Sunken Oil Detection and Recovery Operational Guide

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Operational Guide

1 Scope

1.1 Introduction and How to Use This Guide

This Operational Guide is a companion document to the technical report, *Sunken Oil Detection and Recovery*, which identifies and documents current best practices and alternative technologies possessing the potential to more effectively detect, contain, and recover sunken oil, defined as the accumulation of bulk oil on the bottom of a water body. The technical report includes summaries and lessons learned for 36 case studies of oil spills where a significant amount of the oil sank. For each technology, it includes a detailed description of the method, advantages and disadvantages, and summary tables—the kinds of information needed to select the most effective approaches to sunken oil detection and recovery. Please refer to the technical report for supporting information not in this guide.

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 bottom of the water body. Sometimes it does all three: floats, suspends, and sinks. Furthermore, oil that has sunk to the bottom can become re-suspended and spread by currents. Terminology to describe these various behaviors can be confusing; thus, in this guide, the following terminology is used.

— **Floating oil**—Spilled oil that is on the surface of the water.

— **Submerged oil**—Spilled oil that is in the water column, below the water surface, including oil that is in temporary suspension due to turbulence and will refloat or sink in the absence of that turbulence.

— **Sunken oil**—Spilled oil that is on the bottom of the water body.

This guide addresses only sunken oil.

1.2 Section Descriptions

There are six subsequent sections to this guide.

— **Section 2: Determine the Potential for the Oil to Sink under the Spill Conditions**

This section provides guidance on when to expect that an oil may sink, either initially or later due to processes such as weathering and sediment interactions. It includes a chart to help determine if an oil can sink initially based on its density or API gravity and the salinity of the receiving water. It also includes a chart that shows how turbulence and sediment interaction can cause a floating oil to submerge or sink over time.

— **Section 3: Select Sunken Oil Detection, Delineation, and Characterization Techniques**

This section includes a checklist of the types of information you will need about the oil and spill conditions to start evaluating which sunken oil detection options may be effective for the spill. There is a list of action items to guide the development and approval of a sunken oil detection plan. It also includes tabular summaries of the advantages and limitations of possible options, along with a matrix to guide selection of the best combination of options.

It is important to note that oftentimes multiple detection, delineation, and characterization methods should be used, in combination and/or in sequence. All remote detection methods require ground truthing or need bottom sampling to determine the oil thickness on the bottom or determine the oil's viscosity and thus pumpability.

— **Section 4: Determine if there are Feasible Sunken Oil Containment Techniques**

This section notes that containment of sunken oil may not always be feasible. It includes summaries of the advantages and limitations of possible options under mostly low-flow conditions.

— **Section 5: Select Sunken Oil Recovery Techniques**

This section includes a checklist of the types of information you will need about the oil and spill conditions to start evaluating which sunken oil recovery techniques may be effective for the spill. There is a list of action items to guide the development and approval of a sunken oil recovery plan. It also includes tabular summaries of the advantages and limitations of possible recovery techniques, along with a matrix to guide selection of the best combination of techniques.

— **Section 6: Waste Stream Management**

Because waste generation during sunken oil recovery operations is a very important consideration in both selection of the removal method and the types of waste stream treatment methods to be implemented, this section provides guidance on best practices for handling the oil, liquids, and solids generated during a response.

— **Section 7: Safety Considerations**

Safety is of paramount importance during all phases of sunken oil detection and recovery, as it is during any response. Therefore, this section includes safety considerations throughout the response. It also includes a checklist of the issues to consider when developing a plan to conduct sunken oil detection and recovery operations, including:

— general safety;

— equipment mobilization and heavy lift operations;

— hydraulic submersible pumps and transfer operations;

— diving operations.

2 Determine the Potential for the Oil to Sink Under the Spill Conditions

Key points include the following.

— The API gravity or density of the oil relative to that of the receiving water will determine if the oil will sink initially after release to a water body.

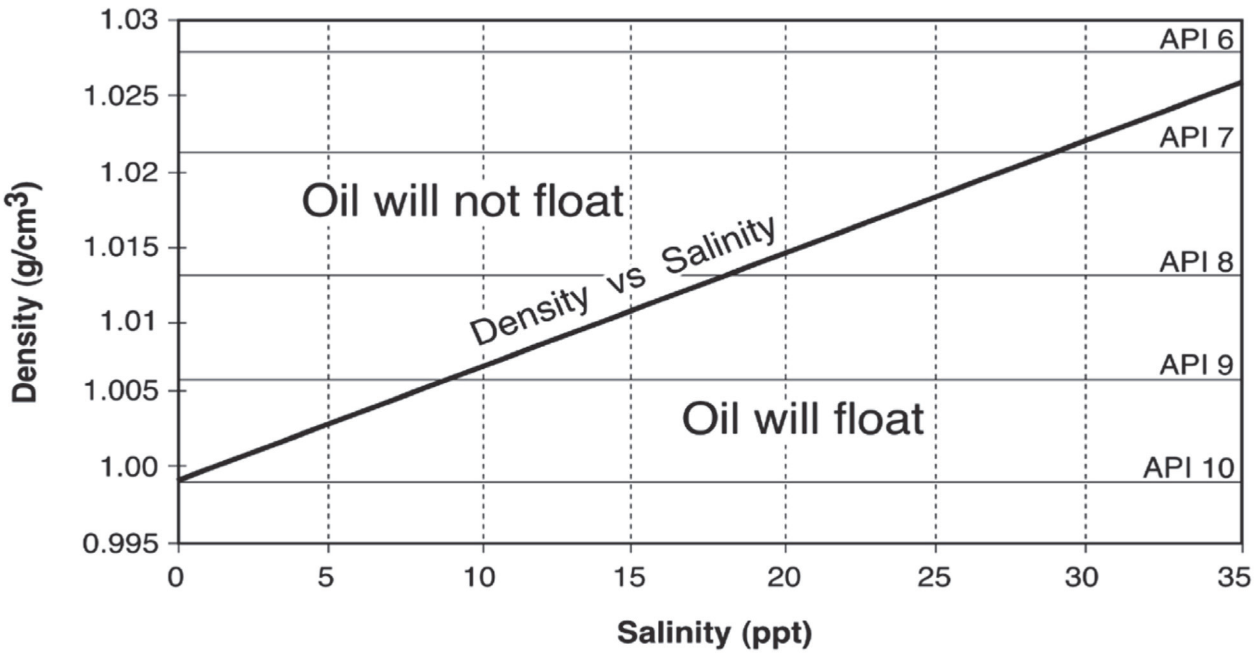
— Over time, weathering or interaction with sediment can cause a floating oil to sink.

— Floating oils that may sink are generally very heavy crude oil, heavy fuel oils, or diluted bitumen products.

Determine the potential for the spilled oil to sink initially.

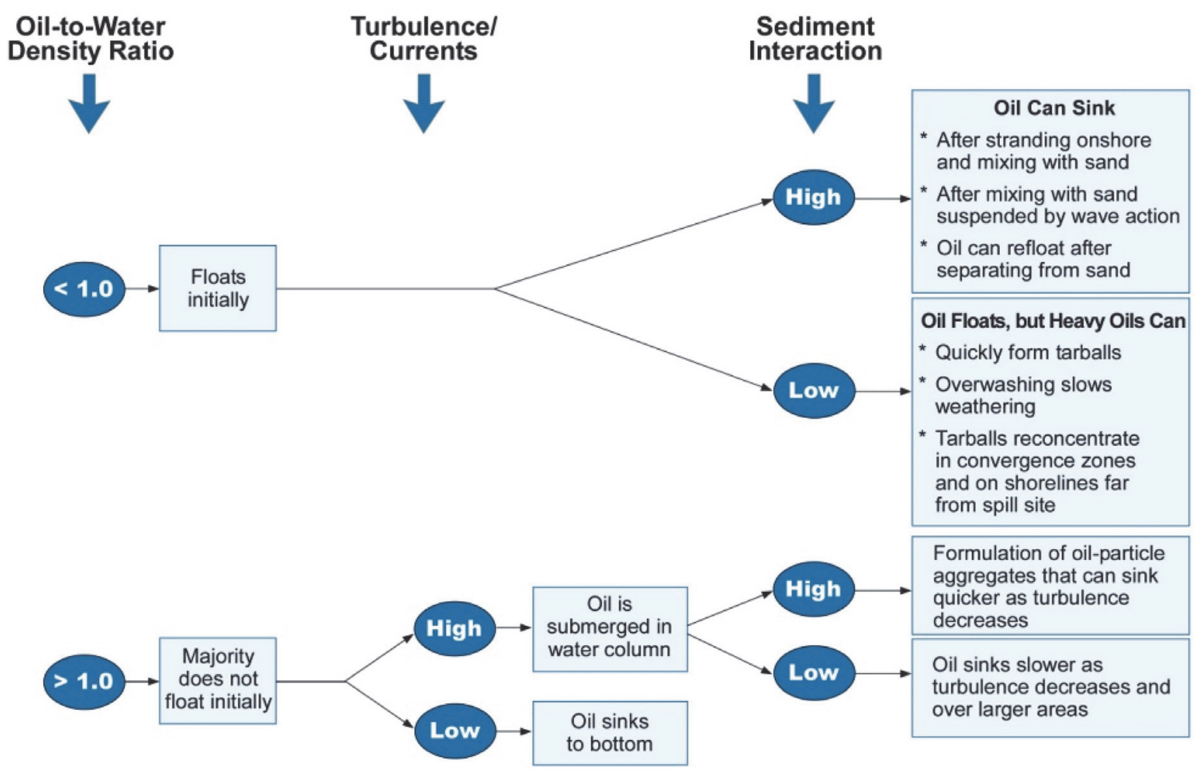
— Determine the API or density of the fresh oil and use Figure 1 and Figure 2 to determine if it will sink initially in the receiving water.

— In freshwater, oils with an API of less than 10 or a density of greater than 1.0 g/cm^3 will sink if the currents are weak or turbulence is low.



NOTE Oils with values below the line will float initially; oils with values above the line with not float initially (modified after NRC, 1999).

Figure 1—Relationship Between Density and API Gravity and Water Salinity



NOTE Modified after NRC, 1999.

Figure 2—Conditions by Which Oils Can Sink Based on the Density of the Oil Relative to the Receiving Water, Turbulence, Currents, and Sediment Interaction

- In seawater, oils with an API of less than ~6.5 or a density of greater than 1.03 g/cm^3 will sink if the currents are weak or the turbulence is low.
- In estuarine waters, be aware that the oil might be suspended in the water column in the freshwater part of the estuary or river, then refloat once it reaches the higher salinity water closer to the mouth of the estuary.
- Conversely, oil that floats or is submerged in estuarine waters may become submerged or sink if transported into less dense freshwater.
- If the currents or turbulence are strong, oils heavier than the receiving water will become suspended in the water column and only sink in low-flow areas downcurrent of the release. These low-flow and low-energy areas should be targets for searching for sunken oil.

Determine the potential for the spilled oil to sink over time.

- Experience has shown that oils that initially float can sink after mixing with sediment. This can occur by two pathways.
  - Floating oil that mixes with sediment after being stranded on a beach can be reworked and moved seaward by wave action to sink in the adjacent nearshore waters.
  - Floating oil can mix with sand in the surf zone and sink, without ever stranding onshore.
- Some oils are lighter than water initially but become close to or even heavier than the density of freshwater once the lighter fractions are lost by evaporation. These oils can sink as either bulk oil or oil-particle aggregates on the bottom of the water body.
- Highly viscous oils can have an increased risk of sinking over time.
  - They can entrain a lot of free water, which can increase their density.
  - They tend to be stickier, which can increase the amount of sediment uptake if stranded on the shoreline or mixed with sediments in the water column, which can increase their density.

3 Select Sunken Oil Detection, Delineation, and Characterization Techniques

Key points include the following.

- Stand up a Sunken Oil Detection, Delineation, and Characterization Group responsible for methods evaluation as soon as it is determined that there is a risk of oil sinking.
- Start mobilizing equipment as soon as possible.
- Recovery should be closely coupled with detection because sunken oil can quickly become remobilized, reducing the overall effectiveness of the response. Thus, evaluation of recovery methods should start as soon as it is confirmed that the oil may sink.
- Include equipment redundancy and alternatives to the preferred method(s) in the plan because of frequent breakdowns, changing conditions, and uncertainty in which methods are likely to be most successful.
- Refer to the matrices in Table 1 and Table 2 on the advantages and disadvantages of sunken oil detection, delineation, and characterization options and the summaries in Table 3 to guide selection of the best options for the spill conditions.

Table 1—Matrix to Evaluate Techniques for Detection, Delineation, and Characterization of Sunken Oil

Red = not likely effective; yellow = may be effective; green = most likely effective

	Sonar Systems	Camera/ Video	Acoustic Camera	Diver Observations	Towed Sorbents	Stationary Sorbents	Visual Observations	Bottom Sampling	Manual Shovel Pits	Laser Fluorosensor	Water Column Sampling
Water Depth (ft)	**10 to 1000**	**10 to 1000**	**10 to 1000**	**5 to 190**	**5 to 100**	**5 to 100**	**0 to 30**	**0 to 1000**	**0 to 5**	**10 to 100**	**5 to >1000**
Water Visibility											
— >30 ft	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green
— 5 to 30 ft	Green	Yellow	Green	Green	Green	Green	Yellow	Green	Red	Green	Green
— <5 ft	Green	Red	Green	Yellow	Green	Green	Red	Green	Green	Yellow	Yellow
Availability	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow
Substrate Type											
— Sand	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
— Silty Sand	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
— Mud	Green	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Green	Green
Bottom Obstruction	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Red	Green	Green
Oil Patch Size											
— <0.1 ft^2	Red	Green	Yellow	Green	Yellow	Yellow	Yellow	Red	Yellow	Green	Yellow
— 0.1 to 1 ft^2	Red	Green	Green	Green	Yellow	Yellow	Green	Red	Yellow	Green	Yellow
— >1 to 10 ft^2	Yellow	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Yellow
— >10 ft^2	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Yellow
Oil Thickness	Yellow	Yellow	Red	Green	Yellow	Red	Yellow	Green	Green	Red	Red
Buried Oil	Yellow	Red	Red	Yellow	Yellow	Red	Red	Green	Green	Red	Yellow
Sensitive Habitat	Green	Green	Green	Green	Red	Green	Green	Yellow	Yellow	Green	Green
False Positives	Yellow	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green
Coverage Rate	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Data Turnaround	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Yellow	Green	Yellow	Yellow

Table 2—Advantages and Disadvantages of Sunken Oil Detection, Delineation, and Characterization Technologies

Advantages	Disadvantages
Side Scan Sonar >350 kHz	
— Rapid area coverage. — Good bottom oil detection shown in T/B *Apex 3508* and T/B *DBL-152* spills. — Able to detect oil patch as small as 1 m^2.	— Requires ground-truth for absolute validation of sonar data. — Will not be able to detect buried oil.
Multibeam Echo Sounder >350 kHz	
— Easy to deploy and provides pseudo-imagery of the bottom. — Provides bathymetry maps showing low spots where sunken oil could collect. — Bathy data may be needed to support recovery Ops.	— Resolution is lower than side scan sonar making interpretation/detection of oil difficult.
Sub-bottom Profiler 4 to 24 kHz Chirp	
— Provides potential for detection of oil mats in the shallow sub bottom region when used in conjunction with side scan sonar and multibeam echo sounders.	— Cannot detect sunken oil on the surface. — Data are difficult to interpret due to limitation in resolution of layering in the sub bottom region.
3D Scanning Sonar	
— 3D mapping and tracking of submerged or subsurface oil. — Real-time observation of sunken oil on the bottom for recovery operations.	— Limited availability in the commercial offshore market.
Digital Still Camera	
— Very high resolution images.	— Discrete images do not provide continuous images of the bottom. — Water turbidity limits effectiveness.
Video Camera	
— Provides continuous color or b/w images of the bottom. — Low-light b/w cameras facilitate imaging in high turbidity conditions by eliminating requirement for light sources.	— Water turbidity limits effectiveness for imaging.
SPI Camera	
— Provides digital images of near sub-bottom for identification of sunken or buried oil layers and benthic communities.	— Fouling of SPI window due to oil in water column or sunken oil on the bottom.
Acoustic Camera	
— Provides acoustic imaging in very high turbidity water conditions. — Could be deployed at a site to monitor sunken oil behavior over time or during events such as storms.	— Acoustic images have limited resolution when compared to optical images.

Table 2—Advantages and Disadvantages of Sunken Oil Detection, Delineation, and Characterization Technologies (Continued)

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td colspan="2">Diver Observations</td></tr>
<tr><td>— Proven effective in detecting, mapping, and recovering sunken oil.
— Quick turnaround on data; divers provide real-time imagery to the surface, may be directed by the diving supervisor and technical specialists while on the bottom, and can immediately communicate observations to the surface.
— Often effective in low to no visibility conditions; divers can feel the oil and changes in bottom topography.
— Accurate determination of oil on bottom; can provide verbal and visual description of extent and thickness of oil and spatial variations.
— Experienced river divers can conduct detection and recovery operations in high current environments that typically restrict ROV operations or towed systems due to bottom obstructions.
— Submersibles and one-atmosphere diving suits may be used to increase depths and bottom times.
— Low false positives.</td><td>— Environmental limitations may include sea state, currents, weather/lightening, water depth, ice/cold water, debris, and dangerous marine life.
— Surface-supplied air diving is limited to 190 feet of salt water (fsw) in the US. Mixed gas, saturation systems, and one-atmosphere suits or submersibles may increase bottom time and depth; will increase project complexity and cost.
— Coverage rate; the length of the diver's umbilical limits movement away from the dive support vessel.
— Contaminated water diving requires special equipment, training, and decon procedures.
— Diving in high-current rivers and ice/cold water requires special training, additional equipment (such as hot water suits and dry suits), and experienced divers.
— Slow; diver movements may be limited by umbilical length and environmental conditions.
— Divers must be replaced routinely to remain within no-decompression limitations and work/rest standards.</td></tr>
<tr><td colspan="2">Towed Sorbents (Heavy)—Sorbents attached to multiple chains attached to a header bar</td></tr>
<tr><td>— Can be towed at up to 5 knots, though usually 3 to 4 knots, thus able to cover a large distance.
— Area swept is about 8 ft.
— Higher confidence that it maintains bottom contact.
— Can vary the length of the trawl to refine spatial extent, to some degree.
— Good positioning capability with onboard GPS; can load assigned tracks into the vessel navigation system.
— Can be used in vessel traffic lanes.</td><td>— Requires larger vessel with crane or A-frame and winch to deploy/retrieve.
— Lots of concern about pipeline and debris snagging.
— Cannot determine where along the trawl the oil occurred; No calibration with actual amount of oil on bottom.
— Longer transects because of handling difficulty.
— Highly dependent on wave conditions.</td></tr>
<tr><td colspan="2">Towed Sorbents (Light)—Sorbents attached to a single chain</td></tr>
<tr><td>— Manually deployed so can be used on smaller boats.
— Can have very short trawls, if needed.
— Can conduct continuous surveys without stopping, towed at 2 to 3 knots.</td><td>— Narrow swath (~1 ft) so less information on patchy oil.
— Concerns about it losing contact with the bottom with wave action.
— Cannot determine where along the trawl the oil occurred.
— No calibration with actual amount of oil on bottom.
— Highly dependent on wave conditions.</td></tr>
</table>

Table 2—Advantages and Disadvantages of Sunken Oil Detection, Delineation, and Characterization Technologies (Continued)

Advantages	Disadvantages
Stationary Sorbents—Detection of oil in the water column or along the bottom	
— Proven to be effective at detecting oil at various depths in the water column and moving along the bottom. — Time-series data very useful to track trends, though requires a lot of data points to be meaningful. — Can be re-deployed as needed as the oil migrates down current.	— Time and labor intensive for deployment, inspection, and replacement. — Can have high loss rates. — No calibration of the efficacy of oil adsorption and it might change over time. — Can not be deployed in active vessel traffic lanes. — Low temporal data on when the oil was mobilized.
Visual Observations by Trained Observers	
— Aerial surveys can cover large areas quickly. — Data are collected in real time, rather than having to view video post-collection. — Observers can adjust their survey once sunken oil is located for better detail. — During water surface surveys, it is possible to stop to take samples to confirm an observation as oil and take photographs.	— Only effective in clear, shallow water during daylight hours. — Not effective for buried oil. — Aerial observations will only identify general areas for ground truthing and more detailed assessment. — Aerial observations are not effective for small, patchy accumulations. — Water surface observations collect data along narrow transects so of limited spatial detail. — Even trained observers can make false positive or negative observations.
Bottom Sampling	
— Allows collection of samples to confirm the presence of oil, either visually or through chemical analysis. — Can be effective in small areas for rapid delineation of a known patch of oil. — Poling method indicated the relative risk of sheening of sunken oil. — Can detect buried oil and indicate oil thickness.	— Only point sample of a very small area. — Not effective in patchy oiling conditions. — Very slow and labor intensive. — Even slower in deep water, rough sea conditions. — Oil may be buried deeper than the sampler can penetrate into the bottom. — Must use a statistically relevant sampling grid to be useful.
Laser Fluorosensors	
— Highly sensitive to oil. — Generates few false positives once calibrated for the sunken oil. — Can be used during day or night.	— Cannot detect buried oil. — Detection ability decreases with water turbidity, distance from the target, and wave height. — Bright, backscattered light (such as from white sand) may saturate the input. — Only one prototype system available, and the latest model has not been tested.

Table 2—Advantages and Disadvantages of Sunken Oil Detection, Delineation, and Characterization Technologies (Continued)

Advantages	Disadvantages
Water Column Sampling	
— Can provide geo-referenced oil locations in real time and at high spatial resolution. — Once oil is detected, the survey can be adapted to sample above potential targets. — Mass spectrometers can determine hydrocarbon composition, allowing differentiation among sources. — Can map gradients of oil levels in the water column, which could be used to identify areas of higher oil accumulations. — Submersible UV fluorometers are readily available and easily deployed and interpreted. — Submersible mass spectrometer technology and availability are improving. — Other sensors can be added to the vehicle to measure other parameters, e.g. salinity, dissolved oxygen, temperature.	— Only works if there are soluble components or small oil droplets in the water column. — The rate of release of soluble oil may decrease to non-detectable levels quickly. — Submersible mass spectrometers require a specially trained team of operators and interpreters.

Table 3—Summary of Sunken Oil Detection Technologies

	Sonar Systems	Still, Video, and Acoustic Cameras	Diver Observations
Description	Sonar systems are utilized to detect sunken oil on the bottom and in the near sub bottom areas.	Visualization devices including still, video and acoustic cameras are utilized to validate the presence of sunken oil.	Professional commercial divers trained, experienced, and equipped for contaminated water diving operations.
Logistical Needs	Support vessels of sufficient size and sea-keeping capability are required to provide an operational platform for the sonar systems. Different sonar systems have specific platform requirements so care must be taken in platform selection to ensure compatibility.	Visualization systems have definite platform requirements depending on technique selected. Diver-operated video devices have specific diver-related logistic requirements as noted for Diver Observations, which must be adhered to.	Diving support vessel/platform; heavy-lift equipment to load compressors, dive control rooms, and other equipment onboard. Emergency transportation to a medical facility with a multi-place decompression chamber. Decompression chamber located on-site as a contingency.
Operational Limitations	Water depth of 10 ft or less establishes an operation limitation on acoustic techniques, although operations in shallower water are possible in certain situations.	Water turbidity limits the functionality of visualization devices with the exception of the acoustic camera which will function in zero visibility water conditions with lesser resolution than optical devices.	Surface-supplied air diving is restricted to 190 fsw. Diving operations are limited by depth, bottom time, visibility, currents, and other environmental conditions.
Pros	Sonar systems are easy to use and have a high area coverage rate for fast establishment of sunken oil locations on the bottom.	Visualization techniques and devices provide visual validation of the presence of sunken oil without the requirement for ground truth of images.	Accurate, immediate observations can be conveyed to the surface. If visibility permits, real-time video can be viewed in the dive control house.

Table 3—Summary of Sunken Oil Detection Technologies (Continued)

	Sonar Systems	Still, Video, and Acoustic Cameras	Diver Observations
Cons	For absolute detection, sonar systems require a ground truth of the detected contact on the bottom to provide positive identification of sunken oil.	Water turbidity limits the capability of visualization devices with increasing turbidity creating decreasing visibility until the acoustic camera is required which provides images of lesser resolution than optical techniques.	Diving in contaminated water is considered a "high-risk" operation requiring thorough planning, safety oversight, trained and equipped personnel, and specialized equipment. The operational limitations noted above combined with diver decontamination requirements often result in a relatively high cost and time-consuming operation.
	Towed Sorbents	**Stationary Sorbents**	**Visual Observations by Trained Observers**
Description	Snares attached to chains are dragged on the bottom at set intervals then pulled up for observation of oiling amount.	Sorbents are suspended in the water column and/or placed in pots/cages on the bottom and inspected at set intervals.	Observers visually detect and record oil on the bottom as seen from aircraft or boats.
Logistical Needs	Light tows (1 chain) can be deployed on small boats. Heavy tows (multiple chains with a header bar) require a vessel with a crane or A-frame and pulley to deploy/ retrieve the tows.	In shallow water, requires minimal support. In deep water, requires davits or winches to deploy and retrieve them.	Aircraft or boat; GPS units to record locations and geo-reference photos; field computers to record descriptions.
Operational Limitations	Standard safety limits for boat operations. No use possible in the surf zone or where snagging on the bottom is of concern. More difficult to deploy/retrieve in >100 ft water depths.	Standard safety limits for boat operations. No use possible in the surf zone or vessel traffic lanes. More difficult to deploy/retrieve in >100 ft water depths.	Can only be used during daylight periods. Standard safety limits for aerial and boat operations, including no surveys possible in the surf zone.
Pros	Effective in low visibility conditions; can be used in vessel traffic lanes; can vary the tow length to refine spatial extent; can be used to confirm removal.	Proven effective at detection of oil moving at various depths in the water column; time-series data are useful to track trends; can be re-deployed as the oil migrates down current.	Aerial surveys can cover large areas quickly and can be adjusted once oil is found to get more detail.
Cons	Do not know where along the tow the oil occurred or how much oil is present (one larger patch or lots of small patches); cannot determine duration of bottom contact or efficacy of oil adhesion; labor intensive.	Very time and labor intensive; can have high loss rates, no calibration of the efficacy of oil adsorption and changes over time; cannot be deployed in active vessel traffic lanes; low temporal data on when the oil was mobilized during the deployment.	Cannot detect buried oil; effective only in clear water and daylight; aerial surveys require ground truth; boat surveys are slow; not safe for work in surf zone, strong currents.

Table 3—Summary of Sunken Oil Detection Technologies (Continued)

	Grab or Core Sampler	Wading-Depth Manual Shovel Pits	Laser Fluorosensors	Water-Column Sampling
Description	Point locations are surveyed with sediment grabs or cores to bring a sample to the surface for description.	A narrow blade shovel is used to dig shallow pits underwater, bringing the sediments to the surface for oil description.	Laser is used to excite the aromatic compounds in the oil to emit light with a unique pattern.	Underwater unit (fluorometer and/or mass spectrometer [MS]) is towed above the bottom to detect oil dissolved/ dispersed in the water.
Logistical Needs	In shallow water, requires minimal support. In deep water, requires a winch, A-frame, etc.	Can require a large team, depending on safety issues and access. Requires safety boat/crew at site, boats for access to sites with no land access.	Unit must be towed close to the bottom; could be deployed on ROV as well.	Units are deployed from boats; navigation system used to record location and measurements in 3D.
Operational Limitations	Standard safety limits for boat operations. No surveys possible in the surf zone.	Many safety limits. Requires wading water depth, low waves and currents, light wind, no lightning, and warm water.	Detection decreases with water turbidity, distance from the target, and wave height. Bright light can interfere. Water depths accessible by boat.	Standard safety limits for boat operations. No surveys possible in the surf zone. Water currents must be low enough to minimize transport of the plume.
Pros	Samples can be collected for confirmation; can detect buried oil and oil thickness; poling can indicate the risk of sheen generation.	May be best option to detect buried oil in the surf zone; can work closely with Operations to achieve rapid removal after delineation of treatment area.	Highly sensitive, few false positives; can be used day or night.	Can map at high spatial resolution and differentiate among oil sources in real time, allowing detailed mapping of targets.
Cons	Slow, labor intensive, not effective for patchy oil; weather and sea limits.	Narrow operational limits, slow coverage rate, and limited to depth of digging.	Cannot detect buried oil; not effective in turbid water; not proven operationally.	Only effective if there is oil in the water; currents can transport the oil away from source; MS requires special teams and gear.

The following is a checklist of actions and information needs for the Sunken Oil Detection Group.

Site Characteristics

- ❑ Survey area (highest priority, next priority): ______________________________
- ❑ Distance from shore: ______________________________
- ❑ Water depth range: ______________________________
- ❑ Water visibility range: ______________________________
- ❑ Water current speed and direction:

  Surface: ______________________________

  Subsurface: ______________________________
- ❑ Wave conditions: ______________________________
- ❑ Substrate type: ______________________________
- ❑ Bathymetry (oil accumulation areas): ______________________________
- ❑ Sensitive habitats in survey area: ______________________________

  Biological resources: ______________________________

  ____

  Cultural/historic resources: ______________________________

  ____
- ❑ Types of obstructions on the bottom: ______________________________
- ❑ Other restrictions to be considered: ______________________________
- ❑ Landowner issues: ______________________________

Evaluate/select the best detection techniques.

1) Select possible detection techniques based on water depth.
2) For the selected techniques, filter them based on water turbidity.
3) Factor in substrate type, presence of bottom obstructions, patch size, whether there is sensitive habitat, and potential for false positives.
4) Refer to the technical report for coverage rates for different sonar systems to estimate the number of days needed to complete the survey.

5) Determine availability and mobilization time. Remember, experienced operators will greatly improve the effectiveness and timeliness of the results.

6) Involve potential qualified contractors in the planning process as they can provide valuable feedback on applications of various techniques. In discussions with potential qualified contractors, provide the site characteristics listed above. Be clear about expected turnaround time, deliverables, and what logistics will be provided.

7) The Sunken Oil Detection Group reviews the detection techniques that are most likely to be effective for the spill conditions and the qualifications of potential contractors to provide the equipment and trained operators.

8) Results of the review are documented in a draft Sunken Oil Detection Plan that is submitted to the Environmental Unit for review and compliance with federal and state permitting and consultation requirements, including:

   a) Section 7 of the Endangered Species Act (ESA),

   b) Essential Fish Habitat (EFH) under the Magnuson Stevens Fisheries Conservation and Management Act,

   c) Section 106 of the National Historic Preservation Act (NHPA),

   d) State Historic Preservation Office,

   e) federally recognized Native American Tribal Governments.

9) After review by the Environmental Unit and with appropriate changes, the Planning Section Chief submits the final Sunken Oil Detection Plan to the Unified Command for review and approval.

10) Once the Unified Command has approved the plan, prepare a ICS 213 resource request form and route through Finance and Logistics for approval and notification of the selected contractor(s).

11) Once approved, contact the contractors to start the planning for the survey.

4 Determine Whether There Are Feasible Sunken Oil Containment Techniques

Oil usually accumulates on the bottom where currents and turbulence are low. However, sunken oil can be remobilized when turbulence increases, such as during higher-flow conditions in rivers and higher-wave conditions in nearshore areas. Containment of sunken oil may not always be feasible. If containment is being considered, use the information on site conditions in Section 3 to determine if there are feasible techniques to contain the oil under the spill conditions. Only those sunken oil containment techniques that have shown to be effective are listed in Table 4.

5 Select Sunken Oil Recovery Techniques

Key points include the following.

— Stand up a Sunken Oil Recovery Group responsible for methods evaluation as soon as it is determined that there is a risk of oil sinking.

— Start mobilizing equipment as soon as possible.

— Safety of the responders and public should remain the top priority throughout the recovery operation (reference Section 7 of this guide).

Table 4—Advantages and Disadvantages of Sunken Oil Containment Technologies

Advantages	Disadvantages
Filter Fences or Gabion Baskets Filled with Sorbents	
— Constructed of readily available materials. — Effective at removal of oil droplets in the water column. — Can be deployed at and just below the surface or on the bottom, depending on water depth and where the oil is moving in the water column or along the bottom. — Closed-loop snare may be more effective.	— If currents are >1 ft/s, there can be scouring of the bottom in front of the baskets and less effective oil recovery. — Not feasible to deploy in high-flow areas. — Can completely fail and be swept downstream if flows suddenly increase. — Can only filter the entire water flow in small streams.
Sediment Curtains	
— Curtains constructed of hydrophilic materials can sorb oil as well as slow the flow and increase sedimentation. — Half-curtains or partial currents can be deployed at angles to the flow in moderate-flow areas to slow currents and increase deposition of oiled sediments.	— Full curtains are only effective in low-flow areas, where the curtain can maintain contact with the bottom, where risk of oil mobilization is also low. — Requires measurement of current speeds at surface and/or bottom and knowledge of hydraulics for proper design. — -Can interfere with navigation.
Air Curtains	
— Does not interfere with navigation. — Could help bring oil in the water column to the surface.	— Only effective in very low-flow areas, where risk of oil mobilization is also low.
Enhanced Passive Sediment Accumulation	
— Builds on natural processes and uses natural materials that can be left in place. — Does not interfere with navigation.	— Restricted to areas of natural accumulation, which may be sensitive or high-public use areas such as impoundments. — Requires dredging or excavation to remove the accumulated sediment. — Need a good understanding of seasonal flow patterns so sudden floods don't flush the oiled sediments out.

— Recovery should be closely coupled with detection because sunken oil can quickly become remobilized, reducing the overall effectiveness of the response. Thus, start evaluation of recovery methods as soon as it is confirmed that the oil may sink.

— Include equipment redundancy and alternatives to the preferred method(s) in the plan because of frequent breakdowns, changing conditions, and uncertainty in which methods are likely to be most successful.

— Develop and get consensus on cleanup endpoints, which will greatly influence selection of removal techniques and validation methods.

— Refer to the matrices in Table 5 and Table 6 on the advantages and disadvantages of sunken oil recovery techniques; and see Table 7 to guide selection of the best techniques for the spill conditions.

The following is a checklist of actions for the Sunken Oil Recovery Group.

Table 5—Matrix to Evaluate Techniques for Sunken Oil Recovery

Red = not likely effective; yellow = may be effective; green = most likely effective

	Suction Dredge	Diver Vacuum	Diver Pump	Excavator	Grab Dredge	Environmental Clamshell	Sorbents/ V-SORS	Trawls and Nets	Manual Removal Shallow Water	Manual Removal by Divers	Agitation/Refloat
Water Depth (ft)											
— <5 ft	Yellow	Red	Red	Green	Green	Green	Yellow	Yellow	Green	Green	Green
— 5 to 40 ft	Green	Green	Green	Yellow	Green	Green	Green	Yellow	Red	Green	Yellow
— 40 to 80 ft	Red	Green	Green	Red	Green	Green	Green	Yellow	Red	Yellow	Red
— >80 ft	Red	Green	Green	Red	Green	Green	Yellow	Yellow	Red	Red	Red
Water Visibility											
— >5 ft	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green
— <5 ft	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Yellow	Green	Green
Water Current											
— <1 kt	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green
— 1 to 2 kt	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
— >2 kt	Yellow	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Yellow
Wave Height (ft)											
— <2 ft	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green
— >2 ft	Yellow	Green	Green	Yellow	Green	Green	Green	Green	Red	Green	Yellow
Availability	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Green	Green	Green
Oil Pumpability											
— Fluid	Green	Green	Green	Yellow	Yellow	Green	Green	Red	Red	Red	Yellow
— Not Fluid	Red	Red	Yellow	Green	Green	Green	Red	Yellow	Green	Green	Red
Oil Distribution											
— <10 %	Green	Green	Green	Yellow	Red	Yellow	Green	Yellow	Green	Green	Green
— 10 to 50 %	Yellow	Green	Green	Green	Yellow	Green	Yellow	Red	Yellow	Yellow	Green
— >50 %	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Green
Oil Patch Size											
— < 0.1 ft^2	Red	Green	Yellow	Yellow	Yellow	Green	Yellow	Red	Yellow	Yellow	Green
— 0.1 to 1 ft^2	Red	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Green
— > 1 to 10 ft^2	Yellow	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green
— > 10 ft^2	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green
Substrate Type											
— Sandy	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green
— Muddy	Yellow	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow	Red
Bottom Obstructions	Red	Green	Green	Yellow	Red	Red	Red	Red	Yellow	Yellow	Yellow
Buried Oil	Green	Yellow	Yellow	Green	Green	Green	Red	Red	Yellow	Yellow	Green
Sensitive Habitat	Red	Green	Green	Yellow	Red	Yellow	Yellow	Yellow	Green	Green	Red
Removal Rate*	Green	Yellow	Yellow	Green	Green	Green	Red	Yellow	Yellow	Red	Red
Waste Generation**	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Green
Environmental Impact**	Red	Green	Green	Red	Red	Yellow	Green	Green	Green	Green	Yellow
Cost **	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Green	Yellow	Green

* Classified as rapid, medium, or slow.

** Classified as low, medium, or high.

Table 6—Advantages and Disadvantages of Sunken Oil Recovery Technologies

Advantages	Disadvantages
Suction Dredge with Cutter/Auger Head Attachment	
— Common piece of equipment, readily available, easy to transport. — Little to no modifications required for sunken oil recovery. — Can cover large areas quickly with 5 ft to 8 ft swath. — Ability to pump/transport great distances. — Ability to pass large solids, i.e. rocks and debris. — Self-propelled or guide-cable operation. — Adjustable “cut” depth allowing the removal of ±1 in. to several inches in one pass. — Can track and document progress with GPS. — Low manpower requirement to operate. — Amphibious models can operate from 0 ft to 20 ft for small units and up to 40 ft for large units.	— Generates large amounts of water and sediment requiring dewatering, handling of solids, and water treatment. — Only suitable for protected waters. — Non-discriminate recovery, cannot tell the difference between oil and water/sediment. — High rpm pump has the potential to create issues with turbulence that results in oil emulsification and shearing. — Not allowed to work in areas with pipelines, cables, or other obstructions.
Diver-directed Vacuuming	
— Vacuum trucks readily available. — Portable Vacuum Transfer Units (VTUs), while not as prolific as vacuum trucks, are available. — Ability to regulate flow. — Minimal mixing of recovered fluids and solids. — Ability to pass some solids (rocks and debris). — Can handle high viscosity. — Selective recovery provided diver has visibility.	— Rapid loss of effectiveness due to hose distance. — Large, heavy units. — Requires larger vessel or barge if unprotected water. — Small coverage area.
Diver-directed Pumping with Centrifugal Pump	
— Lightweight and portable. — Can pump long distances. — High head pressure, can pump several hundred feet up. — Easily modified to protect from rocks with a “rock box”. — Ability to regulate flow. — Selective recovery provided diver has visibility. — Can introduce steam or hot water to reduce viscosity. — Ability to pass some solids (rocks and debris).	— Not readily available; must locate from dive or dredge contractors, some oil spill response organizations. — Generates large amounts of water and sediment requiring dewatering, handling of solids and water treatment. — High rpm pump has the potential to create issues with turbulence, emulsification, and shearing. — Cannot handle viscous oil other than small amounts moved in large amounts of water. — Small coverage area.

Table 6—Advantages and Disadvantages of Sunken Oil Recovery Technologies (Continued)

Advantages	Disadvantages
Diver-Directed Pumping with Positive-displacement Pump	
— Lightweight and portable. — Can pump long distances. — High head pressure, can pump 100s of feet up. — Easily modified to protect from rocks with rock box. — Ability to regulate flow. — Selective recovery provided diver has visibility. — Can handle very high viscosity oils; can introduce steam or hot water to reduce viscosity. — Ability to pass some solids (rocks and debris). — Low rpm thus minimal mixing of fluids and solids, reducing the potential issues associated with turbulence, emulsification, and shearing. — Can adapt water-injection flange for viscous oil.	— Not readily available; must locate from dive or dredge contractors, some oil spill response organizations. — Lower recovery rates than centrifugal pumps. — Small coverage area.
Excavator	
— Readily available in varying sizes. — Can work from shore for nearshore work. — Can work from vessel or barge. — Amphibious models available but less prevalent. — Can scoop sunken oil with bucket. — Easy addition of a thumb attachment for recovering solid or semi-solid sunken oil. — No issues with rocks or debris. — Can track progress with geo-referenced data.	— Limited to ±20 ft of water. — Difficult to be selective, resulting in additional sediments. — Difficult to manage liquid flowing from bucket during lift. — Large, heavy units. — Requires larger vessel or barge if unprotected water. — Small coverage area.
Grab or Clamshell Dredge	
— Readily available from dredge and construction contractors. — Can work from shore for nearshore work. — Can work from vessel or barge. — No issues with rocks or debris. — Can track progress with geo-referenced data.	— Requires logistical support to store and transport recovered sunken oil and sediment (hopper barge). — Generates large amounts of sediment requiring dewatering, handling of solids, and water treatment. — Liquids not contained, allowing leakage during recovery operation. — Small coverage area.

Table 6—Advantages and Disadvantages of Sunken Oil Recovery Technologies (Continued)

Advantages	Disadvantages
Environmental Clamshell Dredge	
— Available from dredge, construction and environmental engineering contractors. — Can work from shore for nearshore work. — Can work from vessel or barge. — No issues with rocks or debris. — Water-tight seal greatly reduces liquid leakage. — Can track progress with geo-referenced data.	— Not as prevalent as conventional clamshell. — Small coverage area.
Sorbents/V-SORS	
— Can be used in active vessel traffic lanes. — Track lines can be recorded with the vessel's GPS to provide actual survey lines. — Could detect both pooled and mobile oil moving above the bottom, but won't differentiate between them. — Relatively efficient in that large areas could be surveyed. — Readily available; can be sized for the task. — Low tech; easy to train crews. — Can vary the length of the trawl to refine spatial extent.	— Time and labor intensive for deployment, inspection, and replacement. — Susceptible to snagging on the bottom. — Cannot determine where along the trawl the oil occurred. — Difficult to calibrate the effectiveness of oil recovery. — In deeper water, requires a vessel with a boom/pulley and adequate deck space on the stern for handling, inspection, and replacement. — Best suited for recovery of small amounts of oil.
Towed Nets or Trawls	
— Readily available in areas with commercial fisheries. — Experienced operators (fisherman) with vessels capable of effectively towing.	— Difficult to specify size of net openings, have to use what is available. — Leakage of oil through net may occur and hard to monitor. — Cannot be cleaned and returned for intended purpose, thus most likely will be a one-time use. — Will require support to handle/dispose of oiled nets. — May have issues with debris. — May snag on rocks or obstructions.
Manual Recovery Shallow Water	
— Low tech, only requires labor force and hand tools. — Selective recovery, limiting co-collection of water and sediment.	— Slow and labor intensive; requires proper PPE. — Restricted to shallow water <5 ft. — Requires relatively good water clarity for visibility. — Severe weather will suspend operations.

Table 6—Advantages and Disadvantages of Sunken Oil Recovery Technologies (Continued)

Advantages	Disadvantages
Manual Recovery with Divers	
— Relatively low tech, requires divers and hand tools. — Selective recovery, limiting co-collection of water and sediment.	— Slow and labor intensive. — May require extensive logistical support if based off vessel or barge. — Requires properly trained commercial diving crew with contaminated-water diving equipment. — Requires decontamination equipment and trained support personnel. — Severe weather will suspend operations.
Agitation/Refloat	
— Off the shelf items such as pumps and rakes can be used. — Aerators designed for waste water treatment or fish ponds can be modified for sunken oil recovery. — Selective recovery limiting associated recovered water and sediment.	— Slow and labor intensive. — Small coverage area. — Restricted to shallow water <8 ft and relatively low water velocity. — Suspended oil can remain mixed with the sediments and resettle to the bottom after agitation. — Mixes remaining oil deeper into the sediments. — Only effective with liquid oils that are loosely adhered to the sediment and will re-float when separated from the sediment, and where complete containment of the resuspended oil is possible. — Generates high turbidity that can spread downstream.

Table 7—Summary of Sunken Oil Recovery Technologies

	Suction Dredge	Diver-directed Pumping and Vacuuming	Mechanical Removal
Description	Commercially available suction dredge used to recover sunken oil and associated sediments and water. Some models incorporate cutter heads for use in removing sediments.	Divers manually direct a nozzle or stinger at the suction end of a hose to recover sunken oil. System can be based on a vacuum system or pump system utilizing a centrifugal or positive displacement pump.	Mechanical removal involves physically removing sunken oil with an excavator, clamshell dredge, environmental dredge bucket, or other machinery used to grab, scoop, or pick up sunken oil. Works well for recovery of solid or semi-solid sunken oil.
Logistical Needs	Requires the need to handle large quantities of sediments and water associated with recovery.	Contaminated water capable commercial divers, proper diver decon, oil/water/sediment separation and storage.	Platform or barge to work from and hopper barge or suitable storage for recovered sunken oil and associated sediment and water.
Operational Limitations	Smaller units work in depths up to 20 ft, larger units can go as deep as 40 ft. Suited for protected waters only.	Vacuum systems can only lift about 28 ft total. Pumps can push long distances and from great depths.	Excavators are limited to ±20-ft depth. Clamshell and environmental clamshell dredge can work in deeper depths but difficult to control accuracy. All can be operated from shore or from large vessel or barge.

Table 7—Summary of Sunken Oil Recovery Technologies (Continued)

	Suction Dredge	Diver-directed Pumping and Vacuuming	Mechanical Removal
Optimal Conditions	Protected water, relatively shallow, small concentrations of sunken oil.	Larger concentrations "pooled" on the bottom in less than 100-ft depth with good visibility and little to no current.	Viscous or solidified oils in shallow or protected water.
Pros	Effective way to recover small concentrations of sunken oil mixed throughout sediments.	Selective recovery, diver can distinguish between sediment and oil limiting the recovery of associated sediment and water.	Effective way to recover solidified oil with little associated water.
Cons	Generates large amounts of associated water and sediments. Requires sophisticated oil water separation, and treatment/ disposal of oiled sediments and water.	Vacuum systems effectiveness decreases with hose length, centrifugal pumps tend to emulsify and shear oil, complicating separation after recovery; positive displacement pumps recover at slower rates.	Requires geo referenced program to control accuracy. Can end up with large amounts of associated sediments. Disturbs bottom, so may be restricted in sensitive benthic habitats.
	Sorbents/V-SORs	**Manual Removal**	**Agitation/Refloat**
Description	Sorbent material are weighted or attached to a pipe/chain and dragged along the bottom allowing sunken oil to adhere to oleophilic material.	Hand and hand tools are used to pick up viscous oil on the bottom. Can be conducted in shallow water by wading; in deeper water by divers in gear appropriate for contaminated water.	Bottom sediments are agitated by physical disturbance or air injection to refloat the oil for recovery using skimmers or sorbents. Can be conducted from boats or by wading in shallow water.
Logistical Needs	Small V-SORs systems can be worked from smaller vessels; large V-SORs systems require larger vessel or platform.	For wading depths working from shore, need shoreline access, trafficable substrate, hand tools, and standard waste handling facilities. For diving depths, will need all logistics for contaminated water diving as well as waste handling and management.	May need sediment curtains or other containment methods to prevent oil migration down current. Other needs are standard: boats, pumps, booms, sorbents, etc.
Operational Limitations	While effective at any depth, accuracy and bottom contact suffer as water depth increases.	For wading depths, safety will drive wave, wind, rain, and lightning restrictions. Diving may be limited by depth and environmental conditions.	Limited to shallow water <8 ft, low-flow conditions, and standard limitations for on-water operations.
Optimal Conditions	Small or trace amounts of oil distributed along the bottom in less than 50 ft of water with little or no current.	Shallow water, good visibility, low currents, viscous oil that can be readily removed by hand.	Static water conditions, fresh oil that will be more easily liberated, and areas with good containment/recovery access.
Pros	Required materials are readily available. No associated recovered water or sediments.	Individual pieces of oil can be removed. Selective recovery, limiting co-collection of water and sediment. Can be low-tech, except where diving logistics are complicated.	May be the only alternative to dredging or excavation of oiled sediments. Does not require sediment or water handling and treatment.
Cons	Low recovery volumes, oiled solid waste generated for disposal. Placement accuracy decreases as water depth increases. Must contact oil/ bottom.	Slow and labor intensive. Requires relatively good water clarity for visibility. Diving may require extensive logistical support if work is offshore on vessel or barge. Will require contaminated water diving gear and decontamination of divers and gear. Severe weather will suspend operations.	Liberated oil may suspend in the water column and settle back to the bottom, with potential to spread down current. Can mix the oil deeper into the sediments during agitation.

Site Considerations

- ❑ Water depth range:________________________________
- ❑ Water visibility range: ________________________________
- ❑ Water current speed and direction:

  Surface: ________________________________

  Subsurface: ________________________________
- ❑ Wave conditions: ________________________________
- ❑ Water temperature: ________________________________
- ❑ Substrate type:________________________________
- ❑ Bathymetry (oil accumulation areas):________________________________
- ❑ Sensitive habitats in survey area:________________________________

  Biological resources: ________________________________

  Cultural/historic resources:________________________________

  Water intake/discharge locations: ________________________________

Oil Property Considerations

- ❑ Oil viscosity/pumpability: ________________________________
- ❑ Bulk oil on the surface:________________________________
- ❑ Volume of bulk oil on the surface: ________________________________
- ❑ Risk of mobilizing oil into water column:________________________________

Equipment Considerations

- ❑ Sorbents/V-SORs
  - Source of snare/pom poms (best with white sorbent materials)
  - Fabricate chain and pipe
  - Identify suitable vessel/platform
  - Proper waste stream for oiled snare/sorbent
  - GPS or tracking for proper documentation
  - Photo documentation

- [ ] Manual removal
  - Select suitable and ADCI certified commercial diving contractor(s) in full compliance with regulatory and industry standards (reference commercial diver safety checklist).
    - Minimum five-member diving team
    - Supplemental divers to ensure continuity of operations and adherence to work/rest requirements
    - Surface-supplied diving operations with CCTV and surface communications
    - Contaminated water diving capabilities
    - Decontamination equipment and procedures
    - Emergency plan that identifies on-site first aid and decompression capabilities
    - Adequate working platform to support safe entry and exit from the water
  - Identify suitable support vessel/platform. Storage barges must be approved by the Unified Command prior to operations.
  - Consider waste stream for recovered oil to include handling and storage. Decanting must be approved by the Unified Command in advance.
- [ ] Agitation/Refloat
  - Options for agitation; pumps, compressors, aerators etc.
  - Segregate areas with containment and sorbent boom.
  - Identify method of recovering refloated oil.
  - Waste stream considerations for recovered oil to include handling and storage.
  - Storage barges and decanting procedures must be approved by the Unified Command in advance.
- [ ] Suction Dredge
  - Identify suitable dredge type and qualified contractors.
  - Determine estimated volume of water/sediment/oil to be recovered.
  - Identify suitable site for handling separation of sediment/oil/water retention ponds, geotubes.
  - Waste stream considerations for water/oil/solids to include separation and storage. Storage barges and decanting procedures must be approved by the Unified Command in advance.

- [ ] Diver-directed Pumping and Vacuuming
    - Determine whether vacuum will work (hose lengths to be used) or pumping.
    - Select suitable and ADCI certified commercial diving contractor(s) in full compliance with regulatory and industry standards (reference commercial diver safety checklist):
        - Minimum five member diving team
        - Supplemental divers to ensure continuity of operations and adherence to work/rest requirements
        - Surface-supplied diving operations with CCTV and surface communications
        - Contaminated water diving capabilities
        - Decontamination equipment and procedures
        - Emergency plan that identifies on-site first aid and decompression capabilities
        - Adequate working platform to support safe entry and exit from the water
    - Select appropriate vacuum system/truck or centrifugal and positive displacement pumps.
    - Identify suitable vessel/platform to work from if not accessible from shore.
    - Waste stream considerations for water/oil/solids to include separation and storage. Storage barges and decanting procedures must be approved by the Unified Command in advance.
- [ ] Mechanical Removal
    - Identify method; excavator, clamshell, environmental clamshell.
    - Identify suitable vessel/platform to work from if not accessible from shore.
    - Waste stream considerations for water/oil/solids to include handling and storage.

6 Waste Stream Management

Managing the oil, water, silt, sediment, and debris waste stream collected during sunken oil response operations is often complex given the multiple variables involved, including oil characteristics, temperature, volumes, recovery system, and pumping method and pumping rates. Unfortunately, there is not a one-size-fits-all decanting or waste stream management system to address all types of oils and environmental conditions. Historically, waste stream management systems have been designed ad-hoc following the discovery of a submerged oil incident and tailored to the specific conditions encountered throughout the operation. As such, adaptability and variability can be expected in the development of a waste stream management system for sunken oil recovery.

Table 8 provides an overview of options for the treatment and management of waste streams associated with sunken oil recovery techniques. The most common and proven system used during sunken oil recovery operations involves the process of phase separation using a series of decanting tanks with the final water phase entering a filtration or "polishing tank" prior to discharge.

NOTE The waste management and decanting plans must be approved by the Unified Command prior to commencing operations.

Table 8—Options for Treatment of Waste Streams from Sunken Oil Recovery Operations

Process Phase	Description	Comments
Phase Separation	Solid Separation	Baffled/Gravity Settling Tank
		Lamella Clarifier
	Liquid Phase Separation	Heat or air may be applied
		Diffused Air Flotation
	Oil Skimmer	
Centrifuge	Physical Separation	
Voraxial Separator	Cyclonic Separation	
Electrocoagulation	Electrical/electron separation	
Media Filtration	Sorbent Material	
	C.I. Agent	
	Imbiber Beads	
Emulsion Breakers	Demulsifier to improve oil-water separation	Consider environmental trade offs
Storage	Regulatory approved tank vessels	Sufficient capacity to store pumping discharge

The following key points should be considered when developing a waste stream management plan.

— The use of tanks with baffles will reduce the free surface effect, speed up oil/water separation, and prevent re-mixing.

— All waste management system tanks should be inspected prior to operation to ensure no residual contamination is present.

— If any part of the waste stream management system is overwhelmed, response operations may be suspended or delayed until sufficient capacity becomes available. The waste stream management plan should consider sufficient back-up storage capacity to ensure continuity of operations.

— Agitation of the system, through vessel movement or pumping, can result in oil emulsions that hinder effective separation and delay waste stream processing. Waste stream management systems should be placed on a stable platform such as a spud barge or jack-up rig. Pumping systems should be regulated to minimize agitation. Additionally, contingency plans should identify receiving vessels with sufficient capacity to store pumping discharge.

— Regional decanting policies vary. For example, many states permit direct decanting of oil into a boomed area on-site while others require media filtration or "polishing" of the effluent with analysis of the outflow. Periodic or continuous analysis of effluent may also be a requirement of a discharge permit. The decision when to decant may also be dependent on whether or not sensitive resources could be affected by the discharged water.

— The state or regional specific decanting checklist should be completed under the direction of the Unified Command in advance of operations.

— Standard phase separation with final water filtration has proven effective on sunken oil recovery operations. Pump selection, pumping rates, and phase separation tanks can be modified to improve system efficiency. As such, responders should consider mobilizing various pump options to expedite operations.

7 Safety Considerations

The detection and recovery of sunken oil require equipment and technical specialists not used during surface oil recovery operations. As the safety of life is consistently the top priority and objective during every oil spill response, responders should focus on taking proactive measures to ensure the safety of response personnel and the public throughout the operation.

The following safety checklists provide an overview of safety issues to address when developing a plan to conduct sunken oil detection and recovery operations.

General Safety Checklist

- ❑ Designate an Assistant Safety Officer with experience in diving, subsea, and offshore operations to oversee on-site operations and to support the Unified Command's safety planning efforts.
- ❑ In addition to reviewing the site-specific safety plan, decontamination plan, medical plan, communications plan, waste disposal plan, and heavy weather contingency plan, personnel must complete a Job Hazard Analysis (JHA) prior to every operational period and when work tasks or environmental conditions change.
- ❑ Personnel assigned to the sunken oil recovery project should be experienced and properly trained. For example, personnel conducting the mobilization of equipment and heavy lift operations should maintain OSHA rigger and signalperson certifications, and the crane operator should also maintain a recognized crane operator certification. Personnel working on-site should maintain certifications in accordance with the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard found in Title 29 of the *Code of Federal Regulations* (*CFR*) 1910.120.
- ❑ All personnel working on-site should wear the required personal protective equipment to prevent exposure and injury, including hard hats, hearing protection, safety glasses, boots, coveralls/Tyvek®, appropriate gloves, and approved life jackets or work vests when working near water.
- ❑ Air monitoring operations should be conducted for respiratory protection and to collect data for daily reports.
- ❑ Respiratory protection should be available and used by properly trained personnel, as required.
- ❑ Personnel should not work alone on shore or on deck and workers should be equipped with adequate communications equipment for emergency purposes.
- ❑ The site-specific medical and safety plans must identify adequate nearby medical facilities and the best travel routes from the project site.
- ❑ First aid equipment must be readily available on the project site.
- ❑ Workers should have current first aid, CPR, and AED certifications and receive a briefing on the safety and medical plans prior to commencing operations.
- ❑ An adequate work/rest cycle should be implemented in an effort to prevent fatigue and accidents.
- ❑ Environmental conditions must be reviewed and considered daily in an effort to ensure workers are properly protected and remain comfortable to perform the required work.

- ❑ Vessels and equipment should be certified for their intended use with up-to-date inspection and/or certification records.

- ❑ Onboard lifesaving and firefighting equipment may need to be supplemented to support additional project personnel and equipment.

- ❑ Aerial heavy lift and personnel transfer operations should also be reviewed to ensure alignment with Office of Aviation Services (OAS) guidelines.

Equipment Mobilization and Heavy Lift Operations Checklist

- ❑ Review crane certification records and annual inspection reports.

- ❑ Ensure all rigging and slings are certified and in good condition.

- ❑ Ensure all Riggers and Signalpersons have completed OSHA required training.

- ❑ Ensure all personnel operating heavy lift equipment are Certified Crane Operators.

- ❑ If lifting operations will be completed from a barge or lift boat, ensure the crane's load chart reflects the integration of the vessel and lifting device and that the vessel's stability letter supports the addition of the crane.

- ❑ Prepare a lift plan that includes the lifting device load chart.

- ❑ Personnel must wear PPE, specifically hard hats when working around lifting operations and hearing protection when working around energized equipment.

- ❑ All personnel operating forklifts should have completed the OSHA required training and maintain a current certification.

- ❑ Prior to lifting, ensure overhead and intended lifting path are clear and safe for operations. The swing radius of the crane should be barricaded to prevent personnel from walking through the area.

- ❑ Conduct pre-use equipment inspections prior to operations in association with the daily JHA process.

- ❑ Weather is a primary source of dynamic loading and should be considered prior to conducting heavy lifts.

Hydraulic Submersible Pumps and Transfer Operations Checklist

- ❑ Equipment should have annual equipment inspection documents and an on-site inspection prior to each transfer operation.

- ❑ Inspect discharge hoses prior to each use and review documentation of the annual static liquid pressure test to 1.5 MAWP.

- ❑ Hose connections must be 4-bolted, full-threaded, or a quick-connect coupling approved by the U.S. Coast Guard.

- ❑ Face shields should be worn when connecting/disconnecting hydraulic lines.
- ❑ To prevent hydraulic oil spills, drip pans should be placed below hose connections and the hydraulic power unit should be placed within containment.
- ❑ Hydraulic hoses should be routed to prevent slips, trips, and falls.
- ❑ Complete a Declaration of Inspection in accordance with 33 *CFR* 156.150 prior to transfer operations.
- ❑ Review emergency shutdown procedures as part of the DOI and JHA.
- ❑ Personnel should wear eye and hearing protection, gloves, boots, and coveralls when working in the vicinity of hydraulic power units and pumping systems.
- ❑ Respiratory protection should be worn in hazardous atmospheres by properly trained and fit-tested personnel as required by on-site air monitoring.

Diving Operations Checklist

- ❑ Conduct all diving operations in accordance with 46 *CFR* 197, 29 *CFR* 1910 and Association of Diving Contractors International (ADCI) standards.
- ❑ Obtain Unified Command approval of Diving Operations Plan, Site Safety Plan, Decontamination Plan, and Disposal Plan, among others.
- ❑ The dive team should consist of at least five members, including an ADCI certified non-diving Supervisor and four ADCI certified divers.
- ❑ Each diver should have documentation of current HAZWOPER, CPR, O_2 administration, first aid certifications, and ADCI Certification Card.
- ❑ Conduct diving operations with a surface-supplied breathing gas supply and an umbilical that includes communications, CCTV, and a pneumo-fathometer.
- ❑ All equipment should have at least annual inspection documents with the exception of depth gauge calibrations and compressor air quality analysis that must be completed every six months.
- ❑ Breathing gas supply hoses must have a rated bursting pressure of four times the rated working pressure and tested annually to 1.5 MAWP.
- ❑ The Diving Supervisor should conduct a pre-dive inspection of all equipment in association with the JHA. The Diving Supervisor must brief the dive crew on the planned diving operation and risk mitigation procedures.
- ❑ Maintain a dive log that includes a depth-time profile for each diver including: diver name and designated person-in-charge; date, time and location; diving mode used; nature of work performed; surface and subsurface conditions; and maximum depth and bottom time. For each dive outside no-decompression limits, greater than 100 fsw, or using mixed gas, record the following: depth-time and breathing gas profile; decompression table designation and any modifications; and elapsed time since last pressure exposure if less than 24 hours or repetitive dive designation for each diver. If decompression sickness is suspected or symptoms are evident, the decompression sickness, depth, and time of onset, and description and results of treatment should be recorded.

- ❑ Locate compressor intakes away from hazardous atmospheres. Conduct continuous air monitoring to confirm air quality is safe for diving operations.

- ❑ Mark umbilicals at 10-ft increments to 100 ft and then every 50 ft thereafter.

- ❑ Conduct diving operations in accordance with U.S. Navy standard or approved contractor decompression tables.

- ❑ Limit surface-supplied air diving operations to 190 fsw, with brief excursions of less than 30 minutes permitted to 220 fsw.

- ❑ Divers must carry a reserve breathing gas supply and be continuously tended from the surface.

- ❑ First Aid equipment, including a hand-held resuscitator, must be located on site. An on-site Automated External Defibrillator (AED) is also recommended.

- ❑ Provide a diving ladder or stage to allow the diver safe access to the water.

- ❑ A decompression chamber must be on-site for diving operations of 100 fsw or more, or for diving operations outside the no-decompression limits. A decompression chamber should also be considered for conducting operations in remote locations or offshore where access to on-shore treatment is not readily accessible.

- ❑ Procedures must be implemented and strictly enforced to prevent oil and other contaminants from entering a hyperbaric chamber. Oil contamination is a fire hazard in a hyperbaric chamber. Additionally, oil contamination poses a respiratory hazard for personnel in a hyperbaric chamber.

- ❑ Display an Alpha Flag at least 3 ft in height to warn other vessels of diving operations.

- ❑ Provide contaminated water diving equipment for at least the diver and standby diver. Additionally, dive support personnel should be provided sufficient PPE to prevent contamination.

- ❑ Divers operating in contaminated water should be sufficiently trained and experienced in dry-suit diving and the required decontamination and emergency response procedures.

- ❑ Set up a decontamination station that is properly equipped and attended with personnel in the appropriate PPE prior to conducting diving operations.

- ❑ Hand-held tools and hydraulic submersible pumps must be de-energized before entering and exiting the water. Underwater tools and pumps should only be energized at the request of the diver.

- ❑ Diving in contaminated water, rivers/high currents, and arctic/cold water conditions are considered hazardous operations. Divers should be properly trained and experienced prior to attempting these operations. Refer to the Technical Report for additional recommendations and guidance on diving in these high-risk environments.

- ❑ As this checklist is not all-inclusive, for additional information on diver life support systems, please refer to the *ADCI Consensus Standards*, Section 6.0, entitled "Life Support Equipment: Requirements, Maintenance, and Testing".

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