Options for Minimizing Environmental Impacts of Inland Spill Response

Jacqueline Michel
Research Planning, Inc., 1121 Park Street, Columbia, South Carolina 29201 USA

Mark Ploen, QualiTech
318 Lake Hazeltine Drive, Chaska, Minnesota 55318 USA

ABSTRACT 2017-054

The 2016 American Petroleum Institute inland guide incorporates lessons learned from spill responses that can minimize the environmental impacts of inland oil spills. In addition, it provides new information on the changing risk profiles of inland spills in North America. such as the increase in oil transportation by rail, the added risks of fire and air quality concerns from spills of very light crude oils from light tight shale production areas, behavior of diluted bitumen products when spilled to fresh water, and special considerations for inland spill response. Best practices for inland oil spill response are organized by Oil Groups 1-4 and Group 5 submerged oil (oil that is suspended in the water column or moving along the bottom). It provided guidance on selecting appropriate cleanup endpoints for inland spills. Finally, it provides response guidelines for issues of special concern for inland spills, including: protection of water intakes, response to spills of ethanol-blended fuels, air quality monitoring and levels of concern, oil field produced waters, treatment of oiled debris, and fast-water booming strategies.

INTRODUCTION

In 1994, the American Petroleum Institute (API) and the National Oceanic and Atmospheric Administration (NOAA) published a guide entitled "Options for Minimizing Environmental Impacts of Freshwater Spill Response" (API, 1993; API and NOAA, 1994). The 1993/4 guides identified response methods for twelve primary freshwater habitats: four water environments and eight shoreline habitats. For each habitat, response methods were given a relative impact score for four general oil types. The 2016 inland guide differs in several ways:

- Information on spill sources and risks is included, to reflect increases in oil transportation by rail, the risks of fire and air quality concerns from spills of very light crude oils from tight shale production areas and diluted bitumen, behavior of diluted bitumen products when spilled to fresh water, and special considerations for inland spill response.
- Five oil groups are used and the guide is organized based on these groups as, in most cases, responders are dealing with a specific oil type that often has a unique set of response options and impacts to various habitats. Thus, this approach helps responders evaluate and select the most appropriate spill containment and recovery, and consequently impact minimization, options for each oil group. Group 5 oils that become submerged in the water column are included in this guide. Response guidance for sunken oil spill detection, containment, and recovery is included in a separate API technical report and operations guide (API, 2016a,b).
- Guidance is provided for two phases of the response: 1) The Control and Contain Phase; and 2) The Cleanup Phase. "Stoplight" matrices indicate the relative impacts of different response techniques for four water environments and seven land habitats.
- Current best management practices are compiled for different types of response actions, with the goal that these can be used in the preparation of treatment recommendations, as another means by which impacts during the emergency response phase can be minimized or avoided.

SCOPE OF THE GUIDE

The 2016 inland guide contains the following sections, which are briefly described. Because they are adequately covered in other documents, the 2016 inland guide does not address the following very important inland response topics: Response during snow and ice conditions; and groundwater contamination or extensive subsurface oil recovery.

Inland Spills: Sources and Risks

This section provides brief summaries of available data and information on inland spill sources (pipelines, rail, tanker truck, tank barge/towing vessel, oil exploration and production facilities, and other regulated facilities), spill types and volumes, and recent trends. Case studies are included to demonstrate successes and challenges of inland oil response to various spill sources and oil types.

Comparisons Between Inland and Marine Oil Spills

This section highlights oil behavior and environmental and human concerns for inland spills that are different from marine spills. Inland oil spills typically have the following behavior characteristics and concerns that are different when compared to marine spills:

- Nearby shorelines on small water bodies can limit spreading, and consequently evaporation, which can prolong air quality concerns for workers and the public, leading to higher air monitoring and safety measure requirements.
- Increased potential for floating oil slicks to break up and form oil-particle aggregates formation in flowing river water, which can change the density of spilled oil to potentially result in oil submergence or sinking.
- Some oils can lose the light fractions and more readily reach the lower density of fresh water, which can result in submergence or sinking.
- Stranded oil can persist longer because of lower energy environments on lake shores or river banks (smaller waves, lack of tidal water motion and currents).

- Less dilution in shallow water bodies and with lower currents.
- Potential to affect larger areas and longer distances because of constantly flowing water, usually in one direction.

This section also describes the different types of sensitive resources of inland environments, outlines consultation requirements under the Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act, and the National Historic Preservation Act.

Oil Properties, Toxicity, and Behavior

This section defines the oil types by groups 1-5, which are used throughout the guide. Summaries are provided on the properties, typical behaviors, toxicity, and changes in properties as oil weathers**.**

Inland Oil Spill Detection, Delineation, and Characterization

This section discusses current accepted methods for oil spill detection, delineation, and characterization for inland spills. It includes guidelines for conducting Shoreline Cleanup Assessment Technique (SCAT) surveys of oil on land, both on the surface and in the subsurface, including use of a canine oil detection (K9-SCAT) team (API, 2016c). There are many natural materials that could be mistaken for oil (e.g., algal blooms, suspended sediments, bacterial sheens), thus ground truthing of aerial observations is essential. A nonpetroleum sheen can often be distinguished from a petroleum sheen by disturbing the sheen, which must be done from the ground. When disturbed, a bacterial sheen typically breaks into small platelets or fractures like broken glass. In contrast, a petroleum sheen swirls and quickly reforms after a disturbance. Other techniques to differentiate nonpetroleum sheens include:

1. Hexane test, where the sheen is collected with a sheen net. The net is inserted into a glass vial containing hexane, shaken, and allowed to stabilize. A petroleum sheen dissolves in

hexane, causing the hexane to discolor. Biogenic sheens do not dissolve in hexane, thus there is no change in color.

2. Ultraviolet test, where hexane vials are viewed under ultraviolet light. Petroleum oils fluoresce, whereas biogenic sheens do not (USEPA, 2016).

Best Practices for Inland Oil Spill Response

This section includes descriptions of the response techniques and inland environments that are the backbone of the guide. Guidance is provided for options to minimize environmental impacts while achieving response goals, and a "stoplight" matrix indicates the relative impact of each response technique on each inland environment. Table 1 is an example of the information included in the matrices, this one is for spills of Group 2 oils—diesel-like oils and light/very light crude oils. Table 2 is an example of the guidance provided on best practices for spills of Group 2 to water during the contain and control phase of the response. Table 3 is an example of the guidance for spills of Group 2 oils during the cleanup phase of a response on land.

Because the API Technical Report 1154-1 (API, 2016a) and Operational Guide 1154-2 (API, 2016b) cover sunken oil detection, containment, and recovery techniques, the 2016 inland guide addresses only oils that either immediately submerge or suspend in the water column after release or become submerged after weathering and/or uptake of sediment and/or organic matter. These oils can be heavier or become heavier than the receiving water, but do not sink at or near the release site because of strong currents or turbulence in the water body. In April 2016, the U.S. Coast Guard updated the Oil Spill Removal Organization (OSRO) Guidelines to include a classification for nonfloating oils. The Nonfloating Oil Classification meets regulatory requirements of Group 5 oils in accordance with criteria set forth by 33 CFR§154.1047 and 33 CFR§155.1052 and the inherent risk of other heavy oil types that can submerge or sink. The information in both API guides (sunken oil and inland guide) can assist OSROs in selection of appropriate equipment and techniques to comply with these regulations.

Table 1. DIESEL-LIKE OILS AND LIGHT/VERY LIGHT CRUDE OILS: Relative Impact of Response Techniques by Habitat

Green = Least Impact; Yellow = Some Impact; Red = Greatest Impact. - = Not Applicable for that habitat and/or oil type

Response Technique	Water Habitats				Land Habitats						
	Lake	Pond	Large River	Stream	Developed Land	Forested Upland	Forested Wetland	Grassland/ Cropland	Grassy Wetland	Permeable Substrate	Impermeable Substrate
Natural Attenuation	Green	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green
Containment/Recovery											
Booming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Skimming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Barriers	Green	Green	-	Green	Green	Green	Yellow	Green	Red	Yellow	Green
Trenching	-	-	-	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	-
Removal											
Manual Removal	-	Yellow	-	Yellow	Green	Green	Yellow	Green	Red	Green	Green
Vacuum/Pumping	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	-	Green
Sorbents	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Excavation	-	Red	-	Red	Green	Green	Green	Green	Red	Yellow	-
Dredging	-	Red	-	Red	-	-	Red	-	Red	-	-
Debris Removal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Washing/Recovery											
Flooding	-	-	-	Green	Green	Green	Green	Green	Green	Green	Green
Low Pressure/Ambient Water Flushing	-	-	-	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green
High Pressure/Hot Water Flushing	-	-	-	-	-	-	Red	-	Red	Yellow	Yellow
In situ Treatment											
Sediment Reworking/Mixing on Land	-	-	-	-	Green	Yellow	Red	Yellow	Red	Yellow	-
Sediment Agitation in Water	-	Yellow	-	Yellow	-	-	Red	-	Red	-	-
Vegetation Removal	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	-	-
In situ Burning	Green	Green	Green	Yellow	Yellow	Red	Red	Green	Green	-	-
Biological Treatment											
Nutrient Addition	-	-	-	-	Green	Green	-	Green	-	Green	-
Microbe Seeding	-	-	-	-	Green	Green	-	Green	-	-	-
Phytoremediation	-	-	-	-	Green	Green	Green	Green	Yellow	-	-
Chemical Treatment											
Solidifier	Green	Green	Green	Green	-	-	Yellow	-	-	-	Green
Surface Washing Agent	-	-	-	-	-	-	-	-	-	-	-
Herding Agent	Green	Green	Green	Green	-	-	-	-	Yellow	-	-
Dry Ice Blasting	-	-	-	-	-	-	-	-	-	-	Green

Table 2. Technique Considerations for Spills of Group 2 Oils on WATER during the Control and Contain Phase of a Response

Control and Contain Phase	**For spills of *Group 2 oils* on WATER in general**:
	— These types of oils quickly spread into thin sheens on rivers and lakes and are readily dispersed into the water column by turbulence, decreasing the effectiveness of booming/containment and skimming/recovery operations. — In rivers and large streams, booms can deflect and contain oil or divert to low-flow areas and natural collection areas (side channels, downstream of point bars, and away from cut banks), ensuring that here is appropriate on-water or on-land access for recovery operations. — Deploy deflection or exclusion booms to protect sensitive areas. Section 7.1 provides additional information on techniques specifically for protection of water intakes. — Monitor wind direction to aid in deflection and containment efforts and for personnel safety. — Monitor weather forecasts as potential increases in water flow and higher water levels could result in failure of containment and spread oil over larger areas. Containment of remobilized oil should be factored into operations planning for this eventuality. More aggressive removal actions might be appropriate prior to a heavy rainfall event to prevent loss of containment. — Oleophilic skimmers (disc, drum, and rope mop) are efficient at recovering refined oils with little associated water. Recent advancements in coated and grooved disc and drum skimmers have increased recovery rates. — In small streams, barriers or trenches constructed downstream can prevent further spread of oil to sensitive areas, for example, into salmon spawning or juvenile fish habitat. Downstream water flow is maintained with underflow dams, siphon dams, or filter fences. Pumps may be appropriate to increase the rate of water passage following rainfall events. — Where the water depth behind the underflow dam is so shallow that oil is entrained into the water and passes through the pipes, consider placing deflection booms at the head of the dam where current is slowed and oil could be diverted to collection areas. — In areas with periods of heavy rainfall, consider construction of at least two dams per location, to provide system redundancy to reduce the risk of dam failure during high runoff events. Appendix B provides BMPs for ground disturbing activities on streams. — Consider lining the upstream side of barriers with plastic sheeting to control erosion and oil penetration. — Loose, particulate sorbents should not be used on flowing water, but could be used on isolated water bodies to increase oil removal rates. — Herders can increase the thickness and thus recovery of oil sheens, or can move oil from under docks in ports and marinas and other shoreline structures. — Flooding and low-pressure flushing can remobilize and herd oil that is trapped in log jams, beaver dams, and vegetation or soaked into sediments at the water edge into open water for recovery. This can be accomplished with pumps, prop washing with vessels, or directed air flow from airboats or leaf blowers. Water pressures should be <20 psi to minimize bank erosion. — Chicken wire fences, hardware cloth, or other screen material can prevent debris from entering recovery devices. — Consider in situ burning for thicker oil (at least 2-5 millimeters on water is needed for ignition, and thicker oil burns more efficiently) contained in booms or trapped in floating debris, snow, or ice. Light oils can leave very little burn residue. Consider near-term changes in water levels that can either strand oil during lower levels or remobilize oil during higher levels. API (2015) provides for guidelines on burning inland oil spills.

Table 3—Technique Considerations for Spills of Group 2 Oils on LAND during the Cleanup Phase

Cleanup Phase	**For spills of *Group 2 oils* on LAND in general:**
	— Quickly identify where oil could reach a water body and install intercept barriers. Appendix B provides BMPs for ground disturbing activities. — Block drains to underground systems using sand bags, water-filled plastic bags, or sorbents to prevent oil from reaching surface water or groundwater. — Construct berms, trenches, and other tactics to prevent further spread of oil. — Deploy plastic sheeting to line the sides of sediment berms to prevent or minimize oil penetration. — Add water and maintain a water layer for oil that is contained behind barriers or in trenches to reduce penetration into porous substrates. — Flooding and low-pressure flush can lift oil from substrates and direct towards recovery devices, being careful to avoid mixing oil with sediment or eroding sediment with too high water pressures. — Light and very light crude oils typically are not sticky when fresh; thus, flooding and flushing techniques can be very effective, particularly if conducted soon after the release before oil weathers. — Reworking of stream bank sediments or extensive woody debris removal should be evaluated for net benefits, because such methods could cause bank destabilization and erosion. Consider low-pressure flushing (<20 psi) at the water line and for oiled debris, which should be very effective on light refined oils. — Recover collected free oil as quickly as possible. — Monitor weather to predict when rainfall could cause containment measures to fail. Be prepared to contain remobilized oil under these conditions. Consider more aggressive removal actions to prevent loss of containment during heavy rainfall events. — Reduce spreading and increase the sorption capacity of surface layers by adding sorbents, including organic sorbents. RRT approval may be needed to leave organic sorbents in place. — Consider in situ burning for oil at least 1-2 millimeters thick that is trapped in wetlands, grassland, open fields, ice, or snow. Light refined oils can burn with very little residue, even weeks after release. Guidance on burning for inland oil spills is provided in API (2015) and for wetlands in Michel and Rutherford (2013).
	For spills of *light and very light crude oils* on LAND:
	— Immediately establish an air monitoring program to determine site safety, warm/hot zones, PPE specifications for workers, and community health concerns. Table 29 provides monitoring parameters and thresholds requiring specific actions for worker safety. — Air monitoring data and/or air quality models can assist in determining the need for and extent of community evacuation zones. These zones would be updated as appropriate. — If the LEL is >10%, do not attempt containment but continue monitoring; once levels are below 10% LEL, proceed with containment and recovery and continue monitoring. — Be aware of vapor ignition hazards in areas where oil has pooled on the ground, been contained by berms or in trenches, or entered sewers and other confined space. — Construct berms, dig trenches, install barriers but only at safe distances as determined by continuous air quality monitoring. Appendix B provides BMPs for ground disturbing activities. — Appendix D provides guidance on response to a spill of very light crude oil in event of a fire.

Potential techniques for submerged oil detection, containment, and recovery are described, and the advantages and considerations for their use are summarized. Table 4 shows the relative effectiveness of response techniques for detection and quantification, containment, and recovery of submerged oil in the water column for different water habitats.

Table 4. Submerged Oil: Relative Effectiveness of Response Techniques by Water Habitat

Green = Most Effective; Yellow = Could Be Effective; Red = Least Effective; ? = Not Proven Yet

Response Technique	Water Habitats			
	Lake	Pond	Large River	Stream
Detection and Quantification				
Acoustic Sensor	Green	Green	Green	Green
Fluorometry	Green	Green	Green	Yellow
Optical Scattering	Green ?	Green ?	Green ?	Yellow ?
Mass Spectrometer	Green	Green	Green	Yellow
Induced Polarization	Green ?	Yellow ?	Green ?	Red ?
Sorbents	Yellow	Yellow	Yellow	Yellow
Nets	Yellow	Yellow	Yellow	Yellow
Underwater Still or Video Camera	Yellow	Yellow	Yellow	Yellow
Diver Observation	Green	Yellow	Green	Yellow
Containment				
Top Curtain	Green	Green	Yellow	Yellow
Bottom Curtain	Green	Green	Yellow	Yellow
Sediment Curtain/Screen	Green	Green	Yellow	Yellow
Air Curtain	Green	Green	Yellow	Yellow
Other Bottom Barrier	Green	Yellow	Yellow	Yellow
Enhance Natural Collection Areas	Yellow	Yellow	Yellow	Yellow
Excavate/Dredge Depression	Yellow	Red	Yellow	Red
Recovery				
Sorbents	Yellow	Yellow	Yellow	Yellow
Pneumatic System	Yellow	Yellow	Yellow	Red
Nets	Yellow	Yellow	Yellow	Yellow

Effectiveness is a function of the following considerations:

Detection and Quantification:

- Minimum depth and width of a water body for deployment of the system. For example, induced polarization systems require water depths of at least 1.5 meters and the unit has two strings of electrodes that have to be towed in the water column.

- Ability to quantify amount of oil present. All of the sensors have the potential to quantify the extent and relative concentration of submerged oil plumes. Sorbents, nets, and visual methods have the potential to detect submerged oil presence but lack the ability to synoptically quantify the extent and amount of submerged oil present.
- Ability to detect oiled area, rather than at point locations that have to be interpolated to generate maps. Rivers and streams are likely to have rapidly changing submerged oil locations and be more difficult to survey, so acoustic systems are expected to be most effective.

Containment:

- Effects of water currents on performance. Most types of curtains or barriers that extend to any appropriate depth or height can fail in large rivers because currents are too strong. Air curtains might be effective for containment or for protection of sensitive resources in areas of lower flow. Curtains and barriers in streams might be effective because they are shallower and smaller, meaning more of the water column could be affected, and oil could be diverted to low-flow areas for containment and recovery.
- Presence/absence of natural depositional areas in the habitat. For lakes and impoundments, these areas would include where rivers or streams enter them. For rivers, these areas would include side channels or man-made diversion dikes. Ponds and streams are not likely to have such natural depositional areas of any significant size.

Recovery:

- Expected efficiency of oil removal. No current option is likely to remove a significant amount of the submerged oil from the water column; most efforts focus on removal from accumulation areas.

- Effective depth of the water body for deployment. Pneumatic barriers are likely to be even less effective in small streams because of shallow water depth and stronger currents.

Cleanup Endpoints

This section provides guidance on selecting appropriate cleanup endpoints for inland spills. The goal of any spill response is to select the appropriate treatment methods and cleanup endpoints that would minimize the overall impacts to, and result in the most rapid recovery of, the environment. For inland spills, an agreement with all stakeholders may be problematic if a scientific assessment indicates that it would be appropriate to leave some oil for natural attenuation where continued treatment or cleanup will exacerbate potential habitat or natural resource damage. Often, there are two perspectives that have to be resolved:

1. Remove all of the spilled oil from the environment, and
2. Remove as much oil as possible without damaging or slowing overall habitat/resource recovery.

Stakeholders and the public often are unfamiliar with cleanup methods and how those methods, and associated operational activities, can result in potential damage due to trampling, road building, vegetation removal, excavation, etc. Stakeholders often also are unaware that natural attenuation can be very effective in the final phase of a spill response. It is important to develop cleanup endpoints early in a response and at the same time realize that they can be different for different phases of a response operation over time, particularly as oil weathers and becomes more difficult to remove. Guidelines for selecting cleanup methods and endpoints for inland habitats are derived primarily from Whelan et al. (2014).

Special Considerations

This section provides guidance on some issues of special concern for inland spills, including:

1. Protection of water intakes
2. Response to spills of ethanol-blended fuels
3. Air quality monitoring and levels of concern
4. Release of oil field produced waters
5. Treatment of oiled debris
6. Guidelines for dealing with intermittent sheens
7. Successful fast-water booming strategies

Additional Information

There are four appendices: A) Properties of Nonconventional Oils: Provides summaries on the categories and environmental behavior and effects for light shale oils, diluted bitumen products, biodiesel, and non-petroleum oils; B) Best Management Practices: Includes current best management practices for different response actions to minimize collateral impacts during implementation of approved response operations; C) Firefighting Foam: Describes the current types of firefighting foam, how they can be used to combat oil fires, and guidelines for management of firefighting foam wastewater; and D) Responding to Spills of Very Light Crude Oils that Ignite: Provides guidance to responders for spills of these volatile oils when they ignite.

SUMMARY

Inland spills have unique characteristics and behavior, may have the potential to pose greater risks to the public, and often necessitate more intensive removal methods, compared to coastal and marine spills. Therefore, choosing the best response options and implementing these in the most environmentally appropriate manner can minimize adverse impacts of a response. The API inland guide will support contingency planners and emergency responders in evaluating response techniques and selecting those techniques that will most effectively prevent or minimize adverse environmental impacts from inland spills.

ACKNOWLEDGEMENTS

Early drafts of the inland guide were improved by technical reviews by Lt. Brandon Aten, Josie Clark, Mary Cramer, Adam Davis, Eric DeMicco, Ralph Dollhopf, David Fritz, Kurt Hansen, Ed Owens, Alexis Steen, Elliott Taylor, Richard Tatner, and Ann Whelan. Their time and knowledge are greatly appreciated. Funding was provided by the American Petroleum Institute, with Ray Bradley as the contract manager.

REFERENCES

American Petroleum Institute (API). 1993. American Petroleum Institute. 1993. Oil Spill Response in Freshwater Environments: Impacts on the Environment of Clean-up Practices. American Petroleum Institute, Washington, D.C., API Pub. No. 4567. 58 pp.

American Petroleum Institute and National Oceanic and Atmospheric Administration (API and NOAA). 1994. American Petroleum Institute, 1994. Options for Minimizing Environmental Impacts of Freshwater Spill Response Options. Joint Publication American Petroleum Institute, Washington, D.C. and National Oceanic & Atmospheric Administration, Seattle WA, API Pub. No. 4558. 136 pp.

American Petroleum Institute (API). 2015. Field Operations Guide for In-Situ Burning of Inland Oil Spills. API Technical Report 1251. Washington, DC. 65 pp. http://www.oilspillprevention.org/~/media/oil-spill-prevention/spillprevention/r-and-d/in-situ-burning/guide-for-isb-of-inland-water-spills.pdf?la=en

American Petroleum Institute (API). 2016a. Sunken Oil Detection and Recovery. API Technical Report 1154-1. Washington, DC. 92 pp. http://www.oilspillprevention.org/oil-spill-research-and-development-cente

American Petroleum Institute (API). 2016b. Sunken Oil Detection and Recovery Operational Guide. API Technical Report 1154-2. Washington, DC. 28 pp. http://www.oilspillprevention.org/oil-spill-research-and-development-cente

American Petroleum Institute (API). 2016c. Canine Oil Detection (K9-SCAT) Guidelines. API Technical Report 1149-4. Washington, DC. 81 pp. http://www.oilspillprevention.org/oil-spill-research-and-development-cente

USEPA. 2016. FOSC Desk Report for the Enbridge Line 6b Oil Spill, Marshall, Michigan. 241 pp. https://www.epa.gov/enbridge-spill-michigan/fosc-desk-report-enbridge-oil-spill

Whelan, A., G. Andrews, J. Clark, J. Michel, and B. Benggio. 2014. Developing cleanup endpoints for inland oil spills. In: 2014 International Oil Spill Conference Proceedings, 2005(1): 1267-1280. http://ioscproceedings.org/doi/pdf/10.7901/2169-3358-2014.1.1267