oil could become submerged; what the submerged oil will look like; what is timescale of the process; potential for stranded oil to remobilize and sink; fate of burn residue; and behavior of submerged oil in the water column–will it suspend or sink?

D2. Research Need	Observation systems that can be deployed on scene at spills of submerged oil to help validate or calibrate models and direct sampling and monitoring.
Objectives	Ability to collect real-time data on currents, sediment grain size, concentrations, and behavior, etc. to improve modeling of submerged oil transport and behavior
Guidelines	Systems need to perform within response timeframes, so data collection and processing should be near real-time. Also a need for systems within restoration timeframes, which would be months to years. Have to be readily available within very short notice (days). Potential systems include ADCP, dye tracer studies, sediment traps, drifters.
Potential Impediments or Enhancements to Research	Will require preplanning for issues such as permits, sources of systems, support logistics for deployment/retrieval, justification of costs, etc.
Application to the Decision-Making Process	Would increase ability to predict submerged oil transport, spread, interaction with bottom habitats, and risks to natural resources. Would significantly improve the confidence and decrease the uncertainty in modeling submerged oil fate and transport.

Table 3. Continued

D3. Research Need	Better understanding of the size, composition, and distribution of particles, both oil and sediment, which are key to developing better models for forecasting, observing, understanding, and hindcasting submerged oil behavior
Objectives	
Guidelines	Should involve a literature review of any previous studies. Consider current work being done with dispersed oil particles. Consider currents, turbulence regimes with depth, and sediment types likely to interact and affect submerged oil behavior. Both bench-scale and wave tank studies may be useful to prove scaling assumptions.
Potential Impediments or Enhancements to Research	The workgroup considered this effort to be very difficult because of the need to mimic environmentally relevant situations. It will be difficult to document if measurements are statistically valid. There will be significant sampling and measurement constraints.
Application to the Decision-Making Process	Better models to predict the fate and transport of oil particles will improve risk assessments (e.g., biological, water intakes), predictions on how long recovery of oil on the bottom might be an option and recovery endpoints, likely concentrations and persistence of submerged oil, and how long the oil might stay suspended or sink to the seafloor.

D4. Research Need	Understanding of oil interaction, impacts, and cleanup options for different seafloor habitats, similar to the sensitivity ranking of intertidal habitats
Objectives	Create matrix first, then maps, of predicted submerged oil behavior on subtidal habitats based on geomorphology, sediments, benthic resources, appropriate response methods and likely operational recovery effects, etc.
Guidelines	Select areas/habitats based on assessment of spill risk considering generators of heavy oils, transportation corridors, etc. Offshore habitats should be considered only at water depths and distance offshore where recovery or protection would be an option.
Potential Impediments or Enhancements to Research	Actual mapping is very expensive so would likely be coordination with existing and on-going benthic habitat mapping efforts.
Application to the Decision-Making Process	Would support understanding of how submerged oil might interact with the seafloor and drive decisions about appropriate cleanup methods, impacts, and endpoints.

Table 4. Group E: Fate and transport research needs: Pre-spill Planning.

E1. Research Need	Pre-spill Planning 1: Understanding of oil interaction, impacts, and cleanup options for different seafloor and water column, similar to the sensitivity ranking of intertidal habitats
Objectives	Map subtidal resources (benthic and water column) that would be sensitive to different types of submerged oil.
Guidelines	Prioritize areas to be mapped based on submerged oil spill risk. Also consider threatened and endangered species.
Potential Impediments or Enhancements to Research	There are likely to be significant costs and data gaps.
Application to the Decision-Making Process	Would improve Area Contingency Planning on resources needed to protect sensitive areas.

E2. Research Need	Pre-spill Planning 2: Access to observing systems to support real-time data collection during actual spills.
Objectives	Develop a database or clearinghouse of data sources that could provide information on existing currents, bathymetry, and sediments to support response.
Guidelines	Develop a database or data clearinghouse on information at the water:sediment interface.
Potential Impediments or Enhancements to Research	There are large, public databases that could be useful. Would provide another justification to support Integrated Ocean Observing Systems (IOOS).
Application to the Decision-Making Process	Would improve Area Contingency Plans and response by knowing what data are available to support responders in determination of fate and transport of submerged oil.

E3. Research Need	Pre-spill Planning 3: Understand bottom substrate dynamics that might affect submerged oil behavior and fate.
Objectives	Locate erosion and deposition areas on the seafloor. Understand local oil and sediment transport patterns.
Guidelines	Prioritize areas to be studied or mapped based on submerged oil spill risk.
Potential Impediments or Enhancements to Research	Would need extensive areas of bathymetry where there are likely to be significant data gaps at the needed resolution. Would meet the data needs for a large user group.
Application to the Decision-Making Process	Would improve the understanding of local submerged oil transport patterns and thus guide cleanup levels and actions.

Table 5. Group E: Fate and transport research needs: Observations and Monitoring.

E4. Research Need	Observations and Monitoring 1: Systems that will support post-spill observations and monitoring of a submerged oil spill
Objectives	Evaluate and recommend observing systems that can be deployed rapidly on scene to track oil movements.
Guidelines	Systems need to be able to generate data in near real-time to support response. Data needs to be processed and formatted efficiently. Systems and network must be robust.
Potential Impediments or Enhancements to Research	Deployment of observing equipment will be very expensive; will need to know which systems are going to be most useful. May need to keep equipment in place for months to gain long-term recovery information.
Application to the Decision-Making Process	Would provide better confidence in models predicting oil fate and transport, and thus focus and optimize response activities. Would allow a better assessment of environmental impact for oil left in the environment.

E5. Research Need	Observations and Monitoring 2: Monitoring of bottom and submerged oil.
Objectives	Develop tools to find submerged oil on the seafloor, determine transport processes, and identify natural entrainment areas.
Guidelines	Will need to map oil on the seafloor at small scales and appropriate level of detail.
Potential Impediments or Enhancements to Research	Weather and visibility can be a significant limitation for monitoring in the field
Application to the Decision-Making Process	If natural entrainment areas can be identified, these areas may be incorporated into containment and recovery plans to enhance recovery. Would provide better situational awareness.

E6. Research Need	Observations and Monitoring 3: Better understanding of the interaction of submerged oil on the seafloor with respect to bathymetry and rugosity.
Objectives	Generate data on which parameterization to build models can be based.
Guidelines	Should consider different oil and substrate types.
Potential Impediments or Enhancements to Research	There are complex interactions among bathymetry, rugosity, and currents that are not well understood. Could use available bathymetry information.
Application to the Decision-Making Process	More accurate models will lead to better planning during response.

Table 6. Group E: Fate and transport research needs: Modeling and Prediction.

E7. Research Need	Modeling and Prediction 1: Understanding the chemistry of submerged oil to better predict its fate.
Objectives	Conduct studies of heavy oils to determine rates of dissolution, weathering, and biodegradation under realistic conditions; determine bioavailability and mechanisms of toxicity including smothering.
Guidelines	Laboratory studies are useful for controlled studies but would want to monitor underwater rates of weathering processes at spills of opportunity.
Potential Impediments or Enhancements to Research	Field studies will be difficult where both the oil and the resources of concern are mobile. Difficulty of field work during emergency response may limit the amount of data collected.
Application to the Decision-Making Process	Would support decision making on cleanup endpoints and long-term risk of oil left in the environment.

E8. Research Need	Modeling and Prediction 2: Development of 4-D transport models.
Objectives	Develop models to predict submerged oil transport on short- and long-term timescales.
Guidelines	Models for response application would likely be different than longer-term damage assessment applications.
Potential Impediments or Enhancements to Research	Collecting the data needed for inputs to the model during spill emergencies will be difficult.
Application to the Decision-Making Process	Would provide improved trajectory analysis of submerged oil spills, which is key to decision making on protection priorities and methods, recovery options, and cleanup endpoints.

E9. Research Need	Modeling and Prediction 3: Integrated models for risk assessment that consider physical, toxicological, and biological components.
Objectives	Define all parameters and databases for an integrated model
Guidelines	Follow the recommendations made for the September 2006 workshop on Innovative Coastal Modeling for Decision Support: Integrating Physical, Biological, and Toxicological Models. Next step would be to use these models to compare ecological effects and recovery for different response options
Potential Impediments or Enhancements to Research	Required data may not be available, particularly during emergency response.
Application to the Decision-Making Process	Improve ability to predicting risk, forecasting environmental effects, selection of response options, and communicating complex modeling to decision makers.

Table 7. Group E: Fate and transport research needs: Chronic Releases from Contaminated Sediments.

E10. Research Need	Chronic Releases 1: Better understanding of the potential threats of chronic releases form oiled sediments and oily residues.
Objectives	Determine the long-term exposure to and toxicity of different types of heavy oils and oiled sediments.
Guidelines	There is particular concern about contaminated muddy soft sediments (black mayonnaise). Should prioritize case studies for study/assessment.
Potential Impediments or Enhancements to Research	Duration of studies; are Ecological Risk Assessment methods sound enough?
Application to the Decision-Making Process	Would provide basis for decision to remove contaminated sediments or leave them in place.

E11. Research Need	Chronic Releases 2: Better understanding of the fate and transport of heavy oil releases from land.
Objectives	Develop tools to predict fate of land-based sources of heavy oil.
Guidelines	Should prioritize case studies for study/assessment.
Potential Impediments or Enhancements to Research	May be difficult to follow the source at available sites.
Application to the Decision-Making Process	Would provide quantitative data on decision to eliminate the source or allow to accumulation.

Table 8. Group F: Containment and recovery research needs.

F1. Research Need	Improve current submerged oil recovery systems for oil on the seafloor.
Objectives	Increase the readiness, performance, and effectiveness of current systems used to recovery oil from the seafloor (divers, pumps, vacuum, etc.).
Guidelines	Should build on existing systems and methods. Reduce diver requirements and challenges. Containment (or lack thereof) will drive recovery needs.
Potential Impediments or Enhancements to Research	There is a limited base of knowledge because of few spills. Because of costs, will require industry to participate in development efforts. Has potential for immediate benefits; responders are not eager to test new technologies during spills.
Application to the Decision-Making Process	Decision makers would be more willing to spin up recovery operations if they had more confidence that the systems would be effective.

F2. Research Need	Improve current oil separation and decanting systems.
Objectives	Develop portable oil separation and decanting systems that will reduce separation time, improve system capacities, and reduce costs.
Guidelines	Must be quickly operational. Systems should be scalable to different volumes and site conditions. Note that they may have to be deployed on vessels rather than land.
Potential Impediments or Enhancements to Research	There may be regulatory restrictions against decanting without treatment. Potential enhancement is the use of belt skimmers as a cross technology.
Application to the Decision-Making Process	Will address issue of how to handle large volumes of water/oil/sediment with certain types of recovery methods.

F3. Research Need	Develop new tools to recover submerged oil, both suspended and on the seafloor.
Objectives	Reduce dependence on divers by developing automated/unmanned systems; improve product recovery rates; extend operational capabilities/parameters.
Guidelines	Systems should be portable and deployable on vessels of opportunity.
Potential Impediments or Enhancements to Research	Could be a long-term project to develop truly new tools. Currently available systems (surface skimmers, dredges, trawl systems) may be adapted to submerged oil applications.
Application to the Decision-Making Process	Decision makers would be more willing to spin up recovery operations if they had more confidence that the systems would be effective, particularly under adverse conditions.

Table 8. Continued

F4. Research Need	Improved strategies for removal of suspended oil from the water column using trawling systems.
Objectives	Improve the efficiency of trawling recovery and unloading systems. Maximize operational time and minimize down time.
Guidelines	Changes can be implemented either in-situ or during the recovery process.
Potential Impediments or Enhancements to Research	Systems should be easily cleaned or disposed of efficiently.
Application to the Decision-Making Process	N/A

F5. Research Need	Enhance recovery of submerged oil by changing its properties.
Objectives	Select and evaluate methods to enhance oil recovery by changing the oil viscosity or density, or by reducing the sediment load, making it refloat.
Guidelines	Changes can be implemented either in-situ or during the recovery process. Not necessarily chemical methods; should consider nanotechnologies, air, ultrasound, etc.
Potential Impediments or Enhancements to Research	Regulatory restrictions on use and permitting of chemical agents may limit applications unless specific products have undergone review and pre-approval.
Application to the Decision-Making Process	N/A

Table 9. Group G: Containment and recovery research needs.

G1. Research Need	Assessment of potential for use of chemical countermeasures to improve response to submerged oil spills.
Objectives	Identify, evaluate, and develop chemical countermeasures that would increase dispersion, encapsulation, containment, and tracking of submerged oil.
Guidelines	Would have to be environmentally acceptable. Application must be effective underwater. Blending with viscous oils should be addressed. Must be cost effective.
Potential Impediments or Enhancements to Research	May be difficult to blend additives into viscous oils in-situ. OHMSETT may provide good testing opportunities. Uncertain cost versus benefit (success).
Application to the Decision-Making Process	Another tool for response under special conditions.

G2. Research Need	Guidelines for protection of water intakes during spills of submerged oil.
Objectives	Develop threshold guidelines (matrix by industry/use) for shut down/restart. Identify protection methods and treatment systems. Educate operators and responders; information to facilitate communications during planning and response. Develop local contingency planning suggestions. Sharing of data during spill events.
Guidelines	Include discussion of intake type by industry. Include operational considerations (time to shut down, duration of shut down capability, start-up time). Include different response and protection methods. Consider a range of flow requirements.
Potential Impediments or Enhancements to Research	Unwillingness of operators to suggest thresholds. Human dimensions/public perception versus actual risks are difficult to convey. Limited experience of operators with oil is a challenge.
Application to the Decision-Making Process	Guidelines would improve decisions about when to shut down intakes and when it is safe to start up again.

Table 9. Continued

G3. Research Need	Submerged oil barriers.
Objectives	Evaluate and test different approaches to contain, divert, collect, and improve recovery of oil on the seafloor.
Guidelines	Could include bottom boom, fences, bales, nets, etc. Need to consider typical characteristics of submerged oil; should function effectively in a range of bottom current conditions. Barriers should be flexible, rapidly deployable, adjustable. Should include ability to track the barrier and measure its efficiency.
Potential Impediments or Enhancements to Research	The range of conditions to be encountered is large and highly variable among spill events. Uncertain about how to conduct field verification. OHMSETT would provide good scale for testing.
Application to the Decision-Making Process	Would improve operations by aiding collection efforts and slowing the spread of the oil which decreases recovery effectiveness.

G4. Research Need	Surrogates for different types of submerged oil for testing and training.
Objectives	Produce surrogates of submerged oil types that can be safely used in experiments to enhance and support research, testing, and training.
Guidelines	Needs to be environmentally friendly for both humans and the environment. Should maintain integrity through testing. Produc products with specified density, viscosity, pour point, etc.
Potential Impediments or Enhancements to Research	Very limited applications so likely not to have commercial viability.
Application to the Decision-Making Process	Improve modeling and training.

G3. Research Need	Determine if trenching is a feasible response option.
Objectives	Evaluate utility of and methods for trenching as an option for containment of submerged oil on the seafloor.
Guidelines	Consider substrate characteristics that would create a stable trench. Consider combinations of technologies (barriers, collection, recovery).
Potential Impediments or Enhancements to Research	Difficult to validate effectiveness in the field. Would need oil surrogate for testing.
Application to the Decision-Making Process	Would improve operations by aiding collection efforts and slowing the spread of the oil which decreases recovery effectiveness.

Table 10. Group H: Effects and restoration research needs.

H1. Research Need	Synthesis of data from past submerged oil spills to understand potential effects and identify data gaps.
Objectives	Develop a database on the behavior, weathering, and effects at past spills of submerged oil. These data could be useful for model validation.
Guidelines	Identify spills where monitoring studies may be appropriate to gather additional data on weathering and effects of residual submerged oil (e.g., DBL-152 as a spill of opportunity).
Potential Impediments or Enhancements to Research	Funding and complex logistics will limit the ability to study recent spills, such as the DBL-152, in a timely manner. Insufficient data on actual oil concentrations over space and time would make it difficult to determine exposure conditions.
Application to the Decision-Making Process	Would support risk assessment of different response options, including natural recovery, for future spills. Essential for natural resource damage assessments (NRDA) of future spills.

H2. Research Need	Development of effective rapid-assessment protocols to determine impacts of submerged oil spills.
Objectives	Develop protocols for collection of ephemeral data on biological resources at risk, oil concentrations, and weathering appropriate for submerged oil. Should be useful for both response decision making and NRDA.
Guidelines	Need statistical sampling design that addresses variations in oil location, oil concentrations, and benthic resources, all of which can be highly mobile. Want guidance on how to modify existing equipment and identify new needs that are cost effective and appropriate for long-term deployment.
Potential Impediments or Enhancements to Research	Logistics can be serious issue, because site may be difficult to access and having to compete for logistics with emergency responders. Insufficient, site-specific data on resources present, where and how to best sample.
Application to the Decision-Making Process	Would provide better information on which to evaluate resources at risk and the degree of risk, to support decisions on cleanup and endpoints.

H3. Research Need	Approaches for long-term monitoring of the impacts of submerged oil spills after termination of cleanup efforts.
Objectives	Develop methods to monitor the oil distribution over space and time, track oil weathering rates and processes, and detect biological effects.
Guidelines	Will have to address issues of temporal variability in oil exposure
Potential Impediments or Enhancements to Research	It will be difficult to assess sub-lethal and behavioral effects from a combination of chemical and physical toxicity pathways. Increasingly patchy oil distribution makes it difficult to assess exposure. Complex logistics, involving divers and special techniques.
Application to the Decision-Making Process	Would provide better information on which to evaluate resources at risk and the degree of risk, to support decisions on cleanup and endpoints.

Table 10. Continued

H4. Research Need	Methods for assessment of the ecological value and services of benthic habitats and resources.
Objectives	Develop appropriate metrics for the types of habitats likely to be affected by submerged oil spills (e.g., productivity)
Guidelines	Prioritize habitats most likely affected by submerged oil spills. Must be measurable and scalable.
Potential Impediments or Enhancements to Research	May not be enough available data for priority habitats.
Application to the Decision-Making Process	Would support better injury quantification and restoration scaling during NRDAs. Also, would be useful to identify the most sensitive habitats and resources at risk during the response phase.

H5. Research Need	How to evaluate the impacts of different remedial options on trust resources.
Objectives	Research submerged oil spills and waste sites with similar types of oil and issues to determine effectiveness of different cleanup methods and endpoints.
Guidelines	Include chronic waste sites and spills with significant free oil contamination of sediments; these sites may have some data and lessons learned.
Potential Impediments or Enhancements to Research	Capitalizes on knowledge of effects of contaminated sediments and remedial efforts at waste sites.
Application to the Decision-Making Process	Would provide better information on which to evaluate resources at risk and the degree of risk, to support decisions on cleanup and endpoints.

Table 11. Group I: Effects and restoration research needs.

I1. Research Need	What are the specific polynuclear aromatic hydrocarbons (PAH) in submerged oils that have toxicity implications?
Objectives	Conduct laboratory toxicity tests with very heavy oils to determine the compounds that cause toxicity to different life stages of organisms. Determine the potential for phototoxic effects.
Guidelines	Fractionate the oil so that the contribution of the alkylated PAH can be determined. Studies should be designed to measure acute and toxicity via different modes of toxic action. Test sediment-associated organisms.
Potential Impediments or Enhancements to Research	Current databases for waste site studies may provide crossover with other research efforts.
Application to the Decision-Making Process	Would inform decision makers on trade-offs of response options in both short and long term.

I2. Research Need	What are the non-PAH in submerged oils that have toxicity implications?
Objectives	Conduct detailed chemical characterizations of representative types of submerged oils for non-PAHs, such as the heterocyclic compounds.
Guidelines	Consider potential additives.
Potential Impediments or Enhancements to Research	Little information from producers of these products. Formulations change frequently so may be difficult to get “representative” oils for characterization.
Application to the Decision-Making Process	Would provide more information on potential effects.

I3. Research Need	Better understanding of the chronic toxicity and pathways of exposure leading to toxicity of submerged oil to benthic resources.
Objectives	Assess bioavailability of toxic components of oil particles to benthic organisms. Do tarmats and emulsified oil (thick, bulk oil accumulations) result in exposure and effects? How important is phototoxicity and under what circumstances?
Guidelines	Test filter feeders (particles/dissolved ingestion), deposit feeders (ingestion), demersal species (dissolution), and predators (food pathway).
Potential Impediments or Enhancements to Research	It is difficult to prepare exposure media to separate out contributions from oil particles and dissolved fractions.
Application to the Decision-Making Process	Would inform decision makers on trade-offs of response options in both short and long term. Would support the injury quantification phase of NRDA.

Table 11. Continued

I4. Research Need	Assessment of the economic, recreational, and commercial effects of submerged oil spills.
Objectives	Conduct studies to provide data to answer the following questions: What oil concentrations or thresholds cause effects on recreational and commercial users? How long will tar balls wash up on beaches from submerged oil spills? How long will oil affect trawl fisheries? What is the risk of tainting? Define how to measure these effects.
Guidelines	Timescales of potential impacts are longer than floating oil spills because of the slow weathering processes. There will be issues of real versus perceived risks. What are the best survey techniques.
Potential Impediments or Enhancements to Research	Lack of significant background data on submerged oil spill economics. Information could be used in modeling and communicating effectively to the public.
Application to the Decision-Making Process	Inform contingency plans and prevention regulations.

I5. Research Need	Determine rates of ecosystem recovery after submerged oil spills.
Objectives	Develop a scaling model for restoration.
Guidelines	Consider the long-term structural function of the affected ecosystem. Consider effects of long-term chronic exposures, such as endocrin disruptors.
Potential Impediments or Enhancements to Research	May have limited data on ecosystem functions for those habitats at risk.
Application to the Decision-Making Process	Would support selection of restoration endpoints and feed into scaling metrics for modeling of impacts and recovery.

IV. Synthesis of Workshop Results into Suggested Research Topics

The workshop results can be synthesized into the following suggested research topics. It is hoped that these topics will be considered by funding agencies and organizations.

Evaluation of Remote Sensing Technologies for Detection and Monitoring of Submerged Oil on the Bottom

Effective oil spill response requires an assessment of the spatial distribution and volume of oil within specific areas, so decisions can be made about the need for and methods of containment and recovery. For nonfloating oil spills, when the oil accumulates on the bottom, new methods are needed to rapidly detect and map locations of oil on the bottom. Promising remote sensing technologies, including acoustic systems, underwater video, LiDAR, and chemical sensors, need to be systematically evaluated to determine their potential utility for detecting submerged oil on the bottom, either individually or as packaged suites. The requirements for such systems are significant. The results must be processed and products generated quickly; the expectation is that each day's results would be available in time to support decision making for the next day's response actions. Furthermore, the spill conditions can change rapidly so the turnaround time for both data processing and repeat surveys must be quick. The systems must be able to handle highly variable spatial scales that change daily. The patch size, oil thickness, and the bottom substrate types will be highly variable for different spills and within a single spill. The products should include ability to determine the presence or absence of oil on the bottom and the amount of oil present within selected areas. The ultimate goal is to generate georeferenced maps of the distribution and amounts of oil over time; however, different detection systems could be used in parallel or sequence to first detect the presence of submerged oil, then target these areas with a finer-scale approach to actually map the oil distribution. Existing technologies should be evaluated for their application for use during spill emergencies. It is important to include experts in submerged oil spills during the evaluation of promising technologies so that realistic assumptions are made on oil behavior and operational constraints. Limitations, such as water clarity, oil properties, oil thickness, minimum patch size, water depth, substrate types and data acquisition and processing times, should be clearly identified. Recommendations should be made for laboratory and field testing of the most promising technologies.

Evaluation of New Technologies for Detection and Monitoring of Oil Suspended in the Water Column

Spills of heavy oils can become suspended in the water column under a range of conditions. A negatively buoyant oil can break into small droplets and be carried by currents, such as in a river. Oil can strand on a shoreline and pick up sediment, and the negatively buoyant oil:sediment mixture can be eroded from the shoreline and be transported by tidal or riverine currents. Oil on the bottom can be episodically resuspened into the water column by storm or flood events. The oil or oil:sediment mixture can be suspended anywhere in the water column, from just below the surface to rolling along the bottom. The suspended oil can occur as liquid droplets or semi-solid masses in sizes ranging from millimeters to meters in diameter. New technologies, such as acoustic systems or chemical sensors, are needed to detect the presence of suspended oil, estimate the concentration of oil, and monitor changes in concentration over time. The ability to detect the size of suspended oil particles is also important. Applications could include stationary systems that could be deployed near water intakes or downcurrent of the spill to detect the oil spread and towed systems to search for oil in the water column. Existing technologies should be evaluated for their application for use during spill emergencies. It is important to include experts in submerged oil spills during the evaluation of promising technologies so that realistic assumptions are made on oil behavior and conditions. Limitations, such as water clarity, suspended sediment concentrations, oil properties, water depth, current speeds, and data acquisition and processing times, should be clearly identified. Recommendations should be made for laboratory and field testing of the most promising technologies.

Refinement of Low Technology Methods for Detection and Monitoring of Submerged Oil

At spills of heavy oil where the oil was suspended in the water column, responders have devised simple, low-technology methods for tracking the presence and spread of the oil over space and time. For suspended oil, these methods include stationary systems such as “snare sentinels” which can consist of any combination of the following: a single length of snare on a rope attached to a float and an anchor, one or more crab or lobster pots on the bottom that are stuffed with snare, or a minnow trap or eel pot stuffed with snare and deployed at selected water depths. The configuration depends on water depth and where the oil is in the water column. For oil on the bottom, these methods include different types of trawled chain drags that vary from a single chain with a few snares, to the large V-SORS with an 8-ft pipe and 28 chains with many snares. Methods are needed to calibrate the degree of oiling on the snares with the amount of oil encountered for both types of systems. Currently, it is not possible to determine the particle size, number of particles, or percent oil cover in the water column or on the seafloor based on the visual observations of oil on these systems. It is not possible to determine if the chain drags encountered one large patch along the distance of the drag or multiple small patches. Also, information is needed on the efficiency of oil pickup by the snares and the rate of oil washoff from the snares. Laboratory tests could be conducted to determine oil pickup and washoff rates on snares under water at different flow rates, oil types, and temperatures. An operations manual with specifications for fabrication of the different configurations and protocols for their deployment, based on the many recent experiences, would be of value to future response teams. Construction and deployment techniques to improve survival and maintenance of both stationary and trawled systems are needed.

Development of a Conceptual Model or Decision Template of the Conditions Under Which Oil Submerges and Recommendations for Additional Research to Fill Data Gaps

In 1999, the National Research Council published the report on Spills of Nonfloating Oils: Risks and Response. This report contained a conceptual model of the combination of factors affecting the potential for an oil to become submerged and whether the oil would sink or suspend in the water column. These factors included the oil:water density ratio, current speed, and sediment interaction. Research is needed to update and refine this model to include factors such as oil viscosity, pour point, etc. and include special cases such as burn residues and emulsified fuels. The results of this assessment would be identification of additional research needed to better understand and predict oil:sediment interactions for different sediment grain sizes, energy thresholds for oil particle remobilization and breakup, bottom substrate types and dynamics that could affect submerged oil behavior, and the size, composition, and distribution of submerged oil particles.

Evaluation of Observation Systems Needed During Submerged Oil Spills

Spills of submerged oil trigger the need for real-time data on current profiles (surface to bottom), wave energy, suspended sediment concentrations, detailed bathymetry, seafloor sediment characteristics, and sediment transport patterns and rates. These data are needed to validate or calibrate models (both computer and conceptual), direct sampling efforts, and predict the behavior and fate of submerged oil. The first phase would be to identify the types and resolution of data needed. The second phase would be to develop a database or clearinghouse of existing data sources, such as regional integrated ocean observing systems and maps and GIS summaries compiled by the U.S. Geological Survey Coastal and Marine Geology Program on seafloor sediment character and textural data (e.g., usSEABED data system and the National Seafloor Mapping and Benthic Habitat Programs). The third phase would be to identify data gaps and evaluate possible systems that could be deployed on scene during spills. Such systems might include acoustic doppler current profilers, dye tracer studies, rapid seafloor mapping systems, and underwater camera or video systems that could record episodic events. Operational constraints such as system reliability, sensitivity to changing conditions, required deployment methods, costs, data retrieval options, and turnaround times for data processing must be considered in evaluating potential systems.

Development of Seafloor Habitat Maps to Predict Oil Interaction, Impacts, and Cleanup Options for Submerged Oil Spills

There is a well-established understanding of how oils interact with intertidal habitat, which is embodied in the concept of the Environmental Sensitivity Index (ESI) ranking of shorelines. The ESI rank of a shoreline is based on the predicted behavior of oil once stranded, the natural rates of removal, the effectiveness of different cleanup options, and the likely impacts of oil and cleanup for each shoreline type. The ESI ranking is an integral component of oil spill planning, response, and restoration. A similar understanding and classification of seafloor habitats, related to the interaction, impacts, and cleanup options resulting from submerged oil, would improve assessment of potential effects and drive decisions on appropriate cleanup options and endpoints, including natural recovery. The first phase would be to conduct the research necessary to create the classification scheme based on geomorphology, sediment characteristics, benthic resources, etc., focusing on those areas of highest risk of having spills of submerged oil. This effort should be conducted in close coordination with on-going benthic habitat mapping being conducted by the U.S. Geological Survey, Fishery Management Councils, and other organizations.

Studies to Determine the Weathering and Fate of Submerged Oil

In past cases of submerged oil spills, the spilled oil was either a very heavy crude oil or a heavy refined product such as slurry oil, No. 6 fuel oil, heavy industrial fuel oil, or heavy cycle gas oil. These refined products are not standard mixtures; rather, they vary widely in composition depending on the sources used to create these blended products. Very little basic characterization studies have been conducted on these oil types, and no studies have been conducted on weathering rates under water, either suspended in the water column or accumulated on the seafloor. Laboratory studies are needed to determine key parameters under typical spill conditions for a range of short- and long-term weathering processes including dissolution rates (from small particles to large mats), oxidation, formation of skins, effects of sedimentation and burial, biodegradation, etc.

Development of 4-D Transport Models of Submerged Oil

The ability to predict the transport of submerged oil on short- and long-term scales is essential to the decision-making process on protection priorities and methods, risk assessment (e.g., when to shut down or restart water intakes), the need for and timing of cleanup efforts, and assessment of the potential for long-term impacts. 4-D models are needed to predict the transport of oil suspended in the water column and oil that is being transported on the bottom. Transport of oil in the water column and on the bottom will be dependent on properties of the oil, characteristics of the water body, and properties of suspended or bottom sediment. Time and space scales of interest are likely to be significantly different than those associated with floating spills. Visual confirmation of model performance will not be readily available to forecasters for submerged oil events. These factors contribute to a very complex set of needs for development of reliable 4-D modeling. Forecasting the fate and behavior of submerged oil provides answers to initial operational questions (e.g., what water intakes might be threatened? where should recovery or sampling efforts be focused? how long until the oil is below a given concentration?); however, answering questions on impacts requires integration of fate and transport with biological effects and toxicological modeling. The conceptual model outlined in the NRC report should be considered a starting point, with initial research efforts focused on identifying model components or parameters and data needed to start building more complex modeling capability. Additional studies must be identified to fill those needs, such as how to predict oil particle size distributions, how the oil will interact with sediments, how stickiness of the oil will affect sediment and bottom interactions, coalescence and settling rates of particles, quantification of weathering rates, determination of energy conditions that lead to mobilization of oil on the bottom, etc. Once the physical transport and weathering components of the model are developed and validated, the next step would be to develop integrated models that include toxicological and biological components to support ecological assessments of potential impacts.

Evaluation of Options to Contain Oil on the Seafloor

The only successful containment of oil on the bottom has occurred naturally, where the oil accumulated in low-flow zones or existing depressions on its own. In more exposed settings, remobilization and spread of oil on the bottom greatly decreases the effectiveness of recovery operations which are usually difficult and slow to reposition. Various containment methods have been proposed, including bottom booms, filter fences, and combinations of trenches and berms. The strategy of containing oil on the bottom, under conditions where it can move or is moving, should be similar to those using booms to divert floating oil to recovery devices; that is, containment must be closely coupled with recovery. Options would have to be easily and rapidly deployed. Since few options would be effective over a range of bottom current conditions and types of oil, it would be important to specify the conditions under which the system is most likely to be effective.

Evaluation and Recommendations on Options to Recover Oil Suspended in the Water Column

Efforts to contain and/or recover suspended oil have focused on different types of nets, either ad hoc use of fishing nets or specially designed trawl nets. The research conducted on design of trawl nets for recovery of emulsified fuels would be a starting point. However, the overall effectiveness for large spills is likely to be very low.

Evaluation and Recommendations to Improve Recovery of Oil on the Bottom

Recovery of submerged oil on the bottom requires multiple systems for picking up the oil, separating the oil, water, and sediments, and treating the waste streams. Different techniques have been used, with varying success. Existing methods need to be refined and new approaches need to be devised to address the following problems: 1) design of nozzles to reduce the amount of water intake during underwater pumping of viscous oils; 2) increasing the pump rate of diver-directed vacuum systems, such as use of powered sleds and techniques to concentrate the oil prior to pumping; 3) use of remotely operated vehicles to pump oil from the seafloor at depths beyond those safely conducted by divers; 4) modification of dredges (which have high recovery rates) to minimize the amount of water and sediment recovered; 5) improved oil separation and decanting systems that will reduce separation time, improve throughput, allow discharge of decant water back into the environment without further treatment, and reduce costs. Because of the infrequency of submerged oil spills, improvements should build on existing systems and methods (including adaptation of surface recovery tools), be portable, and be deployable on vessels of opportunity.

Development of Guidelines for Protecting Water Intakes

Protection of water intakes is of high priority during submerged oil spills, yet there are no guidelines for the thresholds of particulate oil for different types of water intakes and treatment systems. Also, there is a need for improved technologies and engineering guidelines for deployment of systems that will protect water intakes for a range of flow and current conditions. The design of filter fences, curtains, or air bubble curtains during spill emergencies has been ad hoc and of uncertain effectiveness. The guidelines should provide the information needed by operators to understand the risks to water intakes and make the decisions on when to shut down/restart an intake. The guidelines should describe effective protection methods and treatment systems for different types of conditions.

Development of Protocols for Field Data Collection at Spills of Submerged Oil

Spills of submerged oil provide many challenges for field data collection, for both the short-term collection of ephemeral data and longer-term monitoring of impacts of residual oil exposure. There are many needs to improve the capability to assess potential impacts. Sampling designs with adequate statistical power are needed for conditions where the oil and resources at risk are both highly variable in space and time. Sampling methods need to be evaluated and modified for collection of samples (water, sediment, tissues) where the oil contamination includes bulk oil particles of widely varying dimensions. In particular, sampling equipment appropriate for use during the emergency phase of the spill needs to be identified and modifications developed so it can be quickly deployed to the field. Monitoring methods are needed to observe and quantify the behavior of organisms in oiled habitats to assess sublethal impacts of exposure to residual oil on the seafloor and in sediments. Cost-effective methods and equipment are needed to support long-term assessments. The study should include a summary of recommended equipment and methods for different types of samples.

Improving the Understanding of the Sources of Toxicity and Pathways of Exposure for Submerged Oil

Heavy oils are poorly characterized in terms of their chemical composition and identification of the compounds that cause both acute and chronic toxicity. One main concern is that these oils are mixtures that change in composition frequently and may include additives that are batch-specific. Thus, initial studies are needed to identify different groups of heavy oils at risk of becoming submerged when spilled, perhaps regionally, then to develop a database on the types and ranges of concentrations of key compounds in representative oils, including PAHs and non-PAHs that have toxicity implications. For representative oils from each group, studies are needed to assess the acute and chronic toxicity via different pathways of exposure, including dissolution, exposure to particles, smothering, exposure to bulk oil on the surface, exposure to bulk oil in sediments, and ingestion. Studies are also needed to assess the risk of tainting to species of recreational and commercial importance. Studies and ecological risk assessments of marine and aquatic waste sites may provide insights.

Assessment of the Ecological Services and Functions of Benthic Habitats to Support Injury Assessment and Scaling of Restoration Options

Injuries to habitats resulting from an oil spill are often quantified as an adverse change in the ecological services and/or functions of the habitat. Furthermore, restoration options are evaluated as to their ability to restore the lost habitat services/functions usually through habitat replacement projects providing additional services/functions of the same type. Ecological services of habitats include primary production, biogeochemical and sedimentary processes, secondary production, food-web support, fish and shellfish production, and sediment stabilization. There are extensive data and experience in the use of appropriate metrics for intertidal and shallow subtidal habitats; however, there are little data on which to measure ecological services and functions for deeper subtidal habitats. A series of studies is needed to address these limitations. First, studies are needed to identify the subtidal habitat types at greatest risk of exposure to submerged oil. Then, studies are needed to describe the ecological services and functions of these benthic habitats and to identify the metrics most appropriate for scaling of habitat injury. Finally, studies are needed to compile the existing data on productivity (primary, secondary, and tertiary) for these habitats and identify significant data gaps. It is important to coordinate with on-going regional and national efforts to describe and map benthic habitats, to maximize the benefits and application of the study.

Updating of Matrices on Response Options for Detection, Containment, and Recovery of Submerged Oil

In 1999, the National Research Council published the report on Spills of Nonfloating Oils: Risks and Response. This report contained tables that summarized the uses and limitations of various methods for detection, containment, and recovery of oil suspended in the water column and accumulated on the seafloor. For each method, these tables included sections on: description of the method; availability of equipment, logistical requirements, coverage rate, data turnaround, probability of false positives, operational limitations, pros, and cons. Once additional research has been completed to evaluate new and promising technologies, as described above, these tables should be updated and a new response guide generated as a tool for planners and responders for submerged oil spills. The response guide should be designed to assist Area Committees who need to revise Area Contingency Plans to include response to spills of submerged oil.

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Appendix A

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December 12-13, 2006
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