

In Situ Burning: A Decision Maker's Guide

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Purpose of Report

This report is intended to describe the use of and requirements for in situ burning (ISB) as an effective response technology for oil spills on land (including wetlands), on water, or in ice and snow. It was developed to serve as a reference for oil spill response policy makers and decision makers (government, industry, and other stakeholders). This report discusses requirements for ISB and includes a summary of oil chemistry, behavior, and weathering, which are important factors when making decisions to use ISB. Further, it allows decision makers to better understand the anticipated benefits and limitations to be considered when using this technology for an oil spill.

ISB has been used less frequently than other techniques such as booms and skimmers or oiled soil removal. Consequently, familiarity with the pros and cons of ISB might be limited. Extensive practical and operational experience has been gained from ISB efforts to the Deepwater Horizon oil spill response in 2010 and continues with the ongoing research and development efforts for responding in the Arctic. These lessons learned have been incorporated into this document in an effort to capture and share this expanding knowledge base.

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Executive Summary

The objective of this document is to provide a decision maker with information necessary to assess the use of controlled in situ burning (ISB) as a primary response option for oil spills on land, on water, and in ice/snow conditions. ISB is one of the most efficient ways to eliminate spilled oil under the right conditions. Using ISB, a high percentage of even large volumes of encountered oil can be removed quickly.

ISB has been extensively researched and has been used operationally since the late 1950s for spills of oil on land. ISB has been often used as a response procedure for small to medium on-land incidents in the United States, so there is a good understanding of conditions under which on-land ISB is feasible and effective. More recently it gained operational confidence and public notice for on-water responses during the more than 400 individual burns conducted in response to the Deepwater Horizon oil spill. ISB is well suited to cold weather conditions and can be done even in the presence of ice (on land or at sea). Cold slows the rate of weathering, so the window of opportunity for ISB can lengthen. Sea ice reduces wave activity (breaking waves), slows spreading (which keeps the oil thick enough to burn), and reduces the emulsification process.

Major benefits and reasons to consider ISB are its:

- **High efficiency**—an ISB can be up to 98% effective in removing encountered oil from the environment (dependent on oil type, extent of weathering, and oil thickness);
- **Versatility**—ISB can be used **on water** (fresh or salt water, rivers, streams, oceans), **on land** (terrestrial or riparian habitat, wetlands/marshes, other shorelines), and **in ice/snow** environments (including the Arctic);
- **High elimination rates**—most burns are completed within hours after ignition;
- **Minimal equipment and personnel needs**—personnel are needed for collection and containment of the oil to a thickness that will allow for ignition and sustainment of the burn; and
- **Waste stream reduction**—with high burn efficiencies, the need for waste recovery, removal, storage, transport, and disposal is removed or minimized.

The combustion plume contains most burn by-products that are released to the atmosphere:

- 85 to 95% of the total burned oil becomes carbon dioxide and water;
- 5 to 15% that is not burned efficiently is converted into particulates (soot); and
- A few percent is converted into combustion by-products.

Any remaining incomplete combustion product (burn residue) is usually less than 15% of the total volume burned.

The principles for using ISB, including containment, ignition, and controlling the spilled oil, are well established. There is an extensive history of use, research, and testing in the United States and internationally. The basic principle is to collect and/or thicken an oil slick to greater than 2 mm (0.08 in.) and provide an ignition source to heat the hydrocarbon vapors from the slick surface to ignite a burn. Most oils will burn if a slick is thick enough and if sufficient vapors are present to initiate and sustain combustion.

Decision makers should understand and consider the following when considering ISB:

- Spilled oil properties and the effects of weathering on its behavior;
- Operational requirements and limitations;
- Health and safety of response personnel and the public;
- Environmental effects—wildlife, habitats, etc.

When considering the human health and environmental trade-offs for ISB, the benefits often far outweigh any potential negative consequences. In review of the available information on spills where ISB was used, there were no instances where the response community determined burning was the wrong response option.

In the United States, multi-state Regional Response Teams (RRTs) and state or local governments can pre-approve burn zones within their jurisdiction. These organizations jointly develop planning guidance for the use of ISB for the federal and state decision makers on the requirements for ISB use within the region. The RRTs can establish pre-authorization areas such as:

- Pre-approved zones—areas that do not require RRT consultation;
- Case-by-case zones—areas that require RRT approval; and
- Restricted or exclusion zones—areas where ISB is not allowed.

As there is generally a short window of opportunity when a slick is capable of sustaining a burn, pre-authorization zones allow quicker, informed decisions.

Short-term, localized air quality should be considered relative to approved burn plans. For ISB planning purposes, the most significant National Ambient Air Quality Standards (NAAQS) are the primary NAAQS for particulate matter. Concerns for human health typically only exist for responders directly exposed to the visible plume. Monitoring for potential health effects from atmospheric pollutants generated from burning oil is recommended for the workers in the immediate area of ISB operations and, if there are receptors at risk, for several miles downwind of a burn site.

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Acronyms and Abbreviations

ABSORB	Alaskan Beaufort Sea Oil Spill Response Body
ACS	Alaska Clean Seas
AMOP	Arctic and Marine Oilspill Program
API.....	American Petroleum Institute
BSEE	Bureau of Safety and Environmental Enforcement
CAA	Clean Air Act
CDC.....	Centers for Disease Control and Prevention
CERCLA.....	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulation
CTEH.....	Center for Toxicology and Environmental Health, LLC
CWA	Clean Water Act
DOC	United States Department of Commerce
DOD	United States Department of Defense
DOE.....	United States Department of Energy
DOI	United States Department of Interior
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
FOSC	Federal On-scene Coordinator
HAZWOPER	Hazardous Waste Operations and Emergency Response
IFO	Intermediate Fuel Oil
IOSC.....	International Oil Spill Conference
ISB.....	In Situ Burning
JIP	Joint Industry Project
LEPC	Local Emergency Planning Committee
LOSCO.....	Louisiana Oil Spill Coordinator's Office
MMS	Minerals Management Service
MOU	Memorandum of Understanding
NAAQS.....	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEBA.....	Net Environmental Benefit Analysis
NHPA	National Historic Preservation Act of 1966
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOBE	Newfoundland Offshore Burn Experiment
NO _x	Nitrogen Oxides

NRC	National Research Council
NRDA	Natural Resource Damage Assessment
NRT	U.S. National Response Team
OPA 90	Oil Pollution Act of 1990
OSC	On-scene Coordinator
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PEL	Permissible Exposure Limit
PM	Particulate Matter
PPE	Personal Protective Equipment
RCRA	Resource Conservation and Recovery Act
RRT	Regional Response Team
SHPO	State Historic Preservation Officer
SIP	State Implementation Plan
SMART	Special Monitoring of Applied Response Technologies
SOSC	State On-scene Coordinator
SO _x	Sulfur Oxides
THPO	Tribal Historic Preservation Officer
TPH	Total Petroleum Hydrocarbon
UC	Unified Command
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound

In Situ Burning: A Decision Maker's Guide

Section I: Introduction

The primary goal of an oil spill response is to limit exposure time and subsequent effects from spilled oil on natural and economic resources. Preferred response technologies are those that will result in the best outcome for the environment while minimizing possible adverse effects from the cleanup efforts. The objective of this document is to provide a decision maker with information necessary to assess the use of controlled in situ burning (ISB) as a primary response option for oil spills on land, on water, and in ice/snow conditions.

The main categories of response technologies used in the United States (U.S.) include:

1. Manual and mechanical removal of oil from shorelines and land;
2. Mechanical containment, recovery, and removal on water using booms, skimmers, etc.;
3. Application of dispersants;
4. Controlled (in situ) burning;
5. Treatment with specialized agents such as solidifiers and shoreline cleaning agents; and
6. Natural recovery with monitoring for possible future action.

This document focuses specifically on ISB for oil spill response.



Figure 1—Bayou Sorrel burn, 2013. Source: USCG.

I.1 Controlled In Situ Burning

In situ burning is a response technology that removes spilled oil from a land, snow, ice, or water surface by combustion of hydrocarbon vapors and that yields predominantly CO₂ and water to the atmosphere. ASTM International (2014) defines controlled in situ burning as “burning when the combustion can be started and stopped by human intervention.” The combustion by-products (particulates, gases, water, etc.) are released to the atmosphere, with the possibility of some unburned oil or incompletely burned oil residue remaining at the conclusion of a burn.

One of the greatest benefits from ISB is that a burn can rapidly reduce the volume of spilled oil and minimize or eliminate the need to collect, store, transport, and dispose of recovered oil and oily wastes. Each of these actions has associated environmental and human health risks. ISB also has the potential to significantly reduce the duration of cleanup operations. In certain instances, ISB might provide the only means of quickly and safely eliminating large amounts of oil.

ISB has been extensively researched and has been used operationally for spills since the late 1950s as a response technology for spills of oil on land. More recently it gained operational confidence and public notice for on-water responses during the more than 400 individual burns conducted in response to the Deepwater Horizon oil spill. Research on the use of ISB in snow and ice has increased in the last decade as efforts to drill in more remote areas like the Arctic are being considered.

I.2 Document Organization

Key factors to determine the appropriateness of ISB are the feasibility of using ISB under existing spill conditions and safety and health considerations. This report addresses these factors for ISB **on land**,¹ **on water**,² and **in ice/snow**³ and is organized around decision-making considerations for ISB:

- **Section II—In Situ Burning:** the benefits and applicability of ISB;
- **Section III—ISB Decision-making:** local, state, and federal role in the decision-making process;
- **Section IV—Influence of Oil Properties and Weathering:** how oil properties and weathering affect the feasibility of ISB over time;
- **Section V—Oil Combustion and Burn Residues:** the atmospheric by-products and burn residue that result from ISB;
- **Section VI—Human Health and Safety:** the possible health hazards of ISB on response personnel and the general public;
- **Section VII—Effects on Wildlife and the Environment:** the potential effects of ISB from the combustion plume and any burn residue;
- **Appendix A—ISB Case Histories and Lessons Learned:** case studies in which ISB was used as a response technology.

¹ **On land** includes a wide range of habitats, such as salt marshes, wetlands, ponds, grasslands, timberlands, and open fields.

² **On water** is defined as spills of oil on the ocean, coastal waters, estuaries, bays, freshwater lakes, rivers, and streams.

³ **On ice/snow** refers to climates where winter conditions are cold enough to freeze; this includes Arctic-like environments with sea ice and cold temperatures that can exist for all or part of the year and can include spills on water and on land but with the additional environmental and logistical benefits and challenges of dealing with the presence of ice and snow.

Section II: In Situ Burning

II.1 How an In Situ Burn Works

To initiate a burn, sufficient quantities of hydrocarbon vapors are needed in the air above a slick to support combustion. An ignition source can either directly ignite those vapors or heat spilled oil to a temperature at which sufficient vapors to ignite are generated. Once a slick is ignited, hot air rising above the burn will draw air from the sides toward the burn (**Figure 2**). This induced air flow can also draw surrounding oil toward the burn, thereby feeding it with more vapors.

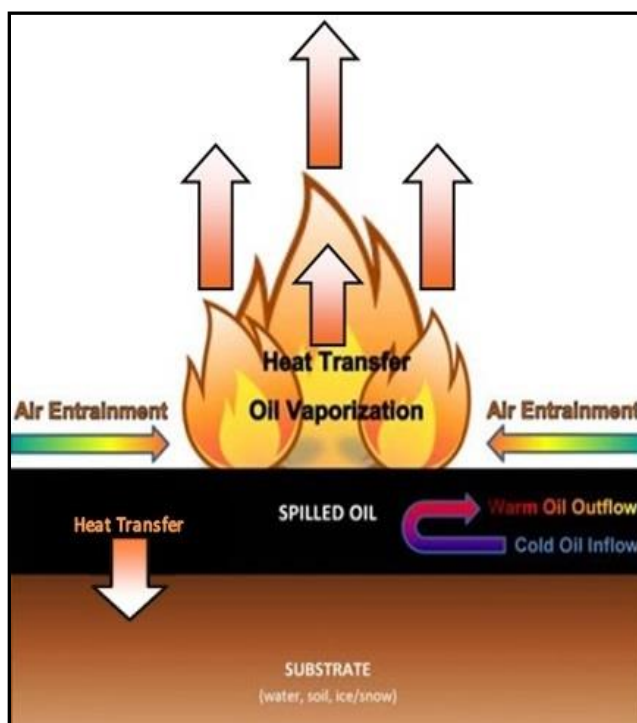


Figure 2—Key oil and heat transfer processes during ISB. Source: Modified from Fritt-Rasmussen (2010).

The key factor that defines whether or not an oil will burn is slick thickness. Slick thickness has two roles:

- Source of hydrocarbon vapors; and
- Retains heat to help vaporization to sustain a burn.

If a slick is thick enough, it insulates the slick by reducing heat loss to underlying media (i.e., water, soil, ice/snow) and keeps the slick surface at a high enough temperature to continue to vaporize. As a slick thins during combustion, its insulating capacity declines and more heat is lost to the underlying substrate. Eventually, the oil temperature will drop, the concentration of vapors will become insufficient to sustain a burn, and it will extinguish. As long as heat transfer to surrounding media is minimized by maintaining sufficient slick thickness, an oil slick will be capable of sustaining a burn.

II.2 Benefits of ISB

The goal of any response is to limit the effect of the spill on nearby communities and responders as well natural and economic resources. Some of the benefits and reasons to consider ISB are its:

- **High efficiency**—an ISB can be up to 98% effective in removing encountered oil from the environment (dependent on oil type, extent of weathering, and oil thickness);

- **Versatility**—ISB can be used **on land** (terrestrial or riparian habitat, wetlands/marshes, other shorelines), **on water** (fresh or salt water, rivers, streams, oceans), and **in ice/snow** environments (including the Arctic);
- **High elimination rates**—most burns are completed within hours after ignition. Once underway, burns proceed quickly. Oil removal rates are a function of the fire size (its diameter), slick thickness, oil type and any emulsification, and environmental conditions at the time of the burn. Larger fires have higher removal rates than smaller fires. Emulsified oils will burn at a slower rate, almost proportional to their water content, until the water content becomes too high; >50%. Empirical observations and experimental data indicate a range of removals (**Table 1**).

Table 1—ISB Elimination Rates

Oil Type	Removal Rate Ranges (mm/min) and (in/min)	
Gasolines	• 4–4.5	• 0.16–0.18
Diesels	• 3.5–4	• 0.14–0.16
Heavy Fuel Oils	• 2–2.2	• 0.08–0.09
Crude Oils	• 3–3.5	• 0.12–0.14

A typical removal rate of about 0.07 gal/min/ft² equates to about 4,350 bbl of oil an hour per acre;

- **Minimal equipment and personnel needs**—less equipment and fewer personnel are needed for collection and containment of oil for ignition and burning than for either mechanical recovery or dispersant use on water or for manual and mechanical recovery on land or shorelines; and
- **Waste stream reduction**—with high burn efficiencies, the need for waste recovery, removal, storage, transport, and disposal is removed or minimized.

Table 2 summarizes some of the advantages and disadvantages to be considered when deciding whether to use ISB in response to an oil spill.

Table 2—Advantages and Disadvantages of ISB ⁴

Advantages	Disadvantages
• High-efficiency oil removal rates from water, land, or ice surface • Less equipment and less labor-intensive than other response options • Can be conducted at night • Can be applied in remote areas where other methods cannot be used because of distances and lack of infrastructure • Prevents or minimizes impacts to the environment and other resources at risk • Does not release toxic components of oil into the water column • Significant reduction in oil and oily waste requiring storage, treatment, and/or disposal	• Oil must be a minimum thickness to ignite and burn • Residue or unburned oil might need to be recovered. Sunken residue could be thick enough to smother/coast benthic organisms and habitats. • Visible smoke plume • Public concern about burn emissions to the air and into the water. Sensitive individuals can be vulnerable to combustion by-products. • Might not be appropriate in close proximity to populated areas; might require evacuation in sparsely populated areas • Risk of fire spreading to other combustible materials

⁴ Modified from Fingas & Punt (2000).

II.3 When to Consider Using ISB

II.3.1 On Land

It is preferable to quickly remove spilled oil to limit its spread and reduce its potential impact to sensitive sites. ISB can remove encountered oil in hours, whereas manual or mechanical recovery can take days to months. Weather conditions and seasonal considerations become important in certain circumstances. For example:

- Forecast rain could flush oil from a spill site into sensitive areas and/or thin slicks such that they become un-ignitable.
- Temporary snow and ice containment structures are expected to fail during a predicted thaw.

These kinds of spill conditions trigger the need to rapidly remove as much oil as possible. Consider using ISB on land for the following spill conditions (Mendelssohn et al., 1995; Dahlin et al., 1999; Michel et al., 2002):

- Access to a spill site is limited, making it difficult for responders and equipment to arrive on scene. Surrounding terrain (e.g., steep canyons, extensive wetlands) can either restrict access or can be too soft to support foot or vehicular traffic without causing damage (e.g., wet tundra, salt marshes, peat bogs). ISB is logistically simpler than mechanical or manual recovery with associated recovered oil handling, storage, and disposal.
- Options for transportation and disposal (temporary and/or permanent) of oily wastes are limited. During both manual and mechanical cleanup operations, large volumes of oily wastes can be generated. The remoteness of a site from approved disposal facilities is an important factor in the decision to burn. Another consideration is weight restrictions on roads. For example, cleanup of a spill along the Trans-Alaska Pipeline changed from mechanical recovery to ISB after weight limitations were placed on the road to the site with the arrival of the spring thaw (Buhite, 1979).
- Other response options are ineffective or might cause additional damage to vegetation, the substrate, and other natural resources. Because cleanup activities such as the construction of access routes, vehicle traffic, foot traffic, or the diversion of water flow can cause unintended environmental effects, it might be advisable to use a less intrusive response option like ISB.
- If oil is spilled in wetlands. ISB is considered a primary response procedure for incidents where oil is spilled in wetlands.

II.3.2 On Water

Consider using ISB for the following on-water spill conditions:

- It is preferable to quickly remove large quantities of spilled oil to limit its spread or potential impact to sensitive sites. Burning can remove large volumes of encountered oil quickly. For example:
 - A 500-ft-long (152-m-long) fire-resistant boom containing 18,000 gal (68.1 m³) of spilled oil is estimated to burn in 10 minutes. Whereas recovery rates by skimmer and vacuum systems after the oil is contained are on the order of 200–300 gal/min (0.8–1.1 m³/min) for a time estimate of 72 minutes.
- Oil recovery is limited by skimming, storage, and recovered oil handling capabilities. On-water mechanical recovery requires skimming systems and logistical support (e.g., boats, booms, skimmers, pumps, storage tanks, support barges, crews for operations and support, fuel for vessels and trucks, etc.). It might not be possible to deploy such systems and provide logistical support to remote sites in a timely manner.

- Even under ideal conditions, most skimmers collect more water than oil, necessitating storage for large amounts of oily liquid. Collected oily liquid has to be transferred from the skimmer vessel to a storage tank or barge. The turnaround time for recovered oil and oily waste to be offloaded and a skimmer returned to active operations can be hours.
- Skimmers are rarely operated at night because crews need to see the slicks or be directed to slicks by observers in aircraft. These operational constraints limit the quantity of oil that can be recovered in a 24-hour period.
- The release is continuous from a source. On water, ISB is considered a primary response technology for incidents with a continuous release source (e.g., a well blowout or a leaking tanker).

II.3.3 In Ice/Snow

Consider using ISB in oiled ice/snow for the following spill conditions:

- **A spill occurs in snow.** Oiled snow can be plowed into piles and burned on the ground or on ice. Alternately, oiled snow can be collected by front-end loaders, loaded into dump trucks, and hauled to a burn pit (ACS, 2006).
 - Oiled snow containing up to 70% snow burns readily (Buist, 2007).
 - Snow and oil mixtures with as little as 3 to 4% oil have been piled into hollow cones and ignited, removing up to 90% of the oil, even two weeks after being spilled (Allen & Nelson, 1981).
 - For higher snow content mixtures (i.e., lower oil content), the use of accelerants or promoters, such as diesel fuel or gelled gasoline, might be necessary to start the burn.



Figure 3—Burning oiled snow in volcano-shaped piles. Source: Alaska Clean Seas.

- **Oil is trapped/contained in ice.** ISB is considered a primary response option when oil is trapped/contained in ice. The presence of ice can increase the window-of-opportunity for ISB by reducing the spreading, weathering, and emulsification of spilled oil.
- **A spill occurs in ice-infested waters.** Mechanical recovery can be either ineffective, too hazardous, or access to surface waters for dispersant spraying is limited. Spilled oil can pool on top of solid ice. Pools of spilled oil encapsulated in ice can rise to the ice surface in spring as oil migrates up from within or below the ice through brine channels.
 - Dickins et al. (2008) demonstrated that ISB can be up to 95% effective even 63 days after initial oil release under ice, when a 660 gal (2.5 m³) spill was burned in field tests leaving a 0.4-in.-thick (1-mm-thick) residue.

- Significant quantities of melt water can be generated allowing oil to migrate upwards and combine with other pools of oil on the ice surface. Dickins et al. (2008) demonstrated that ground penetrating radar could detect oil films as thin as 1–3 cm under 65 cm of ice. Therefore, individual pockets of oil under ice could be located, tracked, and targeted for burning during spring thaw. When the oil is encapsulated in ice, the ice can be removed and treated by melting and then burning or oil recovery.

II.4 Physical Conditions for Successful ISB

Physical conditions such as wind speed, wave height (for on-water spills), slick thickness, and weathering state of an oil can limit the feasibility of ISB. Physical considerations for ISB are summarized in **Table 3**.

Table 3—Physical Conditions for Successful ISB⁵

Operational Conditions	• Fresh oil is easier to burn • Maximum towing speed for fire boom on water is < approximately 0.6 mph (0.5 knots) • Means of fire control is available
Environmental and Location Conditions	• Wind speeds <21 mph (18 knots) for ignition for ISB on water^a • Wind speeds <12 mph (10.5 knots) for ignition for ISB on land^b • Wind speeds <40 mph (35 knots) to sustain a burn • A Beaufort sea state of <3 (4 ft or 1.2 m) for ISB on water • Ice cover <30% or >70% for ISB on water • Un-vegetated land or land where vegetation is not actively growing^c • Saturated soils^d • Wetlands where 1–3.9 in. (2.5–10 cm) of water covers the roots^e • Wetlands that will not be flooded immediately following the burn
Notes: ^a A. Allen (Pers. Comm., 18 December 2012). ^b API (TR 1251, 2015). ^c Mendelssohn et al. (1995). ^d Reardon et al. (2015). ^e Bryner et al. (2003); Lin et al. (2002).	

II.4.1 Evaporation and Emulsions

In general, fresh oil is easier to ignite and burn than oil that has been weathered and lost much of its more volatile hydrocarbons. Evaporation can remove most of the volatile components, making burning of collected oil difficult or unachievable beyond the first 12 to 24 hours. Colder temperatures slow evaporation rates. The longer oil remains on water, the greater chance for water-in-oil mixtures (emulsions) to form, which can greatly reduce the possibility of a successful burn.

II.4.2 Slick Thickness

Studies have shown that most oils will burn if a slick is thick enough. In general, slicks must be at least 2 to 3 mm (0.08 to 0.1 in.) thick to sustain ignition (Buist et al., 1996, 1998; Bech et al., 1992, 1993). Once a slick has thinned to approximately 1 mm (0.04 in.), much of the heat generated by burning can be lost to the underlying substrate (water, sediment, or ice/snow), resulting in insufficient heat to vaporize hydrocarbons, extinguishing the burn (ASTM, 2014). Although there have been cases on land in which thinner slicks have been ignited (Fingas & Punt, 2000), the use of containment, whether booms on water or natural and man-

⁵ Modified from Fingas and Punt (2000).

made barriers on land or in snow/ice, is generally necessary to thicken spilled oil to allow ignition and to sustain combustion.

- For spills in wetlands, where there is a layer of water underneath a slick, the minimum thickness rules discussed above for spills on water usually apply.
- Often oil is naturally contained by wet soil or vegetation, or concentrated in open water areas in wind rows.
- For spills that spread over relatively flat terrain, temporary dikes can be constructed to contain and isolate oil for burning.

II.4.3 Wind Speed

Recommended surface wind speeds for ignition are between 0–18 knots [0 to 21 miles per hour (mph)]. Once oil vapors are ignited, high wind speeds can extinguish a burn. ASTM (2014) recommends that burns be conducted with ambient wind speeds <20 knots (23 mph) for ISB on water. API Field Guides (2015) say burning can be sustained in winds up to 35 knots (40 mph) on land and on water.

II.4.4 Wave Height for On-water Burns

For on-water response, the presence of wave action can limit burning. Greater wave heights or steep waves that lessen boom conformance and make oil containment difficult can result in splash over or boom failure. Higher wave heights can also increase emulsification of a slick, which can limit the success of a burn. Allen et al. (2011) state that swell and wave heights should not exceed 4 ft (1.2 m) for an effective burn.

II.4.5 Ice Cover Ranges for On-water Burns

In open water circumstances to approximately 30% ice cover, an oil's spread and movement will not be greatly affected by ice, so open water ISB techniques are possible. In circumstances with 30% to 70% ice cover, ice will restrict movement of a slick, but will not completely contain the oil. However, deployment and towing of boom in this ice cover range would be difficult. In 70% to solid ice cover, the closely packed ice helps contain oil by serving as a natural barrier. If oil is restricted by the ice and kept thick enough, an effective burn can be possible.

The combination of cold temperatures and reduced wave energy due to the presence of ice and snow on water results in a slowed rate of weathering and an extended window of opportunity (Sørstrøm et al., 2010). Factors such as time of the year and how the ice was formed, will give the ice different characteristics and hazards that can influence the weathering of spilled oil. For more information on the effects of weathering in snow and ice, refer to Potter et al. (2012).

II.5 Equipment Requirements for ISB

There are two main requirements for ISB: containment or herding mechanisms to collect the oil thick enough to provide sufficient vapors for burning, and a heat source (igniters) to heat oil to its ignition temperature.

II.5.1 Containment

Spilled oil can spread rapidly into slicks too thin to provide enough vapors to ignite. Therefore, containment is generally a necessary step to achieve a slick thick enough to allow ignition and to sustain combustion.

- **On land**, oil containment can be achieved through the construction of earthen dikes and underflow dams, the use of lined trenches and pits, natural barriers or ditches, or the enhancement of natural barriers.

- **On water,**

- Boom is used to collect and concentrate the oil for burning. There are three types of fire-resistant boom (ASTM, 2013):
 - Fence-type boom constructed of refractory fabric and using steel and glass floats,
 - Ceramic and stainless steel boom constructed with a solid core flotation,
 - Water-cooled, inflatable boom.

See API Technical Report 1252 (2015) for more details. A key performance factor is how well a boom conforms to waves and/or swells, which is directly influenced by sea state. Some operational and environmental considerations are presented in ASTM (2014).

- Herding agents are chemicals applied to surface water along the perimeter of a slick. These agents alter surface tension of surrounding water and act to “herd” an oil slick into a smaller area, thickening the slick by consolidating the oil.

Herding agents do not require a boundary to push against and will work on open water (Buist and Nedwed, 2011). They work best in warm or temperate waters; however, they have proven effective with light- to medium-weight oils in colder temperatures, where they reduce spreading and work between ice pieces to increase oil thickness for burning. Buist et al. (2007) found herding agents are effective in light wind and swell conditions, but not very effective in short, steep-sided waves with ice.

- **In snow/ice,**

- Oil mixed with snow has been successfully burned. Snow with 70% oil content will successfully sustain a burn. Igniters are used for oiled snow when ignition alone is not effective. After piling the oiled snow, gravity will naturally concentrate the oil, and burns are possible when using an igniter.
- When oil is trapped under ice, it can be exposed for collection and combustion when the oil's location is known. This can be accomplished by digging trenches and pits at the ice surface and augured holes to the water beneath ice to allow oil to rise and fill those temporary containment areas. Two other techniques include:
 - Cutting slots in the ice downstream of the source to intercept the ice as it moves with the currents;
 - Inducing the flow of oil toward the slots with air, water, or propeller-generated currents.

These techniques direct oil to the surface for ignition and burning.

- In areas with heavy ice concentrations, the ice itself can provide natural containment, limit the spread of oil, and help keep it at combustible thicknesses. At very high ice concentrations, especially with the presence of slush ice, it is often difficult to sustain an efficient burn.
- In waters with low ice concentrations, fire-resistant containment boom is deployed in a manner similar to methods employed for open water ISB. Such containment can, however, collect ice along with the oil, reducing the available surface area of oil for combustion and affecting boom function. As ice concentrations increase, the ice can provide sufficient containment of oil without the need for fire-resistant boom.

II.5.2 Slick Ignition

Most ignition systems can be used for oil spills on land, on water, and in snow and ice conditions. For open-water burns or where necessary for safety reasons, ignition is conducted from a vessel or a helicopter. Commonly used ignition devices include propane or butane torches, gelled fuel with an attached flare, diesel-soaked rags or sorbents, helicopter-slung gelled fuel (helitorch), and road flares. Research is underway to expand the options for ignition devices from aerial platforms. Each type of ignition device should be: 1) capable of supplying a reliable heat source to produce oil vapors from a slick to ignite the oil; and 2) safe to use, simple to operate, and have long shelf-life (Fingas & Punt, 2000; ExxonMobil, 2014).

Section III: ISB Decision-making

Decision makers and natural resource trustees were asked what types of information would be requested to assess the benefits from using ISB. Their collective replies provide a view into the wide variety of information desired for decision-making and risk communications. There were three basic types of information desired:

1. Burn planning, logistics, and execution.
 - Does ISB have a >50% chance of success?
 - Where is the burn planned?
 - What is the volume of the burn and how long will it last?
 - How much oil is expected to be removed?
 - Can we maintain fire control?
 - Will the burn be effective?
 - Can the public be adequately notified and the burn still be conducted effectively?
 - What post-burn cleanup might be necessary?
2. Decision-making and natural resource management.
 - What populations/sensitive populations are located downwind?
 - What endangered species are adjacent?
 - What are the potential impacts to these resources from the burn?
 - Is the planned burn to be within an air basin ⁶ that has a “non-attainment” area for PM₁₀ or for some other air pollutant?
 - If burns are planned on water, what are the water body uses?
 - What other government organizations or agencies should participate in decision-making?
3. Contrast in response outcomes between ISB and not burning.
 - What oil type is planned to be burned?
 - What are the fate and transport forecasts for the spilled oil if we do not burn?
 - What are the fate and transport forecasts for combustion by-products?
 - Might there be combustion by-products of concern, in particular any carcinogens?
 - What effect would burning have on habitat recovery, versus other response strategies?

NOTE:

An example checklist for ISB on water was developed by the state of Alaska and could be used as a template for developing a checklist for the concerns of decision-makers. Available from <http://alaskartt.org/>. Additional checklists are available in API Technical Reports 1251 and 1252 (2015).

⁶ Air basins are areas that generally have similar meteorological and geographic conditions and in which air quality is regulated.

The spill location and volume most often determine which local, state, and/or federal regulations will apply and which agencies could be involved in an incident response. Response to spills within the U.S. will be influenced by a variety of U.S. federal laws. Key among them are:

- Clean Water Act (CWA) as amended by the Oil Pollution Act of 1990 (OPA 90);
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986;
- Clean Air Act (CAA);
- Resource Conservation and Recovery Act (RCRA).

Some of these laws contain guidance or requirements that apply to contingency planning (**Table 4**).

Table 4—Main Contingency Planning Guidance and Requirements

Authorities	Key Applicable Laws and Governing Bodies
Federal Authorities	• CWA, OPA 90, CERCLA, CAA, RCRA
Regional Planning	• Regional Response Team, Pertinent area committee
Regional Federal Planning Lead	• U.S. Coast Guard, U.S. EPA
State Planning Lead	• State environmental response agencies
Local Planning Lead	• Local emergency planning committees

III.1 Local and State Level Decision-making

For burns of small oil spills on land and on waters not subject to federal jurisdiction, fire department staff and other local emergency responders might be the only responders. Burns of larger oil spills to land and to waters not subject to federal jurisdiction are expected to be handled first by local officials who would likely quickly request additional emergency response resources from within their state.

It is highly unlikely that local jurisdictions would have any regulations or guidance on the conduct of ISB. Regulations or guidance could be available at the state level and are available at the multi-state, regional level via the U.S. Regional Response Teams (RRTs). Because the network of response experts is collegial and the number of ISB experts is not large, the assistance from ISB experts in state or federal agencies can be requested even if not required.

Over the past 20+ years the RRTs have developed regional guidance for response to a wide variety of hazards and emergencies within the U.S. and its territories (**Figure 4**). Many of the 10 RRTs have prepared guidance for burning of oil spills and on designation of burn pre-approval (or pre-authorization) zones that were published in the mid-1990s. Most of the ISB guidance and any pre-approved zones are for spills to coastal waters rather than for spills on land or non-navigable waters.

For consistency of approach across states within an RRT, it is anticipated that RRT guidance and direction would be requested for inland burns to land and non-navigable waters. RRT member-agency specialists and other technical and scientific resources could be available to states within a given region. The RRT network could help address unique spill circumstances. Local and state agency jurisdiction might also be specified in Regional Contingency Plans and in Area Contingency Plans for particular circumstances or locations.

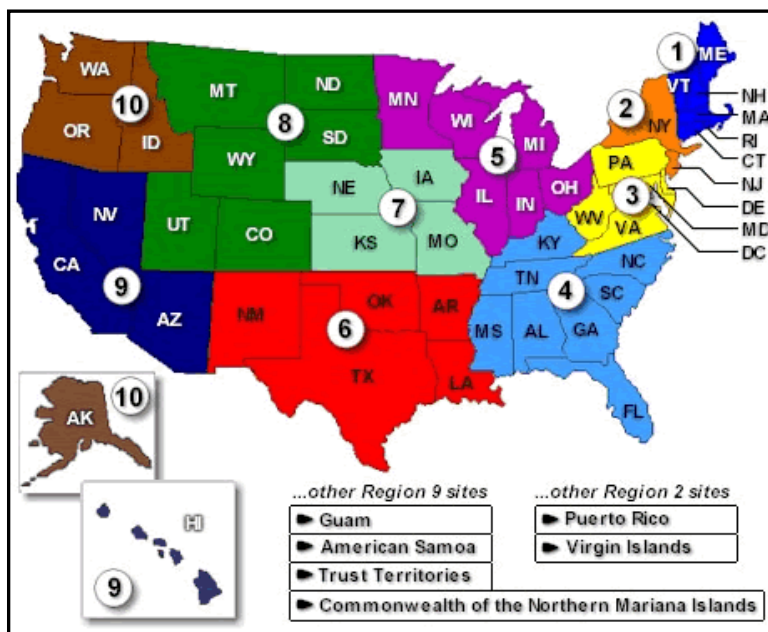


Figure 4—Map of Regional Response Team districts. Source: EPA.

III.1.1 Regional Response Team (RRT)

RRTs have decision-making authority within designated federal districts in the United States (**Figure 4**). Under the NCP, RRTs have the responsibility to evaluate and plan for use of spill response technologies, including ISB. RRTs provide guidance to Area Committees and their two principle components are:

- Standing Teams whose role is to establish pre-spill policy and to assist the FOSC and Area Committees; and
- The Incident-specific Teams whose role is determined by the operational requirements for each specific response.

The RRTs are co-chaired by representatives from the EPA and USCG and they are designed to support an FOSC with agency resources during a response.

III.1.2 Pre-authorization Planning

The Standing RRT develops pre-authorization policies and guidance for the use of ISB in their Region [on water, on land, and in ice/snow (where applicable)] in advance of an incident. These pre-authorization plans specify when and where ISB can and cannot be used within the Region in areas under federal response authority and what monitoring and documentation requirements are necessary. The status of the RRT pre-authorizations for ISB in the U.S. is provided in regional documents accessible from the National Response Team (NRT) website (<https://www.nrt.org/Site/Regionmap.aspx>).⁷ The information includes the status of pre-approval (i.e., pre-authorization, case-by-case approval, non-approval); the conditions and zones where pre-authorizations exist; and the status of monitoring and consultation under Section 7 of the Endangered Species Act.

⁷ The pre-authorization status for a particular region is available from <https://www.nrt.org/Site/Regionmap.aspx> by linking to a specific RRT and reviewing the ISB planning documents established for that region.

As pre-approval agreements are drafted at the local area and regional levels, some variations in terminology have developed in the agreements themselves and/or in the supporting literature. In this document we have employed the following terms associated with pre-authorization status:

- Pre-authorized—areas where the FOSC is pre-authorized to use ISB;
- Case-by-case—areas where the FOSC must consult with appropriate agencies on the RRT [e.g., EPA, Department of Commerce (DOC)/National Oceanic and Atmospheric Administration (NOAA), DOI, and the affected states] to determine whether ISB use is appropriate;
- Additional or Special Consideration Consultation—areas where specific localized requirements are to be met in order for the FOSC to be given RRT concurrence to burn; or
- Exclusion or Restricted—areas where ISB is not to be used.

Many RRTs have established pre-authorization protocols to assist FOSCs to determine if ISB is a viable oil spill response option for their area of responsibility and under what conditions.

III.1.3 Developing the Burn Plan (State and Federal)

Even within pre-authorized areas, it is highly recommended that a burn plan be prepared. At a minimum, the burn plan can be as simple as completing the documentation provided in the regional guidance and should ensure the safety of the responder personnel. If ISB is selected as a response option, the FOSC will determine whether additional plans or provisions for responder or public health and safety are needed, and what approach should be taken for burn monitoring. Regardless of the level of detail in a burn plan used, the FOSC makes every reasonable effort to continuously evaluate the decision to burn and allow RRT agencies and the affected states the opportunity for comment.

A burn plan can evolve over time as the incident-specific conditions change and the requirements for the burn are adjusted accordingly. The FOSC has the authority to stop a burn at any time. The FOSC may receive formal requests to discontinue a burn from the RRT member agencies; these requests might be immediate grounds for discontinuance of burn operations and could entail additional discussions between the Responsible Party, FOSC, and incident-specific RRT members.

NOTE:

For more information on the federal ISB policies and requirements for each Region, go to <https://www.nrt.org/Site/Regionmap.aspx> and access the RRT Regional Home Page of interest and locate their regional contingency planning documents.

III.2 Net Environmental Benefit Analysis (NEBA)

The goal of every response is to minimize the overall impact from the release on natural and economic resources. NEBA is a planning process of considering advantages and disadvantages of different spill response options (against the baseline of no response) to arrive at a spill response decision resulting in the lowest overall environmental and socioeconomic impacts.

A spill response will likely involve some combination of response options. There are no response methods that are completely effective or risk-free. A NEBA compares the environmental and socio-economic outcomes of various spill scenarios using the possible response techniques against a baseline of “no response.” The results are then used in contingency planning and during a response to inform decision-makers as to those options with the least negative effects.

RRTs use the NEBA process to evaluate likely effects from an oil spill to determine which response option or combination of options will limit the spilled oil's overall effect on the potentially impacted resources and the environment and which response option will increase the likely impacts to these same resources. For U.S. oil spill response, all levels of government, industry, and other stakeholders (e.g., members of the RRT, the

natural resource trustees, state and local agencies, non-governmental organizations, etc.) come together to actively participate in the development of a consensus-based evaluation of the various response options, including ISB, to address their regional decision-making needs for responding to an oil spill, prior to an incident.

The decision to use ISB or other response options during an incident involves choosing the lower net risk, i.e., decreasing the expected risks to wildlife on the water surface, along shorelines, inland habitats, or in and around ice while increasing the potential risk to organisms in the water column or in the air.

III.3 Federal Level Decision-making

The National Oil and Hazardous Substance Pollution Contingency Plan (NCP) provides the “playbook” for oil spill response in the U.S. It defines a National Response System (NRS), a mechanism for coordinating response actions by all levels of government in support of the Federal On-scene Coordinator (FOSC) and is divided into national, regional and area levels. The NRS is composed of the National Response Team (NRT), Regional Response Teams (RRTs), the FOSC, Area Committees (ACs), special teams, and related support entities. The basic framework for the response management structure is a unified command system that brings together the functions of the federal government, the state government, and the responsible party to achieve an effective and efficient response, where the FOSC retains authority.

There are nuances to jurisdiction and authorities which can make each spill response different. Enforcement authority is pre-designated; typically, inland spill events are assigned to EPA and coastal and navigable water events to the USCG.⁸

More precise border definitions are described in EPA and USCG agreements and are identified in federal regional contingency plans. Spills originating in inland waters could be transported to coastal waters and ecosystems, particularly if the spill occurs in water systems near the coast (Ramseur, 2012), so it is possible that response leadership could shift in such cases. Further, the U.S. federal government shares jurisdiction over its territorial seas [within 0–12 nautical miles (nm) of shore] with coastal states. After the Deepwater Horizon incident and reorganization of the Minerals Management Service, a Memorandum of Agreement between USCG and the new Bureau of Safety and Environmental Enforcement (BSEE) clarified response jurisdictions for offshore energy and mineral operations between the two agencies (BSEE and USCG, 2012).

Under the NCP, RRTs have responsibility to evaluate and plan, in advance, for use of ISB as one of the available and legal response options. Most RRTs have prepared ISB guidance focused on offshore areas. Based on many anecdotal reports, ISB is believed to be widely used in inland and upland areas of the U.S. for predominately small spills reflecting the familiarity of firefighters and emergency response personnel with burning. For on-water spills, when ISB is a desired option, please seek pertinent RRT's guidance for a specific location (see <https://www.nrt.org/Site/Regionmap.aspx>).

RRT guidance will be used by NOAA Scientific Support Coordinators and by On-scene Coordinators (OSCs) to assess benefits of ISB relative to spill circumstances and to set plans for conduct of a burn(s) deemed appropriate to protect public health, welfare, and the environment.

III.3.1 Federal On-scene Coordinators (FOSCs)

Federal On-scene Coordinator (FOSC) is a designation in the United States for an individual who:

- Is responsible for providing access to federal resources and technical assistance; and
- Coordinates all federal containment, removal, and disposal efforts and resources during an oil or hazmat incident.

⁸ The Department of Defense (DOD) and the Department of Energy (DOE) provide FOSCs for hazardous substance pollution incidents at their facilities or under their jurisdiction.