

Options for Minimizing Environmental Impacts of Inland Spill Response

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Acronyms and Abbreviations

ACM	asbestos-containing materials
ADIOS	Automated Data Inquiry for Oil Spills
AFFF	aqueous film forming foam
API	American Petroleum Institute
AR-AFFF	alcohol resistant aqueous film forming foam
AR-FFFP	alcohol resistant film forming fluoroprotein foam
bbl	barrel
BLEVE	boiling liquid expanding vapor explosion
BMP	best management practice
BOD	biological oxygen demand (sometimes referred to as biochemical oxygen demand)
BTEX	benzene, toluene, ethyl benzene, and xylenes
COD	chemical oxygen demand
DOT	U.S. Department of Transportation
cSt	centistokes
EFH	Essential Fish Habitat
ESA	Endangered Species Act
FAMES	fatty acid monoalkyl esters
FFFP	film forming fluoroprotein foam
FOSC	Federal Onscene Coordinator
g/cm ³	grams per cubic centimeter
GIS	Geographic Information System
GPS	Global Positioning System
LEL	lower explosion limit
MCL	maximum contaminant level
µg/m ³	micrograms per cubic meter
mg/L	milligrams per liter
mg/m ³	milligrams per cubic meter
mmhos/cm	millimhos per centimeter
NAAQS	National Ambient Air Quality Standards
NEBA	Net Environmental Benefit Analysis
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act
NFT	No Further Treatment
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OSHA	Occupational Safety and Health Administration
P&M	patrol and maintenance
PPE	personal protection equipment
ppm	parts per million
psia	pounds per square inch absolute
RRT	Regional Response Team
SCAT	Shoreline Cleanup Assessment Technique
SDS	Safety Data Sheet
SIMA	Spill Impact Mitigation Assessment
SPCC	Spill Prevention, Control, and Countermeasures
STEL	short-term exposure limit
TDS	total dissolved solids
T&E	threatened and endangered
TWA	time-weighted average
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UTV	utility vehicle
VOC	volatile organic compounds

Preface

This 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. There are eight sections and four appendices as follows:

Section 1 Purpose and Background: Describes the purpose of this guide and differences since the 1994 inland guide.

Section 2 Inland Spills: Sources and Risks: 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.

Section 3 Comparisons between Inland and Marine Oil Spills: Highlights oil behavior and environmental and human concerns for inland spills that are different from marine spills. It also describes the different types of sensitive resources of inland environments and outlines consultation requirements.

Section 4 Oil Properties, Toxicity, and Behavior: 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.

Section 5 Inland Oil Spill Detection, Delineation, and Characterization: Discusses current accepted methods for oil spill detection, delineation, and characterization for inland spills.

Section 6 Best Practices for Inland Oil Spill Response: 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 is used to indicate the relative impact of each response technique on each inland environment for each oil group.

Section 7 Cleanup Endpoints: Provides guidance on selecting appropriate cleanup endpoints for inland spills.

Section 8 Special Considerations: Provides guidance on some issues of special concern for inland spills, including protection of water intakes, response to spills of ethanol-blended fuels, air quality, release of oil field–produced waters, treatment of oiled debris, intermittent sheens, and fast-water booming strategies.

Section 9 References and Additional Reading: Includes references cited in the report and suggested further readings.

Appendix 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.

Appendix B Best Management Practices: Includes current best management practices for different response actions to minimize collateral impacts during implementation of approved response operations.

Appendix 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.

Appendix D Responding to Spills of Very Light Crude Oils That Ignite: Provides guidance to responders for spills of these volatile oils.

NOTE Both English and metric units are used independently in this guide, based standard practice in the U.S. In general, metric units are used for chemical and physical properties, whereas English units are used for lengths, area, volume, velocity, and temperature.

Options for Minimizing Environmental Impacts of Inland Spill Response

1 Purpose and Background

The purpose of this guide is to 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. In this guide, inland spills are defined as those that affect terrestrial and freshwater habitats, whereas coastal and marine spills affect water bodies and habitats that are under the influence of tides and marine waters. 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.

This guide addresses only the oil spill emergency phase of a response—that relatively short-term set of activities conducted immediately following a release. The response during this first phase focuses on control and containment of mobile oil, then active cleanup of the oil to established cleanup endpoints. This guide does not address the remediation or restoration phases that occur after the emergency phase of a response is completed.

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 and NOAA, 1994). The 1994 guide identified response methods for twelve primary freshwater habitats: four of which are water environments and eight are shoreline habitats. For each habitat, response methods were given a relative impact score for each of four general oil types. This current (2016) 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, 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.

Because they are adequately covered in other documents, this guide does not address the following very important inland response topics:

- Response during snow and ice conditions: Several manuals and reports are available that provide detailed information and guidance on the complexities and response options for these conditions, including EPPR (1998; 2015) and ADEC (2010).

- Groundwater contamination or extensive subsurface oil recovery: a field guide is available from the Texas Railroad Commission (2016) for spills of condensate and numerous guidance documents have been published on remediation of oil impacted groundwater.

2 Inland Spills: Sources and Risks

2.1 Introduction

In this section, major sources of inland oil spills in the U.S. are described: pipelines, rail, tanker truck, tank barges and towing vessels, oil exploration and production sites, oil refineries and inland-regulated facilities. Spill statistics are provided where available, although there are no comprehensive recent studies for inland areas, and some studies do not separate out inland versus non-inland spills in their analysis. Available U.S. studies include analysis of nearly 52,000 oil spills that occurred in inland navigable waters over the period 1980 to 2003 (Etkin, 2006), all spills over the period 1968 to 2007 (Etkin, 2009; 2010), and crude oil spills from pipelines over the period 1968 to 2012 (Etkin, 2014). Case studies are included to demonstrate successes and challenges of inland oil response to various spill sources and oil types.

Maps for oil-related facilities are not included. The U.S. Energy Information Agency provides a website for the U.S. Energy Mapping System (<https://www.eia.gov/state/maps.cfm>) that can be used to map locations of a wide range of energy facilities. This site can be useful for contingency planning as well as spill response.

2.2 Pipelines

2.2.1 Liquid Petroleum Pipeline Network

Crude oil lines are subdivided into gathering lines and transmission lines defined as follows:

Gathering Lines: Pipelines that transport crude oil over relatively short distances from a production site (wellhead) to a central collection point, frequently a processing facility. Gathering lines typically operate at relatively low pressures and flow, and they are generally less than 8 inches in diameter.

Crude Oil Transmission Lines: Pipelines that transport processed crude oil from production areas to refineries. They generally operate at higher pressures and flow, and they are generally 8–36 inches in diameter. The transmission pipeline network in the U.S. extended for 72,400 miles as of 2015, an increase of 13% over the 5-year period from 2011–2015 (AOPL and API, 2016).

Increases in oil production in the U.S. and Canada since 2010 have resulted in a steady increase in the volumes of crude oils transported by pipelines. In 2014, 9,290 million barrels of crude oil were transported by pipeline in the U.S., of which 71% was light and medium crude oil, 9% was diluted heavy crude oil, 8% was diluted bitumen, 6% was heavy crude oil, and 6% was synthetic crude (National Academies of Sciences, Engineering, and Medicine, 2016). Production and transportation of diluted bitumen are predicted to increase 2.5-fold from 2013–2030 (Canadian Association of Petroleum Producers, 2015), although these predictions might change due to declines in crude oil prices in 2015 and 2016.

Refined petroleum product pipelines transport gasoline, jet fuel, home heating oil, and diesel fuel. They vary in size from relatively 8 to 42 inches in diameter. As of 2015, there were approximately 62,600 miles of refined product pipelines nationwide, delivering products to fuel terminals with storage tanks that are then loaded into tanker trucks, barges, etc. for distribution to consumers. There has been a 3% decrease in the length of these pipelines over the last 5 years (AOPL and API, 2016). Major industries, airports, and electrical power generation plants can be supplied directly by refined petroleum product pipelines.

2.2.2 Pipeline Operations

For pipeline spills, the exact type of oil that is released might not be immediately known, but can be determined by contacting the pipeline operator's control center. Pipeline operators typically store oil from the owners in temporary holding tanks at major terminals where they: 1) consolidate oils from different sources into shipments in batches sized for main-line movement; 2) blend oils to meet quality specifications; and 3) schedule shipments according to the needs of refiners. Therefore, many oils transported by pipeline are "blends" rather than oil from a single source. They are typically sent in batches of at least 50,000 barrels (bbl), and a large pipeline could contain multiple different batches of crude at any time. To reduce undesirable mixing at interfaces, batches are separated and sequenced according to characteristics that include density, viscosity, and sulfur content. Additionally, oil flows through most pipelines at 3–6 miles per hour, (a delivery rate of 500,000 to 1,000,000 bbl of per day in a 36-inch transmission pipeline), which creates turbulent flow conditions, further reducing intermixing of batches and keeping impurities such as water and sediment in suspension (National Research Council, 2013).

A pipeline operator's control center closely tracks the location of each batch and associated interfaces in order to ensure that each batch of oil in a pipeline is delivered to the correct receiving facility and correct storage tank. This enables control room operators to instruct a receiving facility to open valves on lateral lines leading to storage tanks at the correct time to redirect an appropriate batch of oil to the target tank(s). In the event of a pipeline spill, a control center can be contacted to obtain information on the type and volume of oil that was in that segment of line at the time of the spill and the associated Safety Data Sheet (SDS). It is important to recognize the SDS for a particular oil or refined product is often generic to account for minor variations in blending or refining and might not represent the exact properties of the batch of oil that is in the pipeline.

According to the USDOT (No date), the most common threat to the safety of pipelines, particularly in and around cities and towns, arises from third-parties digging in the vicinity of buried pipelines. There is also an increased risk of pipeline failure at river crossing during floods due to erosion of banks/river bottom that can cause a pipeline to shift and rupture.

Pipeline oil spill response plans are required, under 49 CFR 194, to address spill risks and identify and prepare for worst-case discharges that are defined as:

- 1) the maximum release time in hours, plus the maximum shutdown response time in hours (based on historic discharge data or, in the absence of such historic data, an operator's best estimate), multiplied by the maximum flow rate expressed in barrels per hour (based on the maximum daily capacity of a pipeline), plus the largest line drainage volume after shutdown of the line section in a response zone, expressed in barrels; or
- 2) the largest foreseeable discharge for a line section within a response zone, expressed in barrels, based on the maximum historic discharge, if one exists, adjusted for any subsequent corrective or preventive action taken; or
- 3) if a response zone contains one or more breakout tanks, the capacity of the single largest tank or battery of tanks within a single secondary containment system, adjusted for capacity or size of the secondary containment system, expressed in barrels.

Buried pipelines have a risk of underground spills with delayed detection, depending on leak rate and sensitivity of the pipeline leak detection system. As an example, an underground pipeline spill of 20,000 bbl of Bakken crude oil occurred near Tioga, ND in 2013 as a result of a lightning strike and remained undetected for months. The subsequent cleanup activities took over two years and included efforts to prevent further spread of the low viscosity oil using intercept trenches and French drains, and intensive air quality monitoring because of the continuous release of volatiles from newly exposed oil as it seeped into trenches and was excavated in open pits.

Figure 1 shows two plots for crude oil spills from onshore pipelines for the period 1968 to 2012 for: (Top) Number of spills per year; and (Bottom) Volume of oil spilled per year (Etkin, 2014). The overall numbers of reported spills from crude pipelines decreased steadily from 1985 to 2001 (Figure 1, top), then increased sharply in 2002 and continued at this same rate through 2012. Etkin (2014) hypothesized that this sudden increase in spill numbers was due, in part, to a greater responsibility in voluntary reporting.

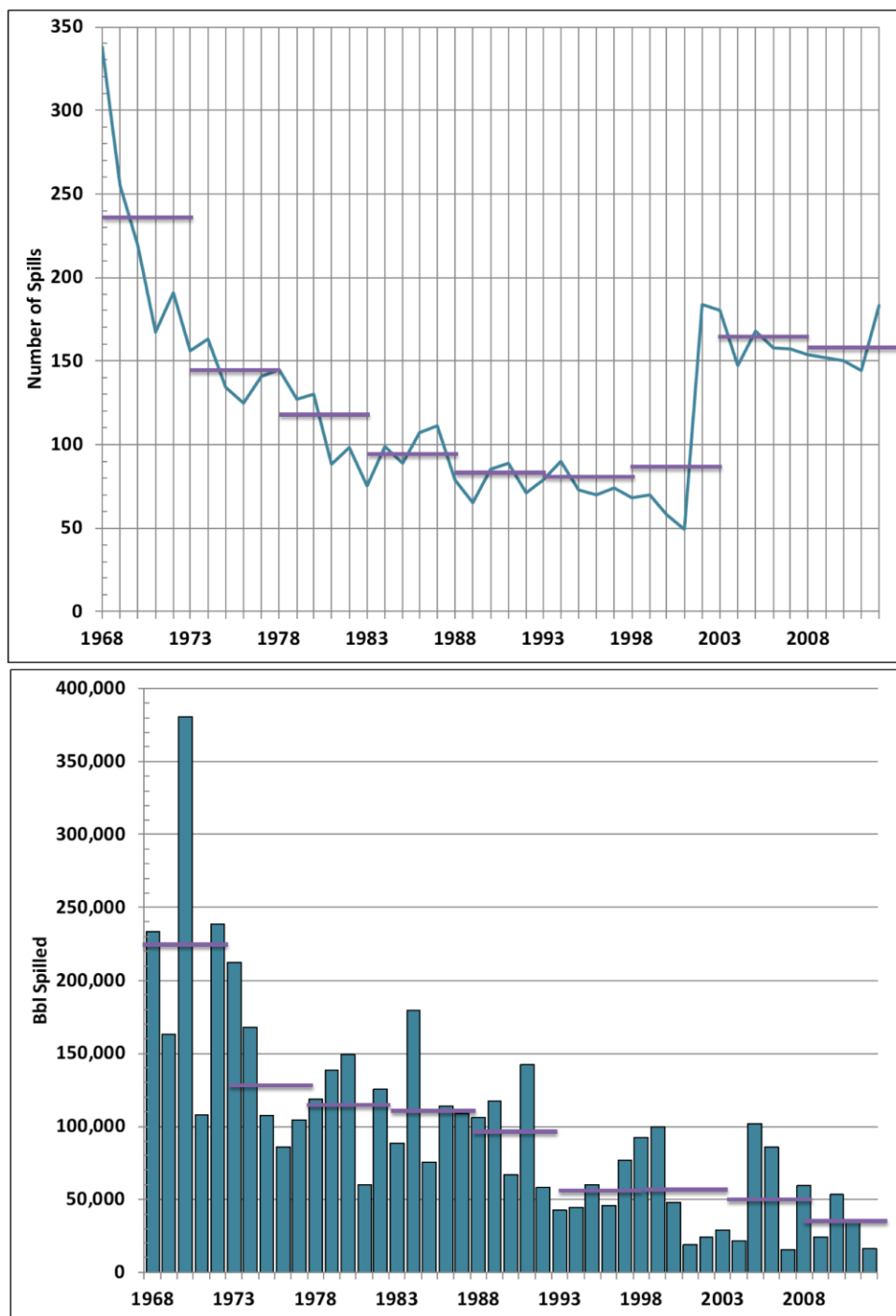


Figure 1—Annual Number (top) and Volume (bottom) of Crude Oil Spills from U.S. Pipelines for the Period 1968–2012. Bars Indicate 5-year Averages (Etkin, 2014)

The annual volume of crude oil spilled from pipelines has decreased over the 45-year period (Figure 1, bottom). Etkin (2010) noted that significant portion of the oil (about 85%) released from inland pipelines spills goes into containment areas around breakout tanks or to solid ground, rather than directly into surface waters. Recent statistics (spills >1 gallon; Etkin, 2014) for crude oil released from onshore pipelines include:

- 2003–2007: 162 spills that averaged 312 bbl per spill,
- 2008–2012: 157 spills that averaged 247 bbl per spill.

Box 1 provides a case study of a pipeline spill response.

Box 1—Pipeline Oil Spill Case Study

Name: Enbridge Line 6B Pipeline	Date: 22 July 2010	Oil Type Spilled: Diluted bitumen Volume Spilled: 20,071 bbl
Location: Marshall, Michigan		
Summary: The oil from a pipeline rupture flowed to a tributary of the Kalamazoo River near Marshall, Michigan, ultimately affecting 40 miles of stream and river channels. The release occurred when the river was at flood stage and had temporarily inundated the floodplain; high water levels stranded oil on vegetation and soils up to 3 feet above normal summer river levels, which then spread further as water levels fell. Air quality concerns were very high for both public safety and occupational health during the initial weeks of the response, mainly due to high levels of benzene; an extensive air quality monitoring program lasted for several months. Initial response operations focused on capturing, containing, and collecting floating oil using conventional techniques. The majority of oil was recovered as floating oil or deposits on land, including from the wetland at the source. Within a week, it became apparent that some of the oil had sunk to the bottom of the river wherever the river flow slowed, particularly behind three manmade dams and in some abandoned river channels. Recovery of sunken oil increasingly became the focus of response efforts after the first autumn, although some heavily oiled islands and floodplain areas still necessitated removal of oiled sediments by excavation. There was extensive oiling of river banks, forested floodplain, islands, and wetlands, which challenged traditional SCAT surveys and recommendations. Initial manual and passive removal methods were eventually revised to more aggressive mechanical methods because of the extent and amount of stranded oil and the stringent treatment endpoints. Detection of sunken oil was accomplished by “poling” methods, whereby a disk on the end of a pole was inserted into the sediments and the number of oil globules and areal sheen production in a one-meter square surrounding the poling location was recorded. Many methods were applied to contain sunken oil that was remobilized, including sediment curtains, gabion baskets, air curtains, bottom curtains, and enhancement of natural sediment accumulation areas. The gabion baskets and half-curtain bottom system were most effective, primarily where the river entered impoundments.		 Oil flowing over Cresco Dam, Kalamazoo River



Sediment agitation with a hydraulic spray bar

Sunken oil removal methods included sediment agitation using manual rakes, hand-held tillers, hand-held stingers, rotating stingers, vessel-mounted water injection, vessel-mounted pipe drags, and hydraulic flushing. Studies of the effectiveness of sediment agitation in 2012 indicate that most of the oil remained mixed with sediment and resettled to the bottom. Dredging and excavation were conducted in depositional areas. Some locations were dredged multiple times over the four-year response.

More information is available in the FOSC report: <https://www.epa.gov/enbridge-spill-michigan/fosc-desk-report-enbridge-oil-spill>

2.3 Rail

The volume of oil transported by rail has increased significantly since 2011 (Figure 2). The number of incidents involving railroad tank cars carrying crude oil and total volume spilled per year are shown in Table 1. Clearly, not all incidents result in a spill, and often the spill volume is small; however, the sharp rise in the number of rail incidents in 2012 can be attributed to the increase in shipments of oil by rail.



Figure 2—Average Weekly U.S. Rail Carloads and Million Barrels of Crude Oil and Petroleum Products Transported by Rail (EIA, 2015)

Table 1—Annual Incidents from Railroad Tank Cars Carrying Crude Oil in the U.S. (National Geographic, 2015)

Year	2010	2011	2012	2013	2014
Number	9	33	86	119	143
Volume (bbl)	117	93	12	22,512	1,371

Crude oil and ethanol comprise approximately 68% of the flammable liquids transported by rail. The inherent risk of flammability of these materials is compounded in the context of rail transportation because petroleum crude oil and ethanol are commonly shipped in large quantities, either as large blocks of material in a manifest (combined cargo/commodity) train or as a single commodity train (commonly referred to as a “unit train”). Box 2 provides a case study of a rail car spill response.

Box 2—Rail Car Oil Spill Case Study

Name: Aliceville, Alabama Rail Cars	Date: 8 November 2013	Oil Type Spilled: Light crude oil Volume Spilled: 17,857 bbl
Location: Freshwater wetland, 1 hour southwest of Tuscaloosa, Alabama		
Summary: A 90-car crude oil unit train was heading to a pipeline injection terminal in Walnut Hill, FL when 26 rail cars derailed and caught fire. The derailment occurred in an isolated wetland. Due to fire danger and difficulty accessing the tank cars, first responders decided to allow the railcars to burn out. An estimated 12,800 bbl of oil discharged into a wetland. Responding crews had to create access roads to transport equipment to the spill site. Road construction and rail wrecking operations required personnel to be working in close proximity to heavy equipment. With multiple contractors conducting different activities in the same congested area, there were risks of personnel being struck by heavy equipment. The use of spotters helped reduce those risks. Community air monitoring was conducted throughout the response for VOCs, benzene, toluene, xylene, NO₂, SO₂, H₂S, CO, and particulates. At the derailment site, particulates were as high as 2 mg/m³, and benzene was up to 0.3 ppm. Peak concentrations downwind of the derailment were 385.1 µg/m³ particulate and of 2.6 ppm total VOCs. Work place air monitoring was conducted during the entire response. A benzene worker exposure program was initiated, of a representative population of workers by work task and potential exposure to petroleum vapors. Selected workers wore benzene dosimeter badges that were sent offsite for analysis. No benzene exceedances were detected.		 Aerial photo of the spill site on 10 November 2015
 Sorbents/filter fences for passive oil recovery		On Day 3, the Unified Command decided to extinguish the burning rail cars using aqueous film forming foam using industrial fire fighters. While moving a rail car, after the final fire watch, a pressure relief device on a ruptured rail car activated and a flash fire ignited. A second flash fire occurred 20 minutes later. All operations were ceased. Industrial fire fighters continued to cool rail cars and the rail bed for the remainder of the night. The source of ignition was never determined, but it was thought to be due to oil coming into contact with hot metal or ballast material. Due to possible re-ignition of the oil, industrial fire fighters remained on-scene until all oil was transferred from impacted rail cars. Oil trapped within the wetland and in rail bed ballast continued to release after initial cleanup; crews returned and flushed the sediments and ballast in June 2014. Source: https://www.epaossc.org/site/site_profile.aspx?site_id=8939

2.4 Tanker Truck

Spills from tanker trucks are, for the most part, light, refined petroleum products (gasoline, diesel, home heating oil, No. 2 fuel oil) or heated asphalt products and tar (Etkin, 2006). In oil production areas, tanker trucks often transport crude oil from wells to processing plants, transmission pipelines, rail car loading facilities, and occasionally refineries, often involving hundreds of round trips per day.

Tanker truck capacity ranges between 5,500 and 11,600 gallons (130–276 bbl) per tanker. A truck could have a tank on the chassis and/or could pull a trailer with a similar volume. Etkin (2010) reported that the average annual volume of the total oil releases from tanker trucks over the period 1998–2007 was about 9,000 bbl, noting that most spills from tanker trucks go to pavements and do not directly impact waterways. The greatest environmental concern is when a light, refined product or light crude oil enters creeks or other small water bodies. Box 3 provides a case study of a tanker truck spill response.

2.5 Tank Barges and Towing Vessels

Barge traffic transits have increased in nearly all directions since 2010 with the exponential increase of oil production throughout the U.S. For example, in 2008, about 3.9 million barrels of crude were transported by barge from the Midwest to the Gulf Coast; in 2013, that volume increased 12-fold to 46.7 million barrels (Vieira, 2015).

Tank barges that operate on inland waters and the Great Lakes and transport the majority of this oil have capacities that average between 10,000 and 30,000 bbl. Most tank barges consist of three cargo tanks with 3,333 to 10,000 bbl in each tank. It is important to note that barge sizes vary within the inland waters, the Great Lakes, and intracoastal waterways. Thus, responders should always confer with the barge owner and/or operator's Qualified Individual and reference the barges' USCG-approved vessel response plan. Towing vessels that operate on inland waters and the Great Lakes have fuel capacities of between 1,000 and 3,000 bbl, with individual tank capacities ranging from 500 bbl to 1,500 bbl.

The average tow has approximately 15 barges, but tows (flotillas) can involve between 1 and 40 barges, consisting of open hopper, covered dry cargo, deck, and tank barges. Typically, tank barges are operated in tows of no more than 3 or 4 barges. Smaller tributaries can support only limited size tows because of the meandering nature of a river and varying width of a river and its locks.

Different petroleum products can be loaded in separate tanks within the same barge. Even a single product can vary among tanks, especially for blended products.

Multiple factors cause oil spill incidents within the inland waterways and the Great Lakes, but a majority of the incidents can be characterized as due to either collisions, allisions (collision of a moving vessel with a fixed object), groundings, and transfers. Collisions and allisions typically increase during high-flow conditions, whereas groundings increase during low-flow conditions.

According to the USCG Marine Information for Safety and Law Enforcement database, an estimated 200,363 gallons of oil were spilled as a result of 85 tank barge incidents in 2014. The single largest oil spill of 168,000 gallons represents 84% of the total volume spilled and the second largest spill 15% of the total volume spilled. Those two spills accounted for 99% of the total volume of oil spilled from tank barges for 2014. The oil spill rate for 2014 projects to be 2.68 gallons of oil spilled per million gallons transported. For 2013, the Army Corps of Engineers reported 273.1 million short tons, or approximately 74.9 billion gallons of oil transported by barge on U.S. waterways. That amount represents 83% of all oil carried on domestic waterways. The amount of oil transported by barge in 2013 increased by 20.7 million short tons or 5.7 billion gallons, representing a 7.6% increase over 2012. Box 4 provides a case study of a barge spill response.

Box 3—Tanker Truck Oil Spill Case Study

Name: Provo River Spill	Date: 28 November 2015	Oil Type Spilled: waxy crude oil Volume Spilled: 107 bbl
Location: Provo River Canyon, Utah		
Summary: A crude oil tanker truck overturned in Provo Canyon releasing a load of 107 bbl. The truck was carrying a waxy crude from the Uinta Basin, and most of the oil solidified along the roadway drainage while an estimated 25–35 bbl of crude oil flowed overland and via a storm drain into the Provo River. The spill occurred approximately 1 mile upstream from the Olmstead Diversion Dam that drinking water supplies for three communities: Orem, Provo, and Salt Lake City. The Central Utah Water District was promptly notified by the local sheriff and fire departments, and they closed the intake approximately 30 minutes before the first observation of oil. The water district switched to an alternative source. The water district also deployed boom, which successfully captured much of the oil. Water sample results indicated dissolved hydrocarbons were low or below detection limits. The water intake was reopened on 4 December, after the majority of oil had been collected. With the quick thinking and actions of first responders and the Central Water District, the impacts from the spill were substantially reduced. Due to the cold weather and water temperature, along with the waxy nature of Uinta crude, the oil largely congealed into soft solid chunks. This greatly slowed the spread of the oil, yet it did eliminate the use of vacuum trucks in oil recovery. Crews raked and lifted congealed oil by hand from behind collection booms. On Day 2, they started removing oiled soil from the crash site. During a brief warming period on December 10–11, crews were able to collect oil that had been stranded in ice.		 Collection boom just upstream of the diversion dam
 Collecting the congealed oil along the bank by hand		The Provo River is valued as a “blue ribbon” fishery and is a highly used recreational area. In this section of the river, there were numerous families of beaver and muskrat. No impacts to wildlife or fish were observed. This was not surprising, given the waxy nature of this crude oil, which solidified in cold water into “flakes” and “chunks.” Boom was left in place at the bridge by the diversion dam and monitored for oil accumulation for several weeks. Source: USEPA OSC website: https://www.epaossc.org/provorivercrudeoil

Box 4—Barge Oil Spill Case Study

Name: T/B <i>E2MS 303</i>	Date: 22 February 2014	Oil Type Spilled: Light crude oil Volume Spilled: 750-800 bbl
Location: Mississippi River Marker 154, 50 miles above New Orleans		
Summary: The spill resulted from a collision between two barge tows. The initial oil release was a dark color, but quickly transitioned to yellowish emulsion and silvery sheen. Recoverable oil was present only within the boom around the barge, or was trapped in a fleet of 216 barges at anchor within 1–2 miles from the release, and in a few pockets within 4 miles downstream. Silver sheens were observed as far as 60 miles downriver for two days. River traffic was closed along 65 miles for 2 days. The first USCG presence on scene typically respond in Level D personal protection equipment (PPE) and equipped with a very limited air monitoring instrument. The standard issue instrument only measures O₂, CO, H₂S, and lower explosive limit (LEL) of flammable gases. These devices lack the capability to measure the presence of VOCs at levels of concern, and are unable to “see” VOCs in a work environment, so cannot quantify the concentration of individual compounds. When the Gulf Strike Team began air monitoring, high readings for VOCs (consistently >200 ppm) were cause for all responders to egress from the vessel and back away until the VOCs could be better quantified. When a benzene-specific detection instrument was used to quantify the level of benzene within the VOCs, the shore side concentration of benzene was >40 ppm. As this was above all recognized exposure limits for benzene, all USCG members executed acute exposure protocols for benzene, to include blood tests at a local hospital. All operations were stopped until the response contractor provided their own air monitoring suite with benzene detection capability and provided Level B PPE to responders working immediately adjacent to the damaged portion of the barge (the primary emission source of toxic vapors). Responders in the vicinity of the barge, who were not immediately adjacent to the site of the damage nor the pooled product on the water's surface, remained in Level D PPE with instructions to egress if air monitoring indicated detection of benzene above 1 ppm (OSHA permissible exposure limit, applicable to contractors) or 0.5 ppm (applicable to USCG responders). These atmospheric hazards were detected by the Gulf Strike Team upon arrival approximately 12 hours after the incident occurred, and elevated levels of benzene persisted for several days into the response. Standard precautions for lightering/transfer operations were taken, including proper grounding/bonding of transfer pumps/equipment, elimination of external ignition sources (mechanical, electrical, smoking prohibited, etc.), and active monitoring of flammable vapors to ensure concentrations were maintained below 10% of the LEL. No exposure concerns to the public were detected through air monitoring throughout communities along the river, and air monitoring was terminated on Day 3. Water intakes were protected with exclusion booming as a precaution. The nearest intake was 4 miles downriver at 10 feet below the surface. Water samples from intakes showed no evidence of contamination. No fish kills were observed. The only shoreline cleanup operations were in the immediate vicinity of the spill, where flushing was conducted to clean oiled riprap adjacent to the T/B <i>E2MS 303</i> and within the barge fleet. Total amount of oil recovered was 2.3 bbl, which was about 0.3% of the amount released. More information is available at: https://incidentnews.noaa.gov/incident/8729		 Light crude oil in the lee of the barge on Day 1

2.6 Oil Exploration and Production Sites

Spills at oil exploration and production sites that spread off-site can occur during flood events, when storage tanks and/or piping are damaged, or when tanks float or move off their foundations. Oilfield storage tanks can range widely in size (210–1,000 bbl), and there could be multiple tanks per location, depending on daily oil production rates. The U.S. Environmental Protection Agency (USEPA) Spill Prevention, Control, and Countermeasures (SPCC) program requires secondary containment; however, failure of the secondary containment can occur during unusually high rainfall events, floods that damage or overtop containment, or other failure causes. Etkin (2010) reported average annual volume of oil released from inland oil production wells over the period 1998–2007 totaled about 5,600 bbl per year. Box 5 provides a case study of an oil production storage site spill response.

Box 5—Oil Production Storage Site Spill Case Study

Name: Poudre Tank Spill	Date: 20 June 2014	Oil Type Spilled: Crude oil Volume Spilled: 178 bbl
Location: Weld County, Colorado		
Summary: The spill resulted when flood waters along Cache la Poudre River slightly dislodged one of the storage tanks at an oil production site, which resulted in failure of a fitting on a valve at the base of the tank. Most of the oil that was reported lost appeared to have discharged to the river during the flood. When floodwaters receded, oil was found at the site and along a path to the river. Sorbents were placed at the point of discharge as a precaution. The remaining product in the tank and observable free product between the tanks and on the river were removed using a vacuum truck. Sorbent pads were aggressively applied to collect any remaining liquid oil and a surface washing agent was used to remediate impacted soils. The production tanks were removed and the most highly impacted soil from around the tanks was excavated. Due to damage that excavation would cause to vegetation between the tanks and the river, the impacted locations in that area were left to recover naturally. Source: https://www.epaossc.org/site/site_profile.aspx?site_id=9335		 Affected soils and vegetation that were left to recover naturally
 Excavating oiled soils beneath the tanks		 Sorbents used to recover free product

2.7 Oil Refineries

There were 142 operable refineries in the U.S. in January 2104 with a total crude distillation capacity of about 17.9 million bbl per calendar day (American Fuel & Petrochemical Manufacturers, 2014). Spill statistics for inland refineries are not available. Etkin (2010) reported average annual volume of spills from all refineries totaled 11,271 bbl per year for the period 1998–2007, and that this volume represented 6% of the total annual U.S. spills from all land, coastal, and offshore sources for that period. Box 6 provides a case study of as oil refinery spill response.

Box 6—Oil Refinery Spill Case Study

Name: Coffeyville Refinery	Date: 1 July 2007	Oil Type Spilled: Crude oil Volume Spilled: 2,145 bbl
Location: Coffeyville, Kansas		
Summary: Severe flooding in southeast Kansas caused the Verdigris River to overtop a levee surrounding Coffeyville, Kansas on July 1, 2007. Flood waters carried approximately 2,145 bbl of crude oil from Coffeyville Resources Refinery through the town of Coffeyville and southward into Oklahoma. Initial on-water containment and recovery operations quickly gave way to shoreline, wetland, and land cleanup as receding flood waters left oil stranded. Agency responders were USEPA Regions 6 and 7 and Kansas and Oklahoma environmental and health agencies. A comprehensive air, water, and soil sampling plan was implemented, and a “boil order” issued for water users in Coffeyville and down river.		 Flood waters carrying crude oil from the refinery
 Crude oil carried by flood waters through town	Approximately 400 buildings were impacted by oil. Coffeyville Resources implemented a voluntary purchase program for the majority of residential properties that were impacted by oil, for demolition and disposal. Buildings not demolished had to be cleaned and inspected to assure that no oil remained. A Shoreline Cleanup Assessment Technique (SCAT) program was implemented to identify appropriate cleanup techniques and end points for shoreline, wetlands and rural land. Consistent representation was used on sign off teams once cleanup endpoint criteria had been met. Oil-stained vegetation in rural areas was left to naturally attenuate. Leaves stained with oil that died and dropped off were recovered as part of the cleanup. The SCAT process also documented the cleaning of storm drains, buildings, and structures. A combination of visual inspections consistent with the SCAT process and soil sample results were used to verify soil standards in rural areas and as part of the residential demolition. Many residential lots had to have the first several inches of soil removed due to high levels of VOCs. The response was complicated due to multijurisdictional issues associated with two USEPA regions and two states. Demolition of structures fell under National Emissions Standards for Hazardous Air Pollutants, which regulates the management of asbestos-containing materials (ACM). Structures had to be inspected and an accredited ACM contractor had to be used to remove and dispose of ACM prior to demolition. Handling and disposal of household hazardous waste, electronic waste, and putrescible waste associated with dwellings, restaurants, grocery stores, liquor stores, automobiles, and tires all required additional oversight. The majority of the cleanup operations were complete within 6 months, with the completion of demolition and land restoration program taking one year.	

2.8 Inland Regulated Facilities

Inland facilities regulated under the SPCC program, other than refineries and production wells, include a wide range of oil storage volumes and types. Etkin (2006) reported that, for the period 1980–2003, SPCC facilities had a total average annual spill volume of 155,000 bbl per year, accounting for 51% of the number of spills and 55% of the volume of oil spilled to inland waters. The most frequent spills from SPCC facilities were light fuel (26%), followed by crude oil (21%), and volatile distillates (19%). Oils that accounted for the largest volume of spills were crude oil (28%), volatile distillates (26%), and light fuel (21%).

3 Comparisons between Inland and Marine Spills

3.1 Spilled Oil Properties and Behavior Comparisons

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 oil:particle aggregate formation in turbulent waters with high suspended solids, 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.

Table 2 presents some relative potential levels of concern for different oil properties and behavior for inland versus marine spills. For many oil properties and behaviors, inland spills have a potential higher level of concern. For example, during an inland spill, responders could have a higher level of concern about fire affecting populated areas, but a lower level of concern about the effectiveness of burning oil because it generally is thicker.

Table 2—Potential Level of Concern for Inland Compared to Marine Oil Spills

Oil Property/Behavior	Potential Outcome	Level of Concern for Inland Compared to Marine Spills
Flammability	— Fire (where it poses risks to populated areas)	More
Density	— Possible submergence or sinking	More
Percent Light Fractions	— Public exposure (if near a populated area)	More
BTEX Concentration	— Worker/public safety — Contamination of water supplies	More
Spreading	— Ability to contain and recover oil on water and floodplains	Less
Solubility	— Contamination of water supplies — Aquatic toxicity	More
Natural Dispersion	— Contamination of water supplies — Aquatic toxicity	Less

Table 2—Potential Level of Concern for Inland Compared to Marine Oil Spills (Continued)

Oil Property/Behavior	Potential Outcome	Level of Concern for Inland Compared to Marine Spills
Oil:particle Aggregate Formation	— Possible submergence — Possible sinking	More
Effectiveness of ISB	— Thicker, less weathered oil	Less
Impacts of ISB	— Damage to fauna, vegetation, soils, cultural resources — Exposure of public and wildlife to air emissions	More
Burn Residue	— Burn residue sinking	More
Oiling of Debris	— Large volumes for removal/replacement	More
Persistence of Oil Residues	— More aggressive removal — Residual soil toxicity	More

3.2 Sensitive Resources in Inland Areas

The resources at risk for inland spills include a wide variety of human, biological, and cultural resources:

- The public could be at risk in populated areas if a spill occurs in close proximity to residential and urban areas. Air quality concerns can become particularly important.
- There could be a strong concern about water quality because of high use of water for drinking, cooling, industrial, agricultural, and recreational uses.
- There are more threatened and endangered (T&E) species listed under the federal Endangered Species Act (ESA) and by similar state legislation that could be affected by both spilled oil and response actions. Table 3 lists the number of federally protected species in the U.S. by group. Note the large number of listed plants, which accounts for 54% of all listed species. Most of these listed species occur in inland areas.
- There are more locations and types of historic and cultural resources that could be affected by response in inland areas.
- Access may be limited so the response team might need to build roads, launches, staging areas, temporary storage, etc., potentially increasing the area of impact during a response.

Levels of concern about damage to these resources during an inland response could result in more stringent criteria for surveys of site operations (e.g., staging areas, transportation corridors, waste storage and disposal locations) and monitoring of operations to document compliance with BMPs.

Table 3—U.S. Species Listed under the Endangered Species Act

Group	Total	Mostly Coastal or Marine
Corals	6	6
Snails	50	2
Fishes	162	20
Amphibians	35	0
Reptiles	42	6
Mammals	102	21
Clams	88	0

Table 3—U.S. Species Listed under the Endangered Species Act (Continued)

Group	Total	Mostly Coastal or Marine
Arachnids (spiders, scorpions)	12	0
Insects	78	2
Crustaceans	25	0
Birds	100	19
Animal totals	719	76
Conifers and Cycads	4	0
Flowering Plants	860	1
Lichens	2	0
Ferns and Allies	31	0
Plant totals	897	1
Totals	1616	77

3.2.1 Consultation Requirements under the Endangered Species Act (ESA)

During a response by the USEPA or USCG to an oil spill emergency, the Federal On-Scene Coordinator (FOSC) is required to consult with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) to meet the requirements of Section 7 of the Endangered Species Act. The Section 7 consultation required for federal undertakings of an emergency spill response includes all activities related to the response, not the spilled material itself. Key guidance for consultation during emergencies is provided by the 2001 Inter-agency Memorandum of Agreement Regarding Oil Spill Planning and Response Activities Under the Federal Water Pollution Control Act's National Oil and Hazardous Substances Pollution Contingency Plan and the Endangered Species Act (https://www.uscg.mil/npfc/docs/PDFs/urg/App/ESA_MOA_AppA_04.pdf). This 2001 Memorandum of Agreement outlines the process for Emergency Consultation during a spill response under Section 7 of the ESA between the FOSC and the federal agencies as follows:

- Notification will occur as agreed in the Area Contingency Plan.
- Spill response activities that could affect listed species or their critical habitat require emergency consultation.
- Emergency consultation will be accomplished by including USFWS and/or NMFS in the Incident Command System organization established by the FOSC. These representatives will provide timely recommendations as conservation measures to eliminate/minimize impacts to listed species/critical habitat. Often, the agencies will prepare BMPs to be followed during response actions.
- The emergency will continue until removal operations are complete in accordance with 40 CFR 300.320(b). The FOSC will continue emergency consultation until the case is closed.

3.2.2 Consultation Requirements under the Magnuson-Stevens Fishery Conservation and Management Act

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act require that federal agencies consult with NMFS when their actions or activities could adversely affect habitat identified by federal regional fishery management councils or NMFS as essential fish habitat (EFH), which means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to

maturity. Through this consultation process, measures are identified to avoid, reduce, or compensate for adverse impacts to EFH.

50 CFR Section 600.920(a)(1) addresses EFH consultation during emergencies:

Consultation is required for emergency Federal actions that may adversely affect EFH, such as hazardous material clean-up, response to natural disasters, or actions to protect public safety. To this end, Federal agencies should contact NMFS early in emergency response planning, but may consult after-the-fact if consultation on an expedited basis is not practicable before taking the action.

Response activities have the potential to adversely affect riverine habitats identified as EFH and therefore trigger the consultation requirement. EFH consultation consists of a federal agency providing NMFS with an EFH Assessment, NMFS responding with EFH Conservation Recommendations followed by the federal agency's response to NMFS recommendations.

The mostly likely EFH in inland areas are for salmonid species that utilize rivers in Idaho, Washington, Oregon, and California that drain into the Pacific Ocean, and Atlantic salmon in rivers in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. EFH can be identified using the EFH Mapper at: <http://www.habitat.noaa.gov/protection/efh/habitatmapper.html>.

In 2013, the USCG issued a policy letter on the process for consultation under Section 7 of the ESA and under the EFH requirements to ensure compliance with these environmental statutes during oil spill planning and response activities (USCG, 2013).

3.2.3 Consultation Requirements under the National Historic Preservation Act (NHPA)

During a response by the USEPA or USCG to an oil or hazardous material spill emergency, the FOSC is required to consider historic properties during emergency response planning and operations. The federal undertaking for an emergency spill response includes all activities related to the response, not the spilled material itself. Historic properties are properties that are included in the National Register of Historic Places or that meet the criteria for the National Register. Section 106 of the NHPA requires consultation with affected tribes and trustees on assessing potential effects of proposed response activities and determining acceptable methods of minimizing negative impact of those actions. Key guidance for historical and cultural resource protection is provided in the 1997 Programmatic Agreement on Protection of Historic Properties during Emergency Response under the National Contingency Plan (<http://www.achp.gov/pa14.pdf>). This document is a national guideline for providing protection to historic properties in an emergency. Most Regional Response Teams (RRTs) have developed implementing guidelines, which should be reviewed.

When a spill response has the potential to affect cultural resources, an FOSC can appoint an Historic Properties Specialist to provide advice on historic preservation matters, including compliance with historic preservation laws. Highest levels of concern are for National Historic Landmarks, sites listed under the National Register of Historic Places, sites determined to be National Register eligible, Traditional Cultural Property, human remains and funerary objects, and areas of special concern to tribes. The Historic Properties Specialist reviews proposed response work plans and develops strategies to avoid or minimize potential adverse effects of response activities on historic properties. The Historic Properties Specialist advises and may represent the FOSC in NHPA compliance communications and assists with Section 106 consultation with affected tribes and trustees on potential effects of proposed response activities and acceptable methods to minimize negative impacts. The Historic Properties Specialist works with the FOSC, as directed, to generate pertinent directives regarding cultural resources and historic properties; these directives apply to all emergency response personnel and activities. The Historic Properties Specialist may, with an FOSC's concurrence, assemble a Technical Working Group (or advisory group) and/or liaisons with consulting parties to facilitate consultation and develop and review strategies for

protecting historic properties. Inland spills are more likely to affect tribal lands or Traditional Cultural Property, thus triggering the need to consult with potentially affected tribes.

4 Oil Properties, Toxicity, and Behavior

The oil type (and thus likely properties and behavior when spilled) and amount spilled are key pieces of information during the initial stage of a response. However, oil type information is not always immediately known or appreciated, as discussed in Section 2. Obtaining a SDS for the **exact product** as early as possible is essential in determining the spilled oil's type and properties and its predicted behavior. In addition, early collection and analysis of a sample of the oil can also provide this information. Simple observations or “tailgate” tests can help determine if an oil will float and the relative viscosity and inform predictions on how it might weather (changes in physical and chemical properties) over time.

The type of oil spilled determines, to a large extent, its behavior and the range of appropriate response actions and potential environmental impacts. The oil type also largely determines its persistence in the environment which is an essential prerequisite to identifying environmental risks during an oil discharge. The USCG and USEPA use oil persistence levels within their oil spill response regulatory frameworks to calculate potential impact areas, determine response capability requirements, and influence other planning aspects. The USEPA Facility Response Plan rule (40 CFR 112.20 and 112.21) defines oil as either “persistent” or “non-persistent.”

Non-persistent or Group 1 oils include:

A petroleum-based oil that, at the time of shipment, and consists of hydrocarbon fractions:

- at least 50% of which by volume, distill at a temperature of 340°C (645°F);
- at least 95% of which by volume, distill at a temperature of 370°C (700°F).

The volatility and flammability of non-persistent oil typically preclude an active response due to safety. The response could be one of simple evacuation and monitoring.

Persistent oils include petroleum-based oils that do not meet the distillation criteria listed above. These oils are further classified based on specific gravity as follows:

- Group 2: specific gravity less than 0.85;
- Group 3: specific gravity equal to or greater than 0.85 and less than 0.95;
- Group 4: specific gravity equal to or greater than 0.95 and less than 1.0;
- Group 5: specific gravity equal to or greater than 1.0.

The USCG definition of persistence is consistent with that of the USEPA. However, the USCG does require that distillation characteristics are determined using the American Standards and Testing of Materials Method D 86/78, “or any subsequent revision thereof.” Despite the existence of persistent and non-persistent oils with respect to USEPA and USCG regulations, neither agency has an official list of persistent and non-persistent oils. This is in part because different batches of a particular oil type can have different characteristics, and any oil type can have different degrees of persistence at different times in a spill due to weathering and other environmental factors.

Table 4 lists the properties and typical behaviors of the 5 oil groups and Figure 3 discusses the potential toxicity and long-term effects of each group. Many response guides refer to these oil groups.

Table 4—Oil Groups: Properties and Typical Behaviors

Group	Properties and Typical Behaviors
Group 1: Gasoline Products	— Specific gravity is less than 0.80; API gravity >45 — Very volatile; National Fire Protection Association (NFPA) class is “flammable liquid” — Very volatile and evaporates quickly with no residue (in a matter of hours for spills to water) — Relatively soluble, but dissolved components often rapidly partition into the air — Low viscosity; spread rapidly into thin sheens — Readily penetrate into porous substrates, but are not sticky — High acute toxicity but short-term exposure due to rapid evaporation — High risk of ignition and air quality concerns for responders and the public
Group 2: Diesel-like Products, Jet Fuels, Kerosene, Light Crude Oils, and Very Light Crude Oils	— Specific gravity is 0.80–0.85; API gravity 35–45 — NFPA class is “combustible liquid” — Volatile, with refined products leaving little to no residue. Crude oils can have residue after evaporation is complete — Moderately soluble and toxic with dissolved components somewhat persistent as partitioning into air is slower — Low to moderate viscosity; spread rapidly into thin slicks on water — Do not readily emulsify except in cold temperatures — Readily penetrate porous substrates — Are more bioavailable/toxic than lighter oils (in part because they persist longer), so that animals in water and sediments are more likely to be exposed
Group 3: Medium Crude Oils and Intermediate Products	— Specific gravity of 0.85–0.95; API gravity 17.5–35 — Moderately volatile — For crude oils, up to one-third can evaporate in the first 24 hours — Moderate to high viscosity; spread into relatively thick slicks — Can form stable emulsions which increases viscosity — Many have limited solubility — Are more bioavailable/toxic than lighter oils (because they persist longer), so that animals in water and sediments are more likely to be exposed — Can penetrate porous substrates — Persistent residues can have long-term toxicity
Group 4: Heavy Crude Oils and Residual Products (includes Diluted Bitumen products)	— Specific gravity of 0.95–1.00; API gravity of 10–17.5 — Very little product loss by evaporation or dissolution (with exception of diluted bitumen products where the diluent component may evaporate over time) — Very viscous to semi-solid; can be heated during transport — Can form stable emulsions which increases viscosity but tends to break into tar balls quickly — Low acute toxicity to water-column biota — Penetration into substrates can be limited at first, but can increase over time — Can cause long-term effects via smothering or coating, or as residues in a water column and sediments, though generally less bioavailable than lighter oils
Group 5: Nonfloating Oil Products: Slurry Oils, Coal Tar Oils, Carbon Black Feedstock, Very Heavy Crude Oils, and Asphalt	— Specific gravity of >1.00; API gravity <10 — Limited product loss by evaporation or dissolution — Very viscous to semi-solid; can be heated or blended with a light product (which can evaporate once spilled) to facilitate pumping/transport — Low acute toxicity to water-column biota (though can have some toxicity if blended with a lighter, more-toxic diluent) and less bioavailable than lighter oils — Penetration into substrates may be limited at first, but can increase over time — Can cause long-term effects via smothering or coating, and as residues in soils



Oil Type	Group 1: Very Light	Group 2 Light	Group 3 Medium	Group 4 Heavy	Group 5 Non-floating
Acute toxicity to aquatic organisms	High toxicity from soluble compounds	Moderate toxicity from soluble compounds	Moderate to low toxicity	Low toxicity, but high risk of smothering	Low toxicity, but high risk of smothering
Long-term environmental effects	Likely not severe	Can cause long-term sediment contamination	Can cause long-term impacts	Possible long-term sediment contamination	Can cause long-term sediment contamination
			Can impact bird, fur-bearing mammals, and shoreline habitats		Can smother benthic habitats and organisms

Figure 3—Toxicity and Long-term Environmental Effects of Oil Groups 1–5

Four types of “non-conventional” oils are transported in inland environments and have somewhat different properties and potential behaviors compared to the five oil groups described in Table 4. These types are described briefly in the following paragraphs and more detailed data are provided in Appendix A.

- Light shale oils: These oils are very light and contain a higher percent of dissolved gases than most crude oils, which poses a higher risk of ignition as well as inhalation hazards to responders and the public shortly after a release, compared to other crude oils. When released to water, they can lose about 50% of their mass by evaporation and are readily dispersed under turbulent conditions. Spills on land that penetrate into soil lose the volatile fractions more slowly, and there can be secondary releases of volatiles during excavation and trenching in oiled areas.
- Diluted bitumen products: These products initially behave like a medium crude oil. However, as the light ends evaporate, their density can approach and occasionally exceed 1 gram per cubic centimeter (g/cm^3), and their viscosity can reach over 1,000,000 centiStokes (cSt) under real-world conditions. After evaporative loss of light ends, diluted bitumen spills have a greater potential to submerge and sink in freshwater, compared to seawater, particularly in freshwater environments with turbulent flow and moderate to high volumes of suspended particulate matter. Because bitumen is so highly weathered initially in its natural state, spilled residues can undergo little additional weathering when stranded on a shoreline or accumulated in bottom sediments and can be highly persistent.
- Biodiesel (unblended): Spills of biodiesel to water are expected to behave similarly to petrodiesel at first, but they can have a higher rate of natural dispersion and a slower rate of droplet resurfacing. Over time, biodiesels are likely to become more viscous, thus can have higher recovery of any remaining floating product using skimmers and sorbents. Aquatic life could suffocate because of the depletion of oxygen caused by releases to shallow or isolated water bodies. The high biodegradation rates of biodiesels in water (both fresh and salt) and soils of days to weeks under aerobic conditions and weeks to months under anaerobic conditions might support a decision to allow natural attenuation of residues after gross oil removal, if supplemental oxygen is supplied or naturally occurring oxygen is sufficient to support microbial degradation.

- **Non-petroleum oils:** These oils include animal fats (e.g., beef tallow oil) and vegetable oils (e.g., soybean oil, palm oil, rapeseed oil, sunflower oil). Spills can affect aquatic resources due to rapid depletion of oxygen levels in sediments and isolated water bodies because of high biological oxygen demand (BOD). They can polymerize (components cross-link), thus harden into concrete-like lumps in sandy sediments that can persist for years. However, these lumps can be readily removed during cleanup operations.

Because most oils start to weather once released to the environment, understanding how key properties change because of weathering (Table 5) is important in the response decision process and in understanding the habitats that may be impacted and how. Weathered oil tends to be denser, stickier, and more viscous but generally less toxic. Figure 4 shows how viscosity of different petroleum oils (fresh and weathered) compares with common materials whereas Table 5 provides a comparison of selected properties for fresh and weathered oils in each oil group.

Table 5—Comparison of Different Oil Properties as Oil Weathers^a

Crude Oil	Adhesion (g/m ²)	Density (g/cm ³)	Viscosity (cSt @ 20 °C)	Flash point (°C)
Light Crude ^b	0	0.77	1	−30
Weathered Light Crude (60% mass loss)	9	0.84	5	95
Medium Crude ^c	12	0.85	8	−10
Weathered Medium Crude (32% mass loss)	33	0.90	110	110
Heavy Crude ^d	75	0.94	820	−3
Weathered Heavy Crude (19% mass loss)	600	0.98	5,000	110
Diluted Bitumen ^e	98	0.925	285	<−5
Weathered Diluted Bitumen ^f (25% mass loss)	1,580	1.008	50,000	169
Bakken ^g	N/A	0.8	13	−36 (−59 to 50)
Weathered Bakken (45% mass loss) ^g	N/A	0.865	24	N/A
^a Modified from NAS (2016); N/A = not available ^b Scotia Light; ^c West Texas Intermediate; ^d Sockeye Sour; ^e Cold Lake Winter Blend; ^f Cold Lake Winter Blend that was artificially weathered to a high degree; ^g USEPA (2015b)				

The oil fate plots for representative oils in each oil group in Section 6 was generated using the NOAA oil weathering model called ADIOS2 (Automated Data Inquiry for Oil Spills). The model was run on representative oils for each oil group and with the following input parameters:

- an instantaneous release of 50 bbl of oil into a confined area of 80,000 square feet (such as spreading in downstream for 800 feet in a river that is 100 feet wide), thus oil would spread out to a thickness of 0.03 inches or 0.8 millimeters;
- wind speed of 0 knots, to be representative of inland conditions where wind can be blocked by vegetation in smaller water bodies, thus there is no natural dispersion;
- sediment load of 50 g/cm³, which is the average for rivers, and water temperature of 60°F.

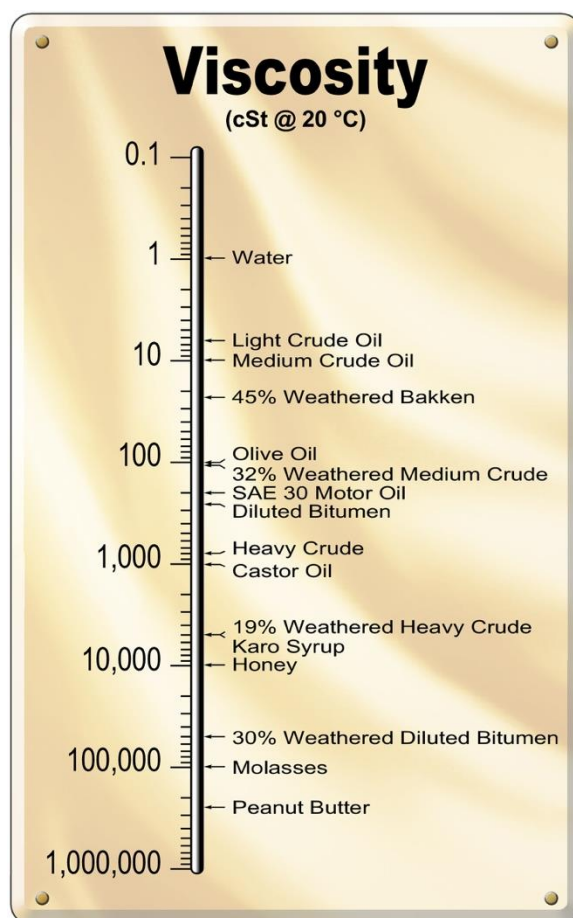


Figure 4—Viscosity of Different Oils (Fresh and Weathered) Compared to Common Materials

The model was run for five-day periods for all oils except for gasoline, which was run for 8 hours because it evaporates quickly. In the model, natural dispersion is only a function of wind speed, which is 0 knots, so no wave-generated turbulence was input that typically would naturally disperse oil; turbulence from riverine processes is not included in ADIOS2. Thus, the plots are conservative in terms of the volume of oil that might remain on a water surface.

Models that can predict the spread and weathering of oil on land are valuable for oil spill planning at specific release locations. However, oil spreading processes are driven by soil type, topography, vegetation, surface roughness, etc. so that results only reflect a specific scenario being modeled, making it difficult to generate useful comparisons among oils groups. Therefore, no modeling was undertaken for spills on land.

5 Spilled Oil Detection, Delineation, and Characterization

Timely detection and delineation is the key to effective containment and recovery and, thus minimization of environmental impacts. Inland spills that occur on land can spread, penetrate porous substrates, migrate downslope, and potentially reach a water body. Surveys to map the location of the oil and identify the affected habitats might be required to evaluate the appropriate response actions. Although facility, pipeline, and vessel response plans include general response approaches, spill-specific response actions should integrate field data on oil behavior, current physical processes, affected habitats, access points, and ecological and cultural resource issues. Repeated surveys may be appropriate to monitor the effectiveness and effects of ongoing response methods, so that benefits from possible changes in tactics,

additional treatment, or constraints can be evaluated throughout the different phases of a response. This section describes current approaches and surveys for detection, delineation, and characterization of spilled oil on land and water habitats.

Managing essential response data in spatial databases using Geographic Information Systems (GIS) from the very beginning of a response should be standard practice for spills that last for more than several days or affect many different areas. Whenever practical, field data should have Global Positioning System (GPS) coordinates and all photographs should be georeferenced. A GIS is an extremely valuable tool for maintaining a common operating picture throughout a response, and it can help to track/visualize temporal patterns in oil distribution and cleanup operations.

5.1 Oil On Land/Wetlands/Shorelines

5.1.1 Surface Oil

The Shoreline Cleanup Assessment Technique (SCAT) is commonly used to survey the affected area and detect, delineate, and characterize the oil and recommend appropriate response options. SCAT teams use standard terminology to collect data on oiling conditions to support decision making on where to conduct removal actions and the preferred options to remove or treat the oil, considering the site constraints and resource sensitivities. The NOAA (2013) Shoreline Assessment Manual and the Environmental Canada SCAT manual (2016) provide detailed guidance for a SCAT program. The NOAA manual includes forms for SCAT teams to use for spills on shorelines, wetlands, river banks, and stream banks, as do many other agencies and organizations. Safety concerns should be paramount when searching for highly volatile oils as the light fractions can evaporate and present a SCAT team with inhalation hazard and pits and be a potential ignition risk.

River bank zonation for is often based on water levels (Sergy and Owens, 2011), for example:

- Over-bank area: where flood plain is inundated only by over-bank flow during flood conditions.
- Upper bank: portion which is under water only during bank-full river stage.
- Lower ban: portion is exposed only during low flow conditions.
- Exposed mid-stream: areas consisting of a shoal or bar separated by water from a river bank.

Inland oil spills can pose challenges to a SCAT program because:

- Oil can spread over wide areas and in three dimensions, for example, in floodplains during high water events where oil coats vegetation as water levels drop.
- Oil that stranded during low water can be difficult to map and characterize when water levels rise and flood oiled zones.
- Oil distribution within an “oil zone” as recorded on the SCAT forms can be highly variable, with Thick Oil in depressions adjacent to a Coat or Stain on vegetation.
- Surveys, and therefore good documentation, may be difficult in thick vegetation. Teams might need local field guides to correctly identify both sensitive and invasive species of plants and animals.
- Natural hazards (poisonous snake and plants, dangerous animals, debris piles, and soft substrates) can be a safety issue.
- The subsurface extent of substrate oiling and groundwater impacts might be difficult to document.

These complications challenge SCAT survey and data documentation methods. Under these conditions, SCAT teams might have to rely on several approaches, including aerial, boat, and ground surveys. Aerial

surveys can generate data to develop general oiling categories and target areas for more detailed ground and boat surveys. The use of Unmanned Aerial Vehicles to collect aerial video and photographs in areas of difficult access is an option, assuming that operations are in compliance with current Federal Aviation Administration regulations.

GPS track lines document a survey team's locations and waypoints at observation points during ground and water surveys and can be used to generate survey maps that a team uses to delineate oiled areas for treatment. Timely delineation of areas of thick oil or oil that can be potentially remobilized is essential so that removal actions can be quickly recommended and implemented. Timeliness is particularly important when forecasted rain or increasing water levels are likely to remobilize and spread oil over larger areas, when new snow may cover oil deposits, or when snow or ice that are providing natural containment could start to melt. Close attention to changing weather conditions and water levels, typically using real-time field observations and on-line monitoring data, is particularly important for inland spills.

Ground or boat-based surveys for detection and delineation of oil on land can, in certain cases, be supported by a canine oil detection (K9-SCAT) team (API, 2016c). A canine detection team consists of:

- a trained detection canine that has been imprinted with the target odor;
- a trained and experienced handler to control the search pattern and reward the canine;
- an experienced SCAT observer to manage and direct the survey;
- an animal health and welfare protocol implemented by the handler and supported by a canine veterinarian.

K9-SCAT can be an integral part of a traditional SCAT program and has the potential to:

- rapidly clear large shoreline/inland areas or pipeline corridors with a high-confidence, low-risk survey to ensure that oil is not present in those areas that otherwise would be time consuming for a traditional ground observation team;
- be effective in areas that would be difficult or hazardous for a ground team, including large sediment (boulder and riprap), bedrock, vegetated terrain, thick debris, and deep snow;
- find oil that is hidden from visual assessment, under snow or ice, or trapped under debris.

Many of these situations, where K9-SCAT can be useful in addition to traditional SCAT surveys, are of particular value during inland oil spill response. Refer to API Technical Report 1149-4 (2016c) for additional technical information, results of field trials, and implementation plans using a K-9 SCAT program.

5.1.2 Subsurface Oil

Survey techniques are different for spills where an oil leak begins below ground (e.g., from buried pipelines or underground storage tanks) or penetrates into the subsurface from a surface release (API 2013). Pits and trenches (dug manually or mechanically), push cores, or auger drilling rigs can detect and delineate the oil's extent (both horizontally and vertically) and can provide information on soil profiles to determine risks for downward migration of oil to the water table or penetration into bedrock fractures. K9-SCAT teams can be effective in detecting subsurface oil to depths of several feet with 100% coverage, versus spot sampling by manual or mechanical excavation or coring. Groundwater wells might be appropriate to determine groundwater flow directions, measure of the thickness of oil on the water table, and to collect samples for chemical analysis. The light oils that are produced from shale areas can migrate readily through permeable subsurface sediments, similar to light refined products such as gasoline and diesel. Similar to surface oil SCAT surveys, significant safety concerns are also associated

with subsurface assessments of highly volatile oils as vapors can collect in trenches and pits and be a potential health or ignition risk.

5.2 Oil On Water

5.2.1 Floating Oil

Standard terminology to describe floating oil is an important element of documentation and the NOAA (2012) Open Water Oil Identification Job Aid for Aerial Observation provides guidance on terminology and definitions. Observations in vegetated areas can be difficult due to vegetation that can create canopies over the water: boat-based K9 teams may be able to support a SCAT survey in these situations.

Spills on rivers and streams can move downstream quickly with the currents, spreading bank-to-bank in some areas, or being pushed by wind to one side. Water currents will also tend to move oil to the outside of bends in rivers or streams although the current speeds often preclude oil from accumulating in these areas. It is important to identify areas of low flow or eddies where oil can concentrate, including downstream of point bars and islands, and in side channels, oxbow lakes, and natural or man-made impoundments. Oil may also be trapped by, or accumulate in, floating debris within a waterway or along a shoreline or where vegetation or woody debris extends from a shoreline into the adjoining water. Areas with accumulations of floating oil should be prioritized for recovery as changes in water levels, current speeds or wind direction can easily remobilize the oil and impact additional areas downstream.

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 usually 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 a sample of a sheen is collected using a small piece of 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).

5.2.2 Submerged and Sunken Oil

Most oil spill response techniques and equipment are based on the simple principle that oil floats. However, oil does not always float. It can float on a water surface, suspend in a water column, or sink to the bottom of a water body; and it could do all three on the same incident: float, suspend, and sink. Furthermore, oil that has sunk to the bottom can become re-suspended by an increase in turbulence or temperature (which reduces the oil's viscosity, allowing it to separate from the sediment) and spread by currents over time. Terminology to describe these various behaviors can be confusing; thus, the following terminology is used in this guide:

- Floating oil: Spilled oil that is on the surface of a water body.
- 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 absence of that turbulence.
- Sunken oil: Spilled oil that is on the bottom of a water body.

API published two documents in 2016 that addressed sunken oil spill response:

- *Sunken Oil Detection and Recovery: Technical Report* (API, 2016a: Technical Report 1154-1)—This report identifies and documents current best practices and alternative technologies to more effectively detect, delineate, characterize, contain, and recover sunken oil.
- The report identifies and describes the following sunken oil detection technologies: 1) sonar systems; 2) underwater visualization systems; 3) diver observations; 4) sorbents; 5) laser fluorosensors; 6) visual observations by trained observers; 7) bottom sampling; and 8) water-column sampling.
- Additionally, the report includes descriptions of seven sunken oil recovery technologies: 1) suction dredge; 2) diver-directed pumping and vacuuming; 3) mechanical removal; 4) sorbent/V-SORs; 5) trawls and nets; 6) manual removal; and 7) agitation/refloat.
- For each technology, a detailed description of the method is provided with advantages and disadvantages and summary tables—the types of information that are used to select the most effective options for sunken oil detection and recovery.
- *Sunken Oil Detection and Recovery: Operational Guide* (API 2016b: Technical Report 1154-2)—This guide includes decision support tools to assist responders in selection of the most appropriate techniques for sunken oil detection, delineation, and characterization, and then recovery, depending on spill conditions.
- These two documents present current best practices for spill incidents where oil has sunk to the bottom of a water body. Therefore, this topic is not discussed in this report. However, Section 5.7 includes response techniques for detection when the oil is submerged in the water column.

6 Best Practices for Inland Oil Spill Response

6.1 Introduction

This section provides guidance on best practices for inland oil spill response. Response techniques appropriate for inland habitat types are described briefly. Colored “stoplight” matrices identify the potential relative impacts of different response techniques, in the absence of oil and for each oil group.

6.2 Response Phases

Guidance to help minimize the environmental impact during implementation of treatment techniques is provided for each oil group for two different operational phases of response:

Control and Contain Phase: Represents the first hours to days of a response, when the focus is on controlling the source and containing the active spread of spilled oil on land and/or water. This phase includes efforts to protect sensitive resources at risk through construction of barriers and trenches on land, placement of underflow dams, overflow dams, weirs, and filter fences on streams, and deployment of containment, deflection, and exclusion booms on larger water bodies. This phase also includes the initial gross oil removal from active containment and natural accumulation areas. The timeliness and effectiveness of this phase of a response are two keys to environmental impact minimization and a successful response. The decision process should be keenly aware of near-term changes in meteorological conditions, water levels and flow rates, and pending rainfall events that can result in loss of containment whereby oil can spread and affect much larger areas, as well as be more difficult and expensive to remove.

Cleanup Phase: Represents the days to months following the Control and Contain phase of an emergency response, when the focus is on active and timely removal of residual oil to levels that meet spill-specific cleanup endpoints. The objective is to expedite the removal of the oil to prevent or minimize any ongoing environmental impacts. For this phase of a response, changes in water levels or rainfall events can increase the rate of natural removal of residual oil or remobilize oil that had been inaccessible.

There is often a third phase of a response, often referred to as the Project Management phase, when the initial cleanup endpoints have been reached, but some residual oil remains in the environment. In this phase the oil is generally no longer mobile, acute environmental impacts have been mitigated and only a limited amount of residual oil remains to be remediated and/or monitored. In this phase, active response operations have also been terminated but may have transitioned from active oil removal to passive techniques, such deployment of sorbents to remove intermittent sheening or maintenance of booms to contain residual oil that may be remobilized by weather or water level change events and prevent it from impacting sensitive resources. This phase often consists of patrol and maintenance (P&M) activities, when SCAT teams periodically document oiling conditions and Operations crews inspect, maintain, and replace sorbents, booms, or other passive measures. The key challenge of this phase is the process by which the response effort gradually is decreased and by which agreement is reached on when to complete and terminate this phase and the overall response; this topic is covered in Section 6 on cleanup endpoints.

6.3 Response Techniques and Relative Potential Impacts on Inland Habitats

Awareness of the response techniques that are generally applicable to inland spills, their general effectiveness on the different oil groups/types and the relative collateral environmental impacts to various habitat types often associated with their implementation are paramount in selecting the response technique(s) that will minimize the overall impacts of the spill and the response. To that end, Table 6 provides a brief description of response techniques applicable to inland spills of Group 1–4 oils and Table 7 describes the general habitats associated with inland areas. Table 8, described later in this section, identifies the relative impacts of the response techniques. The techniques described and habitats noted in this report complement those described in ASTM International F2204 and F2464, respectively. These techniques and habitats are the basis for the relative effectiveness and impact guidance provided for Oil Groups 1–4 in Sections 6.4 to 6.7. Section 6.8 includes techniques and guidance for response to Group 5 oils that are submerged in a water column or have sunk to the bottom and become resuspended.

Table 6—Response Techniques Included in This Guide for Oil Groups 1–4

Response Technique	Description
Natural Attenuation	No attempt to remove spilled oil from the land or water to minimize environmental impacts or due to infeasibility or impracticality of applicable response options or insignificant predicted potential impacts. Can be an option after gross oil removal. Can include monitoring to confirm assumptions and expectations.
Containment/Recovery	
Booming	Deployment of barriers on water to deflect, divert, exclude, or contain floating oil. Often involves vessels or anchors for deployment and/or to attach to anchor points on land. Can include use of barges as barriers.
Skimming	Mechanical equipment placed at the oil/water interface to recover floating oil. Needs containers for interim storage of recovered liquids and appropriate treatment of liquids prior to discharge. Large amounts of debris can be challenging.
Barriers	Earthen berms and other manmade or ad hoc materials, such as sand bags, used to physically contain the movement of oil on land and small creeks; underflow dams, overflow dams, air bubble curtains and silt curtains to prevent further spread of oil on water.
Trenching	Excavation of a trench (either manually or mechanically) to intercept oil flow on the surface or in the subsurface. Can include French drains in the subsurface.
Removal	
Manual Removal	Hands and hand tools (rakes, shovels, sieves) to remove oil and oiled sediments. Often includes involves utility vehicles (UTVs) or boats for worker and waste transport, and on site and/or adjacent staging areas for waste storage and handling.
Vacuum/Pumping	Vacuum or pumping system to recover bulk oil on land, on water, and under water; Range from small, portable units to large, truck- or barge-mounted systems, typically manually directed.