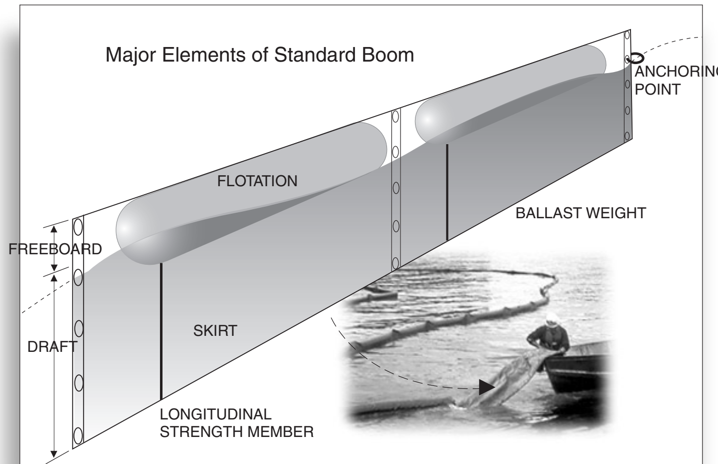
Characteristics of Response Strategies:

A Guide for Spill Response Planning in Marine Environments



American Petroleum Institute
National Oceanic and Atmospheric Administration
U.S. Coast Guard
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Characteristics of Response Strategies: A Guide for Spill Response Planning in Marine Environments is based on information contained in *Environmental Considerations for Marine Oil Spill Response*, published by the American Petroleum Institute, National Oceanic and Atmospheric Administration, the U.S. Coast Guard, and the U.S. Environmental Protection Agency. Refer to that publication for complete information on proper use and cautions regarding the information presented in this document.

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Introduction

Oil is a complex and variable natural substance. When released into the sea it can be transported long distances, undergo various physical and chemical changes, and adversely affect marine ecosystems. Oil's fate and effects depend on the type and quantity of oil spilled, properties of the oil as modified over time by physical and chemical processes, the organisms and habitats exposed, and the nature of the exposure. All of these factors should be considered when evaluating response methods. Interactions among these variables result in a large range of spill situations. Accordingly, spill responders must determine the combination of response methods that best suits the spill situation.

Response techniques have "windows of opportunity," specific timeframes when each response method works the best. These windows are defined by the type of product spilled, the initial spill conditions, product weathering and emulsion rates, and the very different environments and ecosystems that are, or will be, impacted. When the methods are used within these windows, they are more effective and less damaging to populations that survive the oil, reducing the time affected ecosystems need to recover.

In every oil spill, government and industry decision-makers are presented with a unique set of challenges requiring timely application of appropriate response methods.

- How does an on-scene coordinator or a responsible party sort through the myriad of options and select those methods that will effectively mitigate and clean up the oil?
- What is the rationale for selection?

Characteristics of Response Strategies addresses these questions by providing information to decision-makers relating to tradeoff decisions for specific habitats and response options. It focuses on maximizing response effectiveness while minimizing resource impacts.

Remember that the selection of a proper response method is highly dependent on incident-specific conditions, and that the strengths and weaknesses of a given response tool affect the suitability for its employment in a given habitat for a specific spill. Accordingly, using multiple methods simultaneously throughout an incident can produce a more effective response and minimize environmental impacts.

Selecting response options, including natural recovery, involves considering tradeoffs among their potential environmental impact, appropriateness for habitat, and application timing.

Characteristics of Response Strategies and its companion guide, *Characteristic Coastal Habitats: Choosing Spill Response Alternatives* (NOAA 2000), are based on information contained in *Environmental Considerations for Marine Oil Spill Response*, published by the American Petroleum Institute, National Oceanic and Atmospheric Administration, the U.S. Coast Guard, and the U.S. Environmental Protection Agency. Refer to that publication for complete information on proper use and cautions regarding the information presented in the document.

Characteristics of Response Strategies is a useful aid for informing people who will be participating in cleanup assessments as part of Operations and Planning Units within the Incident Command System.

How to Use this Document

This document summarizes the technical rational for selecting response methods. A companion guide to *Environmental Considerations for Marine Oil Spill Response*, *Characteristics of Response Strategies* can help you select appropriate response options to minimize adverse environmental impacts of a marine oil spill. The guide discusses developing incident-specific strategies and describes the characteristics of individual response methods. Response methods include natural recovery, mechanical, chemical, and biological treatments; and in-situ burning.

When choosing effective response options including natural recovery, you must consider trade-offs affecting the options' potential environmental impact, their appropriateness for the habitat, and the timing of the application. *Environmental Considerations for Marine Oil Spill Response* discusses these considerations in detail; consult it before using this guideline. Remember, the benefits and impacts of response options depend upon incident-specific conditions and affect the options' suitability for use in a habitat during any spill.

This guide includes information about response methods now used during oil spill responses in marine environment. It provides guidelines for developing response actions, evaluating incident-specific feasibility issues for both on-water and shoreline environments, and developing incident-specific strategies.

The final section of this guide includes detailed descriptions of the response methods now in use during oil spill responses in marine environments. These descriptions begin on page 41 with Natural Recovery.

Strategies for Selecting Response Methods

During emergency response operations, available information may be highly uncertain and fragmented at best, as will forecasts of environmental conditions or evaluations of response equipment needs. Nonetheless, the response community must sort out what is actually known about the spill, and select and deploy equipment as soon and as effectively as possible. What information is needed to help guide the response? What can be done to promote any gains in environmental protection?

Because the goal of oil spill response is to minimize the overall impacts on natural and economic resources, some resources will be of greater concern than others; and response options offering different degrees of resource protection will be selected accordingly. Decisions regarding cleanup method(s) must balance two factors: 1) the potential environmental impacts with the no-action alternative, and 2) the potential environmental impacts associated with a response method or group of methods.

Potential impacts can be determined before considering the need for, or type of, response strategies. For example, evaluating a gasoline spill in an exposed seawall environment might lead to the conclusion that, due to evaporation and low habitat use, minimal environmental effects will occur and further evaluation is unwarranted. On the other hand, assessing a spill of a middle-weight crude oil in a soft intertidal area would likely indicate a high potential for environmental effects; therefore, response methods would need to be evaluated.

The decisions to select response methods should consider the potential of each possible method for reducing the environmental consequences of the spill and the response (including a natural recovery alternative). The method, or combination of methods, that most reduces consequences effectively, should be the preferred response strategy. A method that increases impacts in the short term can be the preferred alternative if it speeds up recovery. (Recovery cannot be defined as pre-spill conditions since natural changes in biological communities will introduce variability to organisms affected by the spill.)

The environmental consequences of a spill and the response will depend on the specific spill conditions, such as the type and amount of oil, weather conditions, habitat where the spill occurred, and effectiveness of the response methods. It is imperative that planners and responders discuss and develop resource protection priorities during contingency planning so that valuable time is not lost during an actual response.

Guidelines for Developing Response Actions

This document provides information to help the reader understand the tradeoffs that were considered in developing the Environmental Considerations for Marine Oil Spill Response (API et al.) and the Characteristics of Coastal Habitats (NOAA, 2000). These companion documents reflect a consensus of extensive and technically appropriate, pre-spill decision processes regarding response:

- **Goals** (overall aims of the response, defined by government);
- **Objectives** (specified response outcomes, defined by response management);
- **Strategies** (plans used to carry out objectives, protect resources at risk);
- **Tactics** (specific actions taken to carry out a strategy); and
- **Windows of opportunity** (timeframe during which response actions are viable).

Goals

Generally, oil spill response goals, in order of priority, are:

1. Maintain safety of human life;
2. Stabilize the situation to preclude it from worsening; and
3. Minimize adverse environmental and socioeconomic impacts by coordinating all containment and removal activities to carry out a timely, effective response.

Objectives

Responders should develop incident-specific objectives and strategies to address all three goals simultaneously. While attaining the first two goals, responders must develop incident-specific response objectives that achieve the third goal (minimize further spill impacts and protect resources at risk). Objectives must be clearly articulated and be measurable and achievable, e.g., prevent oil from reaching a specific part of the shoreline from one point to another. Effectively planning and executing a response requires a framework within which limited response resources (people, equipment, time) can be allocated to protect multiple resources at risk. Not all of these can be protected, some will have higher priorities than others for protection.

Strategies

Strategies are the conceptual plans designed to achieve response objectives. For example, a combination of mechanical containment and recovery equipment, dispersants, and in-situ burning can prevent oil from reaching the shoreline.

Initial spill conditions will play a large role in developing an effective strategy, and sufficient initial information must be gathered to determine:

- Type and amount of oil spilled;
- Spill location;
- Behavior of spilled oil;
- Spill trajectories and persistence;
- Locations and resources that may be impacted, and types of impacts; and
- Current and forecast weather.

As information is gathered, strategies can be developed (and revised) to protect those resources at risk. Though response strategies will vary according to incident-specific conditions, strategies can often be established in spill response planning, consistent with response goals.

Tactics

Tactics are site-specific and individual activities taken to implement strategies, and can also be established in spill response plans, consistent with response goals. Specific tactics are usually developed for 12- to 24-hour time periods.

Windows of Opportunity

Windows of opportunity (timeframes during which response actions are viable) are constrained or bound by certain influences or conditions, and are available, or "open," for limited times.

Three primary windows exist following a marine oil spill. Within each window, certain spill control measures can be taken to minimize adverse environmental effects:

Very early - Oil is fresh and concentrated near the discharge source.

- Window may be open for 1-2 days; and
- Responders focus on source control, containment near the source, and removal (these offer the best opportunities to reduce adverse environmental impacts).

Early - Oil has spread, is no longer concentrated, and threatens sensitive resources and habitats.

- Window may be open for several days to weeks;
- Sensitive resources and habitats are threatened; and
- Responders work to minimize the spread of oil, prevent it from contacting resources at risk, and protect resources and habitats most vulnerable to longer-term oil impacts.

Later - Oil has stranded.

- Window may be open for days to months, or longer; and
- Responders use habitat-appropriate shoreline cleanup options to minimize environmental effects and enhance natural recovery (in some cases, oil may be left to degrade naturally because physical removal would cause a greater negative impact than leaving it in place).

Options for reducing spill impacts during each of these windows are addressed later, but, because information regarding Window 2 will be site-specific (and is addressed in area contingency plans), the emphasis here is on Windows 1 and 3. Figure 1 depicts the range of response possibilities for a generic, large marine oil spill (generalized response phases and windows illustrate the relative timing constraints of various response options).

Incident-specific Feasibility Issues

After assessing the situation, defining goals, priorities, objectives, and identifying the possible response strategies, the next step is to consider the feasibility of field operations. Tables 1 and 2 summarize the issues (discussed in detail in the following section) to be considered in developing incident-specific, on-water and shoreline operations.

Incident start (window of opportunity) →	...hours... (very early) →	...hours/days/weeks... (early) →	...months... (later)
PHASE / STRATEGY	STABILIZE/SECURE SOURCE	ON-WATER CONTAIN/ RECOVER/PROTECT	SHORELINE TREATMENT/CLEANUP
MECHANICAL	Close valves Patch Pump/offload	Manual oil removal Boom, skimmers Sorbents Mechanical oil removal Vacuum Barriers	Sorbents Manual oil removal Mechanical oil removal
CHEMICAL		Shoreline cleaning agents Dispersants Emulsion treating agents Solidifiers Herding agents Elasticity aodifiers	Shoreline cleaning agents Solidifiers
OTHER COUNTERMEASURES		In-situ Burning	Bioremediation
WASTE MANAGEMENT		On-siteStorage Recycle Incineration	Stabilization Recycle Landfill Incineration Bioremediation

Figure 1. Types of response options during a major oil spill (modified from Walker et al., 1993).

Table 1. Incident-specific on-water strategy issues.

Category	Issues
Nature and Amount of Oil	• Oil type spilled • Oil volume and area and shape of slick(s) and stranded oil • Average oil thickness and distribution • Emulsification
Proximity	• Source considerations • Water depths • Shoreline and resources at risk • Air and vessel traffic • Equipment staging and support locations • Exclusion zones
Timing	• Personnel and equipment availability • Logistics support for sustained operations • Time until impact • Weathering

Table 1. (cont.)

Category	Issues
Environment	• Water depth • Wind and waves • Tides and currents • Visibility • Temperature • Ice and floating debris • Vulnerable species and habitats • Human use
Authorization	• Approval to burn and/or apply CCPs* • Approval to access restricted areass • Transport and disposal of recovered oil or wast • Permits

* Agents requiring approval can include dispersants, surface washing agents, surface collecting agents, bioremediation agents, and miscellaneous oil spill control agents.

Table 2. Incident-specific shoreline strategy issues.

Category	Issues
Safety	• Slip and fall hazards • Worker oil exposure hazards
Nature and Amount of Oil	• Oil type spilled • Stranded oil amount • Stranded oil distribution
Proximity	• Access from on water and/or roads • Worker support services • Staging/deployment sites
Timing	• Timely strategy development • Rapid cleanup to prevent oil remobilization
Environment	• Waves and breakers • Tides • Currents • Weather • Shoreline type • Water depth and sea bottom character

Table 2. (cont.)

Category	Issues
Environment	• Vulnerable species and habitats • Human use constraints • Cultural constraints
Authorization	• Approval to burn and/or apply CCPs* • Approval to access restricted areass • Transport and disposal of recovered oil or waste • Permits

* Agents requiring approval can include dispersants, surface washing agents, surface collecting agents, bioremediation agents, and miscellaneous oil spill control agents.

On-Water Feasibility Issues

On-water response strategies and procedures must address a broad range of site-, spill-, and environment-specific issues, including:

- Safety risks;
- Environmental effects; and
- Timing, spatial, and environmental limits.

These must be carefully considered in establishing response option performance levels. Safety is always paramount, but other priorities can be different for each spill.

Nature and Amount of Oil

Oil Type

Identifying the type of oil spilled and being able to anticipate its changing physical and chemical character as it spreads and degrades will help responders:

- Conduct personnel safety assessments;
- Determine fire or explosion risks;
- Identify response option feasibility; and
- Determine windows of opportunity.

Oil Volume, Area, and Shape

Because on-water response equipment has predictable, limited areal coverage rates, a slick's volume, changing area, and shape as it is transported and spread by wind and currents will determine response option feasibility, effectiveness, and efficiency. Since mechanical recovery will remove only a fraction of the oil spilled:

- Spills on water must be attacked early (a sudden release, even in a light surface current, can spread and be transported rapidly beyond any at-source containment; moderate- to large-volume spills on the order of 1,000 barrels or more can easily spread over 1 to 10 square miles [3 to 26 square kilometers] in a day or two); and
- Response methods should be combined wherever possible (large spills can quickly exceed the holding capacity of most containment barriers).

Average Oil Thickness and Distribution

Though oil slick thickness can vary by orders of magnitude within different parts of a slick, average slick thickness and actual oil distribution are crucial for determining response method feasibility. Figure 2 illustrates the general relationships between on-water response techniques and average slick thickness. Windrows, heavy oil patches, tarballs, etc., must also be considered, as they influence oil encounter rates, chemical dosages, and ignition potential.

Emulsification

Weathering often involves water-in-oil emulsification, which can impair response operations by:

- Increasing overall oil volume and recovered fluid storage requirements;
- Decreasing oil's buoyancy (increasing its tendency to submerge);
- Increasing the oil's viscosity (or pumpability) and stickiness (complicating recovery operations);
- Decreasing the oil's affinity for surface tension modifiers (reducing its dispersibility);
- Decreasing the oils' ignitability (burning is difficult or impossible); and
- Decreasing available surface area for biodegradation (less biodegradable).

All of the above are important for understanding and estimating on-water response effectiveness, since some options may only be appropriate for a few hours under adverse conditions, or for several days during ideal conditions.

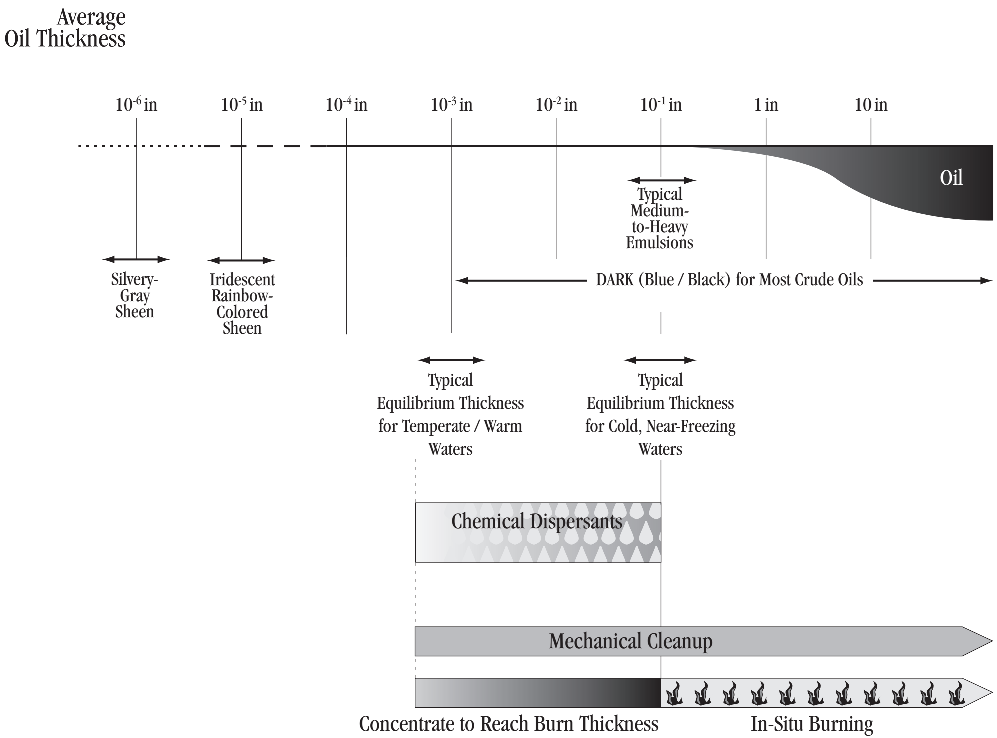

Figure 2. Average oil thickness versus potential response options (modified from Allen and Dale, 1996).

Proximity

Source Considerations

Response operations must be conducted at safe distances from existing or potential spill sources, to reduce the risks of accidental ignition, exposure to harmful vapors, or changes in source characteristics that could endanger personnel or equipment.

Shoreline and Resources at Risk

Recovering or treating oil at sea can reduce the consequences to open-water and shoreline resources. Distance to shore is important because it will influence the type of vessels and equipment employed (size, draft, maneuverability, anchoring limitations) and the response countermeasures used. It is often more efficient and effective to recover or treat oil before it comes ashore.

Air and Vessel Traffic

On-water response and monitoring normally involve boats and/or aircraft, and activities of these vehicles must be carefully planned and controlled to prevent interference with other, ongoing (or planned) operations.

Equipment Staging and Support Locations

Response success will depend, in part, on the proximity of equipment and personnel staging locations to actual operations. Because response activities may interfere with each other (e.g., vessels transiting to and from staging areas) or with private or commercial activities, support operations will require careful planning.

Designated Response Exclusion Zones

Designating certain areas as public, private, or government exclusion zones may be necessary for conducting effective on-water operations. These zones may include national marine sanctuaries, archaeological sites, military operations areas, or may be pre-designated chemical dispersant operations or in-situ burning areas. Some exclusion zones may have special activity or time requirements.

Timing

Personnel and Equipment Availability

The time required to bring resources to the scene will be a significant factor in establishing an effective response. Because response operations are critically influenced by oil spreading, transport, and weathering, realistic estimates of time to arrive on scene must be established in response plans and re-evaluated as daily Incident Action Plans are developed.

Logistics Support for Sustained Operations

Effective, sustained response operations must be supported with:

- Trained, well-rested personnel for crew rotations (food, shelter);
- Spare parts and supplies (fuel, dispersants, personal protection equipment, boom, ignition systems, etc.) to keep equipment and personnel functioning;
- Secondary storage containers for recovered oil/water; and
- Sufficient, certified final disposal sites.

Time Until Impact

Responders must determine realistic oil encounter and recovery rates, to make maximum use of the time available before oil impacts sensitive resources. If estimates show that on-water, mechanical response systems cannot handle a sufficient portion of a spill, the environmental impact tradeoffs among containment and mechanical recovery, dispersant use, or in-situ burning must be carefully weighed against the impacts of that same oil reaching the shoreline. In some instances, it may be necessary to forego some on-water response in order to use those resources for shoreline protection and cleanup.

Oil Weathering

During the first 24 to 48 hours of open water exposure, most oil spills become difficult to recover, burn, or chemically disperse, because:

- Evaporation accelerates as oil spreads and thins, increasing its density, viscosity, and tendency to emulsify;
- Emulsification can produce oily fluids of greater volume and viscosity than the original spill; and
- Decreasing slick thickness makes removing oil increasingly difficult.

Environment

Water Depth

Shallow-water response requires careful use of response equipment, since:

- Vessel size and/or draft will limit speed, maneuverability, and operating areas;
- Vessel or boom anchors can disturb benthic communities;
- Shallow-water locations with strong currents create unique problems:
  - Booms with a draft greater than 1/4 the water depth will lose significant amounts of oil from entrainment.

– Vessel squat (settling of the stern as speed increases) may limit operating areas or parameters.

Chemical dispersant use must not unnecessarily expose local biota to harmful concentrations of dispersed oil.

Water depth may be a consideration during in-situ burning deliberations because residues may sink, but heat transferred from a burning slick to the water is negligible and will not be a factor.

Wind and Waves

All weather will affect spill response activities, and rising wind and waves will:

- Increase oil spreading, transport, evaporation, and emulsification;
- Increase responder fatigue due to vessel and equipment handling difficulties; and
- Reduce containment boom effectiveness.

While there are exceptions for certain types and conditions of oil, and specific types of equipment or dispersant, Figure 3 illustrates wind and wave influences on response operations feasibility over a broad range of average oil film thicknesses:

- **Mechanical Cleanup:** Effectiveness drops significantly because of entrainment and/or splash-over as short-period waves develop beyond 2 to 3 feet (0.6 to 0.9 meters) in height. Containment and recovery decrease rapidly as slick thicknesses drop below a thousandth of an inch (i.e., very low oil encounter rates).
- **Dispersants:** Effective dispersion requires a threshold amount of surface mixing energy (typically a few knots of wind and a light chop) to be effective. At higher wind and sea conditions, dispersant evaporation and wind-drift will limit chemical dispersion application effectiveness; and, there is a point (~25-kt winds, 10 -foot [3 meter] waves) where natural dispersion forces becomes greater, particularly for light oils. Because of droplet size versus slick thickness constraints and application dose-rate limitations, dispersants work best on slick thicknesses of a few thousandths to hundredths of an inch. Improved dispersants, higher dose rates, and multiple-pass techniques may extend the thickness limitation to 0.1 inch (0.25 centimeters) or more.

- **Burning:** Fire boom is affected by the same entrainment and splash-over problems as most conventional booms in 2 to 3 feet (0.6 to 0.9 meters), short-period waves. During calm conditions, sustained burning is easier and normally requires a minimum oil thickness of about 0.1 inch (0.25 centimeters) of oil; for heavier and emulsified oils, this thickness will be greater. When oil has spread and thinned, it may sometimes be possible to collect and concentrate it to minimum combustion thickness.

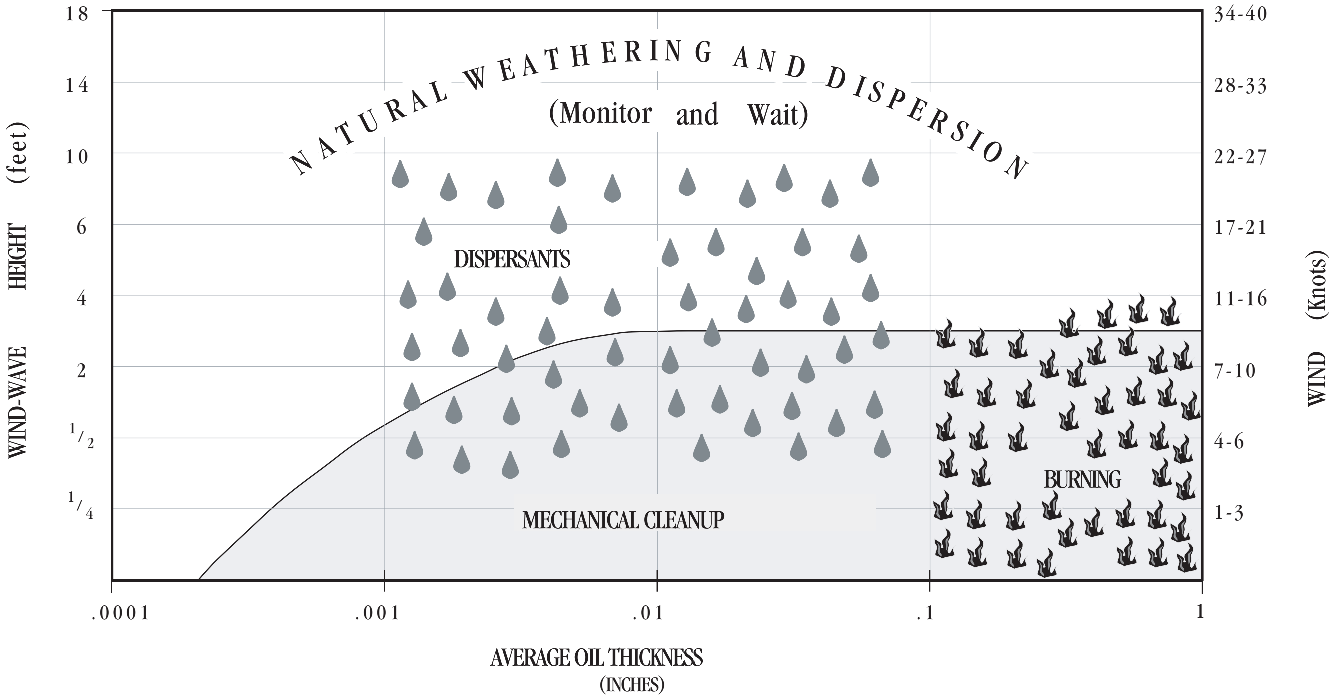

Figure 3. Primary spill response options under various wind/sea conditions and oil film thicknesses (modified from Allen, 1988).

Fresh, volatile oil slicks cannot be ignited in winds greater than 20 knots.

- Surveillance: Remote sensing technologies may be helpful for locating floating oil depending on environmental conditions.

Tides and Currents

Tides can:

- Change or reverse the direction and speed of water flow; and
- Change water depth.

Tides and currents can:

- Operate with wind to transport surface and subsurface oil over great distances.

Thus, tide and currents will dictate vessel size and power requirements; anchor size, type, and placement; towed boom drift distances; the time and location of possible sensitive resource impacts; and the amount of oil loss from entrainment (particularly with high-viscosity oils and oils of density near 1.0). Booming and skimming while drifting with the current will help minimize such losses.

Visibility

If response activities are conducted in low visibility, artificial light, or bright moonlight it will be difficult to find the heaviest oil concentrations or to monitor oil losses from booms and skimmers. Depending upon incident specifics, it may be feasible to conduct on-water operations in static or on-station modes during low visibility, allowing oil to come to recovery sites.

Temperature

Low temperatures will generally increase oil viscosity (requiring viscous-oil recovery system use), inhibit spreading, evaporation, and emulsification, and may extend response windows of opportunity (but some oils may form stable emulsions in low temperatures).

During extreme cold weather, ice may limit the spread of oil and improve the chances of recovery or burning. Extreme cold will also:

- Increase hypothermia potential, requiring responders to use special, cold-weather personnel protection equipment, machinery, and procedures.

In high temperature and humidity situations, the above constraints will usually be reversed: oil will spread and evaporate faster, increasing fire and explosion potential, accelerating weathering processes, reducing response windows, and impacting equipment deployment times (equipment that works better on thicker oils that have retained their lighter ends must be deployed quickly). Extreme heat and humidity will also:

- Increase hyperthermia potential, requiring use of warm-weather personnel protection procedures, equipment, and machinery.

Ice and Floating Debris

In some situations, ice or other floating debris may actually help contain oil and enhance in-situ burning, but heavy concentrations, particularly in strong currents, will clog, overload, or destroy most interception barriers. Debris will also tend to keep oil thick, dampen waves, and reduce dispersant effectiveness.

Frequent surveillance, and assigning resources to keep debris clear of recovery operations, will be necessary. If the debris is not too large, responders may be able to use interception barriers or screens with relatively narrow oil interception swaths.

Authorization

Approval to Burn and/or Apply Dispersants

In-situ burning or dispersant use requires government authorization, (generally requested by the party responsible for the spill). Because safety, environmental impact, wildlife, and public concern issues are involved, a number of formal, pre-spill agreements allow an On-Scene Coordinator (OSC) to authorize dispersant use or in-situ burning. Specific constraints are usually applied regarding:

- Zone and boundary designations;
- Distances from shore;
- Water depths;
- Weather; and
- Time (daylight, season).

Some states and regions may consider these requests only on a case-by-case basis, which delays response activity and may force responders to miss particular windows of opportunity. Such delay must be factored into the response planning process.

Approval to Access Restricted Areas

As noted earlier, vessels and/or aircraft response operations may require special clearances or approvals, particularly near shore, where residential, commercial, industrial, recreational, or environmentally sensitive areas may be directly or indirectly impacted. Permission from government or owners/operators may be necessary before responders can enter or use these areas.

Transport and Disposal of Recovered Oil or Waste

Response planners must assess the time, cost, and effectiveness of storing, transporting, and disposing of recovered oil/oily wastes, including the effects that such operations will have on available resources (e.g., the length of time that response systems may be suspended due to lack of storage space). Disposal of recovered oil and oily wastes must comply with government regulations. Planners must also address:

- Temporary storage (onshore, offshore) of oil and oily debris, or sorbent materials;
- Decanting and discharging free water from recovered fluids;
- Transfer of waste from vessels/barges to onshore facilities;
- Handling waste from offshore equipment/vessel cleaning operations;
- Disposing of waste, burn residue, and debris at approved sites; and
- Product sampling and analyzing.

Shoreline Feasibility Issues

Shoreline response strategies may be constrained by safety, physical, or environmental considerations.

Safety

The dangers or risks inherent in land-based operations involving mechanized equipment are similar to those of on-water activities. Weather-related hazards from high winds, waves, currents, and tides, though less critical on land, still exist near the shoreline.

Stranded oil, or nearshore oil, has usually weathered, and the threat of harmful exposures or accidental ignition is lower than at, or near, its source; however, some oils may still contain enough light ends to make exposure, inhalation, or ingestion risky (except for asphalt-type oils).

Nature and Amount of Oil

Understanding how a particular spill has weathered will help responders select appropriate treatment or cleanup options. Such information can be gathered by shoreline assessment surveys; these involve systematically collecting data to describe (using standard terms and definitions) the location, amount, distribution, and character of stranded or nearshore oil.

Proximity

Responders must consider shoreline proximity issues so that inshore on-water operations can be safely conducted. Considerations may include distance(s) to:

- Safe or sheltered anchorage;
- Support services (e.g., medical, food, lodging, maintenance and repair, and communications);
- Suitable staging or deployment sites; and
- Shoal waters; uncharted, underwater obstacles, etc.

Timing

Shoreline assessments must be conducted as soon as practicable so that planners can incorporate the information into response strategies and provide sufficient resources to remove the oil and prevent it from refloating and impacting other areas.

Environment

The operating environment for shoreline protection and cleanup involves a number of issues, including: waves and breakers, tides, currents, water depths, weather, shoreline features, ecological constraints, human use or cultural resource constraints, and public or government requirements or perceptions.

Waves and Breakers

Small boats operating near shore, or responders working near the water's edge, are directly exposed to hazards from nearshore waves and breakers. Although these can usually be easily seen and activities adjusted to account for them, unexpected or unpredictable conditions can occur, since:

- Vessel wakes can travel several miles, and produce unexpected, steep, breaking waves 3 or 4 feet (0.9 or 1.2 meters) high;
- Wave and breaker heights can vary unexpectedly (and rare, but dangerous, "sneaker" waves can occur on open ocean coasts); and
- Dangerous wave backwash and rip currents are common along open ocean coasts.

Most shallow- or calm-water booms are ineffective in waves over two feet, because they cannot follow short, choppy waves. Although specifically designed for use at the water's edge, shoreline or intertidal booms can be easily rolled or twisted by wave action.

Tides

Though tides and currents are predictable, rapid changes in water levels can isolate and strand unwary personnel, particularly in areas with high tidal ranges, or on wide, flat intertidal areas. Tidal changes from storm surges or wind setups are not as readily predictable, but must also be considered.

Currents

Nearshore currents may be strong (particularly tidal inlet currents, longshore currents, or rip currents), and booms must be regularly redeployed or reconfigured to account for changing water flow.

Weather

Coastal weather can change rapidly and responders must consider the risks from:

- High wind – violent winds (wind shear/microbursts) in electrical storms;
- Remote access – isolation of responders;
- Low visibility – fog, rain, snow, smoke, darkness, or extreme light intensity;
- Ice formation – rafting, damming, or breakup – vessel or equipment icing; sea/river ice floes;
- Intense precipitation – flooding, ground destabilization (mudslides/sinkholes); and
- Extreme temperature/humidity – hypothermia/hyperthermia.

Shoreline Condition

Not all response methods are appropriate for every shoreline type; some may be impractical, unfeasible, environmentally intrusive, or damaging. Shoreline conditions to be evaluated, so responders can select proper response methods, will include:

- Rock falls or slides from backshore cliffs;
- Slippery rock surfaces;
- Presence of ice;
- Limited bearing capacity on mud flats, sand flats, beaches, backshore areas;
- Beach or backshore width and accessibility; and
- Surface mat stability in floating marshes (bogs).

Water Depths and Sea Bottom Character

Nearshore operational safety depends, in part, on responders' knowledge of bottom configuration and navigation conditions (e.g., bottom conditions will dictate which anchors or mooring systems will work; generally, rock bottoms provide poor anchorage). Keys to success include local knowledge, and the scale, accuracy, and availability of:

- Nautical charts; and
- Sailing directions and Notices to Mariners.

Environmental (Ecological) Constraints

Response strategies must allow responders to meet defined response objectives without causing more damage than the oil itself. If, after initially removing gross oil amounts, the level of intrusion necessary to remove any residual oil may cause unacceptable changes, damage, or become inefficient, response activities should be modified. This concept is discussed in Section 2.3.

Certain animals, plants, or insects may be hazardous to shore-zone responders, and response managers must make full use of local knowledge to help reduce such risks (during the Exxon Valdez response, armed guards were used to protect responders from Kodiak brown bears).

Human Use Constraints

Day-to-day human activities can affect responder safety afloat or ashore:

- Small boats, commercial traffic, ocean-going vessels, or ferries may transit areas where response activities are planned or underway;
- Vehicle traffic on piers, wharves, docks, or backshore roads may be dangerous; and
- Backshore residential, commercial, industrial, or recreational activities may conflict with response operations.

Cultural Constraints

Historically, archaeologically or culturally-significant sites or resources are found on all coasts, but are more likely in areas remote from, or undisturbed by, recent human activity (e.g., much of the Pacific Northwest coast). Even if these sites are not directly affected by oil, shoreline activities may result in contact with these resources.

If such sites are present within response areas, special permission will normally be required from cognizant tribal, government, cultural, historic, or archaeological organizations prior to commencing cleanup activities.

Authorization

In addition to shoreline access, which may require permission from outside the response organization, government organizations:

- May restrict use of non-mechanical countermeasures listed on the National Contingency Plan Product Schedule (e.g., dispersants, surface washing agents, bioremediation agents, or burning); and
- Will require specific authorization and permits to transport and dispose (including temporary storage of recovered oily materials) of recovered oily wastes.

Process for Developing Incident-Specific Strategies

Spill response management follows a general sequence of steps for each spill, spill phase, and response location:

1. Gather information and assess the situation.
2. Define response goals and priorities.
3. Define response objective(s).
4. Develop strategies to meet the objectives, based on windows of opportunity.

5. Evaluate the feasibility of the options and strategies in view of the environmental conditions and spill specifics.
6. Select response options and tactical arrangements to implement identified strategies (begin process to obtain necessary approvals, permission, permits).
7. Prepare an Incident Action Plan for carrying out the identified strategies.
8. Implement field response operations plans for each strategy.

While certain objectives, strategies, and tactics can be identified before an incident, and will usually be included in both owner/operator response plans and area contingency plans, responders must develop incident-specific response strategies (step 4, above) at the time of the incident. Steps 4, 5, and 6 are related to the incident response objectives, and are subject to a variety of incident-specific conditions, such as those discussed in detail in the remainder of this section. The remaining steps will be sufficiently incident-specific that discussing them further in this manual is not possible.

Integration of On-water Response Options

If a response objective is to minimize or prevent shoreline impact, using multiple, integrated on-water countermeasures offers the best chance of success. Thus, if "very early" window of opportunity options are to be used, decision-making, strategic plan development and approvals, and implementation must be rapid. Each response tool has advantages, disadvantages, and limitations in its effectiveness. Decision-makers must weigh various tradeoffs when considering and comparing response options. Since there is no single, perfect response option, the best solution is to use all the "tools in the toolbox" in combined (integrated) operations to achieve response objectives. In general, these tools include:

- Monitor and wait. No active response to remove oil;
- Physical containment and mechanical recovery. Removes oil from the water, with few environmental impacts but involves operational limitations associated with weather, visibility, physics, etc.;

- Dispersant application. Protects waterfowl and shoreline habitats but increases oil in the water column and exposure of water column organisms;
- In-situ burning. Protects sensitive shoreline habitats by removing floating, burnable oil but heavy, black smoke is unsightly, alarming, and can be a respiratory hazard for humans and animals. Removal of burn residue may be technologically difficult and may further damage the environment; and
- Shoreline cleanup will not disrupt water column species but allowing oil to reach shore means that intertidal and shore-based species have already been impacted.

Temporal Considerations

Mechanical recovery, dispersant application, and in-situ burning operations can be used singly, or in combination, to improve efficiency and effectiveness.

- Mechanical recovery: oil that escapes containment or recovery will still be available for subsequent mechanical removal, treatment with dispersants, or for burning;
- Dispersants: some of the dispersant-treated slick may actually be missed and be available for additional dispersant operations, burning, or mechanical containment and recovery (except oleophilic skimmers for a few hours). Also, containing and burning a partially treated slick should remain viable, since dispersant application may decrease the slick's tendency to emulsify and prolong or reopen the window of opportunity for burning;
- Burning: most (>90%) of the oil burned will be converted to carbon dioxide, water vapor, and soot. Any oil that escapes the fire boom will be available downstream for re-collection and burning, mechanical recovery, or dispersant treatment; and
- The residues from a successful burn or partially-burned Categories III and IV oils, on the other hand, are not suitable for chemical dispersion. However, residues can be physically removed using viscous-oil recovery systems,

or nets and hand tools. If partially burned oil/residue sinks, then the environmental consequences of leaving the submerged oil must be compared to the consequences of removing the submerged material.

Spatial Considerations

Integrating response options also includes spatial considerations. For safety reasons, combined, simultaneous operations should be conducted only in designated safe operating zones that take into account spill and site specifics:

- Response vessels must always be far enough apart to preclude near-misses, collisions, or other disruptions of operations;
- Aircraft operations must be coordinated through a single air-traffic control system with specific directives for allowable altitudes, airspace, air and surface radio frequencies, emergency procedures, etc.;
- Mechanical cleanup and in-situ burning operations should be positioned in the thickest layers of oil, consistent with safety and environmental constraints;
- Burning should be positioned and conducted to: 1) avoid ignition of source; 2) avoid endangering personnel, facilities, vessels, or equipment downstream/downwind; 3) prevent accidental ignition of nearby contained or uncontained slicks or vapors; and
- Dispersants should be used on slicks that are sufficiently downstream/downwind from other operations that wind or current will not carry dispersant into those operating areas. Safe operating distances will be spill-specific.

Shoreline Strategies

Shoreline response strategies differ from on-water response strategies because:

- Stranded oil generally remains in place or is slow-moving; and
- Land-based operations usually are less weather-dependent than water-based activities, and there are different safety and feasibility factors to consider.

Since shoreline response can be a long-term operation (days-weeks-months), integrating multiple shoreline protection and cleanup options into strategies that are implemented simultaneously is common practice (nearshore containment and recovery often take place alongside various types of shoreline cleanup).

The following discussion includes all options operated from shore.

Shoreline Protection

The basic shoreline protection objective is to:

- Prevent or minimize contact between oil and the shore zone (or a resource at risk in the zone).

This can be done by combining activities, techniques, and equipment to:

- Remove shoreline debris before the oil is washed ashore;
- Contain and recover floating oil prior to shoreline impact;
- Deflect oil away from shore;
- Trap or contain and collect oil at the shoreline;

- Prevent stranded oil from refloating and affecting adjacent areas; and
- Prevent oil being washed over a beach into a lagoon or backshore area.

Shoreline Treatment and Cleanup

For an oiled shoreline, the main treatment objective is often to restore the oiled shore zone to a pre-spill "clean" condition. But defining a specific level of "clean" will be different for each spill (or even different for different phases of a single response) and, although promoting recovery usually includes removing some portion of the oil and allowing the rest of the oil or residue to degrade naturally, the best course of action may be to let all the oil degrade naturally. Final levels of allowable oil concentrations can, and should, be determined by consensus (considering overall environmental consequences) during contingency planning and sensitivity mapping before any spill. This process should balance conflicting environmental and socioeconomic concerns.

Reducing overall environmental consequences in an effective and efficient manner usually requires a combination of techniques, including:

- Natural recovery;
- Physical washing;
- Physical removal;
- Physical in-situ treatment (including burning); and
- Chemical or biological treatment.

Natural Recovery

Objective:	No attempt to remove any stranded oil either to minimize impacts to the environment or because there is no effective method for cleanup. Oil is left in place to degrade naturally.
Description:	No action is taken, although monitoring of contaminated areas may be required.
Applicable Habitat Types:	All habitat types.
When to Use:	When natural removal rates are fast (e.g., gasoline evaporation, high-energy coastlines), when the degree of oiling is light, or when cleanup actions will do more harm than natural removal.
Biological Constraints:	This method may be inappropriate for areas used by high numbers of mobile animals (birds, marine mammals) or endangered species.
Environmental Effects:	Same as from the oil alone.
Waste Generation:	None.

Booming

Objective:	To prevent oil from contacting resources at risk, and to facilitate oil removal.
Description:	A boom specially designed for pollution response is a floating, physical barrier, placed on the water to contain, divert, deflect, or exclude oil. Containment is deploying a boom to contain and concentrate the oil until it can be removed. Deflection is moving oil away from sensitive areas. Diversion is moving oil toward recovery sites that have slower flow, better access, etc. Exclusion is placing boom to prevent oil from reaching sensitive areas. Booms must be properly deployed and maintained, including removing accumulated debris.
Applicable Habitat Types:	Can be used on all water environments (weather permitting). Booms begin to fail by entrainment when the effective current or towing speed exceeds 0.7 knots perpendicular to the boom. Waves, wind, debris, and ice contribute to boom failure.
When to Use:	When preventing oil from contacting sensitive resources is important. Most responses to spills on water involve deploying boom to help remove floating oil. Containment booming of gasoline spills is usually not attempted, because of fire, explosion, and inhalation hazards. However, when public health is at risk, gasoline can be boomed if foam is applied and extreme safety procedures are used.

Booming (cont.)

Biological Constraints:	Placing and maintaining boom and anchoring points should not cause excessive physical disruption to the environment, and both must be maintained so they do not fail nor tangle and cause more damage. Vehicle and foot traffic to and from boom sites should not disturb wildlife unreasonably, and booms in very shallow water should be monitored so they do not trap wildlife (such as migrating turtles returning to sea or fish coming in at high tide).
Environmental Effects:	Minimal, if disturbance during deployment and maintenance is controlled.
Waste Generation:	Cleaning booms will generate contaminated wastewater that must be collected, treated, and disposed of appropriately. Discarded booms will need to be disposed of according to appropriate waste disposal regulations.

Skimming

Objective:	To recover floating oil from the water surface using mechanized equipment. This includes specifically designed pollution equipment called skimmers, and other mechanical equipment such as draglines and dredges.
Description:	There are numerous types of skimming devices, described in the annually published World Catalog of Oil Spill Response Products (Schulze 1998): weir, centrifugal, submersion plane, and oleophilic. They are placed at the oil/water interface to recover, or skim, oil from the water's surface and may be operated independently from shore, be mounted on vessels, or be completely self-propelled. Because large amounts of water are often simultaneously collected (incidental to skimmer operation) and treated, efficient operations require that floating oil be concentrated at the skimmer head, usually using booms. Adequate storage of recovered oil/water mixtures must be available, as must suitable transfer capability. Skimmers are often placed where oil naturally accumulates in pockets, pools, or eddies.
Applicable Habitat Types:	Can be used on all water environments (weather and visibility permitting). Waves, currents, debris, seaweed, kelp, ice, and viscous oils will reduce skimmer efficiency.
When to Use:	When sufficient amounts of floating oil can be accessed. Skimming spilled gasoline is usually not feasible because of fire, explosion, and inhalation hazards to responders. However, when public health is at risk, gasoline can be skimmed if foam is applied and extreme safety procedures used.

Skimming (cont.)

Biological Constraints:	Vehicle and foot traffic to and from skimming sites should not disturb wildlife unreasonably.
Environmental Effects:	Minimal if surface disturbance by cleanup work force traffic is controlled.
Waste Generation:	Free-floating oil can be recycled. Emulsions formed during the process must be treated (broken) before recycling. Oil-contaminated waste from the treatment phase should be treated as wastewater.

Barriers/Berms

Objective:	To prevent entry of oil into a sensitive area or to divert oil to a collection area.
Description:	A physical barrier (other than a boom) is placed across an area to prevent oil from passing. Barriers can consist of earthen berms, trenching, or filter fences. When it is necessary for water to pass because of water volume, underflow or overflow dams are used.
Applicable Habitat Types:	At the mouths of creeks or streams to prevent oil from entering, or to prevent oil in the creek from being released into offshore waters. Also, on beaches where a berm can be built above the high-tide line to prevent oil from overwashing the beach and entering a sensitive back-beach habitat (e.g., lagoon).
When to Use:	When the oil threatens sensitive habitats and other barrier options are not feasible.
Biological Constraints:	Responders must minimize disturbance to bird nesting areas, beaver dams, or other sensitive areas. Placement of dams and filter fences could cause excessive physical disruptions, particularly in wetlands.
Environmental Effects:	May disrupt or contaminate sediments and adjacent vegetation. The natural beach (or shore) profile should be restored (may take weeks to months on gravel beaches). Trenching may enhance oil penetration and quantity of contaminated sediments.
Waste Generation:	Sediment barriers will become contaminated on the oil side and filter fence materials will have to be disposed of as oily wastes.

Physical Herding

Objective:	To free any oil trapped in debris or vegetation on water; to direct floating oil towards containment and recovery devices; or to divert oil from sensitive areas.
Description:	Plunging water jets, water or air hoses, and propeller wash can be used to dislodge trapped oil and divert or herd it to containment and recovery areas. May emulsify the oil. Mostly conducted from small boats.
Applicable Habitat Types:	In nearshore areas where there are little or no currents, and in and around man-made structures such as wharves and piers.
When to Use:	In low-current or stagnant water bodies, to herd oil toward recovery devices. In high-current situations to divert floating oil away from sensitive areas.
Biological Constraints:	When used nearshore and in shallow water, must be careful not to disrupt bottom sediments or submerged aquatic vegetation.
Environmental Effects:	May generate high levels of suspended sediments and mix them with the oil to deposit contaminated sediments in benthic habitats.
Waste Generation:	None.

Manual Oil Removal/Cleaning

Objective:	To remove oil with hand tools and manual labor.
Description:	Removal of surface oil using hands, rakes, shovels, buckets, scrapers, sorbents, pitchforks, etc., and placing in containers. No mechanized equipment is used except for transport of collected oil and debris. Includes underwater recovery of submerged oil by divers, for example, with hand tools.
Applicable Habitat Types:	Can be used on all habitat types.
When to Use:	Light to moderate oiling conditions for stranded oil, or heavy oils on water or submerged on the bottom that have formed semi-solid or solid masses and that can be picked up manually.
Biological Constraints:	Foot traffic over sensitive areas (wetlands, tidal pools, etc.) should be restricted or prevented. There may be periods when shoreline access should be avoided, such as during bird nesting.
Environmental Effects:	Minimal, if surface disturbance by responders and waste generation is controlled.
Waste Generation:	May generate significant quantities of oil mixed with sediment and debris that must be properly disposed of or treated. Decontamination of hand tools may produce oily wastewater that must be treated properly. Worker personal protective gear is usually disposed of daily or decontaminated and the resulting oily wastewater treated properly.

Mechanical Oil Removal

Objective:	To remove oil from shorelines, and bottom sediments using mechanical equipment.
Description:	Oil and oiled sediments are collected and removed using mechanical equipment not specifically designed for pollution response, such as backhoes, graders, bulldozers, dredges, draglines, etc. Requires systems for temporary storage, transportation, and final treatment and disposal.
Applicable Habitat Types:	On land, possible wherever surface sediments are both amenable to, and accessible by, heavy equipment. For submerged oil, used in sheltered areas where oil accumulates. On water, used on viscous or solid contained oil.
When to Use:	When large amounts of oiled materials must be removed. Care should be taken to remove sediments only to the depth of oil penetration, which can be difficult with heavy equipment. Should be used carefully where excessive sediment removal may erode the beach or shore. Buried oil lift-off consists of removing clean overburden and oiled sediments, and replacing them with clean overburden. Care is also needed to minimize further oil penetration from uncontrolled vehicle traffic.
Biological Constraints:	Heavy equipment use may be restricted in sensitive habitats (e.g., wetlands, soft substrates) or areas containing endangered species. Will need special permission to use in areas with known cultural resources. Dredging in seagrass beds or coral reef habitats may be prohibited. The noise generated by the mechanical equipment may present a constraint as well.

Mechanical Oil Removal (cont.)

Environmental Effects:	The equipment is heavy, with many support personnel required. May be detrimental if excessive sediments are removed without replacement. All organisms in the sediments will be affected, although the need to remove the oil may make this response method the best overall alternative. Resuspension of exposed oil and fine-grained, oily sediments can affect adjacent bodies of water.
Waste Generation:	Can generate significant quantities of contaminated sediment and debris that must be cleaned or landfilled. The amount of waste generated by this cleanup option should be given careful consideration by response planners when reviewing potential environmental impacts of the oily wastes, debris, and residues.

Sorbents

Objective:	To remove surface oil by using oleophilic (oil-attracting) material placed in water or at the waterline.
Description:	Sorbent material is placed on the floating oil or water surface, allowing it to sorb oil, or is used to wipe or dab stranded oil. Forms include sausage boom, pads, rolls, sweeps, snares, and loose granules or particles. These products can be synthetically produced or be natural substances. Efficacy depends on the capacity of the particular sorbent, wave or tidal energy available for lifting the oil off the substrate, and oil type and stickiness. All sorbent material must be recovered. Loose particulate sorbents must be contained in a mesh or other material.
Applicable Habitat Types:	Can be used on any habitat or environment type.
When to Use:	When oil is free-floating close to shore or stranded on shore. The oil must be able to be released from the substrate and sorbed by the sorbent. As a secondary treatment method after gross oil removal, and in sensitive areas where access is restricted. Selection of sorbent varies by oil type: heavy oils only coat surfaces, requiring use of sorbents with high surface areas to be effective (adsorbents); lighter oils can penetrate sorbent material (absorbents).
Biological Constraints:	Access for deploying and retrieving sorbents should not adversely affect wildlife or be through soft or sensitive habitats. Sorbents should not be used in a fashion that would endanger or trap wildlife. Sorbents left in place too long can break apart and present an ingestion hazard to wildlife.

Sorbents (cont.)

Environmental Effects:	Physical disturbance of habitat during deployment and retrieval. Improperly deployed or tended sorbent material can crush or smother sensitive organisms.
Waste Generation:	Sorbents must eventually be collected for proper disposal so care should be taken to select and use sorbents properly, and prevent overuse and generation of large amounts of lightly oiled sorbents. Because large amounts of waste may be generated, recycling should be emphasized rather than disposal.

Vacuum

Objective:	To remove oil pooled on a shoreline substrate or subtidal sediments.
Description:	A vacuum unit is attached via a flexible hose to a suction head that recovers free oil. The equipment can range from small, portable units that fill individual 55-gallon drums to large supersuckers that are truck- or vessel-mounted and can generate enough suction to lift large rocks. Removal rates from substrates can be extremely slow.
Applicable Habitat Types:	Any accessible habitat type. May be mounted on vessels for water-based operations, on trucks driven to the recovery area, or hand-carried to remote sites.
When to Use:	When oil is stranded on the substrate, pooled against a shoreline, concentrated in trenches, or trapped in vegetation. Usually requires shoreline access points.
Biological Constraints:	Special restrictions should be established for areas where foot traffic and equipment operation may be damaging, such as soft substrates. Operations in wetlands must be very closely monitored, and a site-specific list of procedures and restrictions developed to prevent damage to vegetation.
Environmental Effects:	Minimal, if foot and vehicular traffic are controlled and minimal substrate is damaged or removed.
Waste Generation:	Collected oil and or oil/water mix will need to be stored temporarily before recycling or disposal. Oil may be recyclable; if not, it will require disposal in accordance with local regulations. Large amounts of water are often recovered, requiring separation and treatment.

Debris Removal

Objective:	To remove debris in path of spill before oiling and to remove contaminated debris from the shoreline and water surface.
Description:	Manual or mechanical removal of debris (driftwood, seaweed, trash, wreckage) from the shore or water surface. Can include cutting and removal of oiled logs.
Applicable Habitat Types:	Can be used on any habitat or environment type where access is safe.
When to Use:	When debris is heavily contaminated and provides a potential source of secondary oil release; an aesthetic problem; a source of contamination for other resources in the area is likely to clog skimmers; or likely to cause safety problems for responders. Used in areas of debris accumulation on beaches before oiling to minimize the amount of oiled debris to be handled.
Biological Constraints:	Foot traffic over sensitive areas (wetlands, spawning grounds) must be restricted. May be periods when entry should be denied (spawning periods, influx of large numbers of migratory waterbirds). Debris may also be a habitat.
Environmental Effects:	Physical disruption of substrate, especially when mechanized equipment must be deployed to recover a large quantity of debris.

Debris Removal (cont.)

Waste Generation: Will generate contaminated debris (volume depends on what, and how much, is collected, e.g., logs, brush). Unless there is an approved hazardous waste incinerator that will take oily debris, burning will seldom be allowed, especially on-site burning. However, this option should still be explored, especially for remote locations, with the appropriate state or Federal agencies that must give approvals for burning.

The advantage of pre-spill debris collections is that waste disposal requirements will likely be less restrictive than if the debris is oiled. Once oiled, the debris is likely to be handled as a hazardous waste.

Sediment Reworking/Tilling

Objective:	To break up oily sediments and surface oil deposits, increasing their surface area, and mixing deeper subsurface oil layers, thus enhancing the rate of degradation through aeration.
Description:	The oiled sediments are roto-tilled, disked, or otherwise mixed using mechanical equipment or manual tools. Along beaches, oiled sediments may also be pushed to the water's edge to enhance natural cleanup by wave activity (surf washing). The process may be aided with high-volume flushing of gravel.
Applicable Habitat Types:	On any sedimentary substrate that can support mechanical equipment or foot traffic and hand tilling.
When to Use:	On sand to gravel beaches with subsurface oil, where sediment removal is not feasible (due to erosion or disposal problems). On sand beaches where the sediment is stained or lightly oiled. Appropriate for sites where the oil is stranded above the normal high waterline.
Biological Constraints:	Avoid use on shores near sensitive wildlife habitats, such as fish-spawning areas or bird-nesting or concentration areas because of the potential for release of oil and oiled sediments into adjacent bodies of water. Should not be used in clam beds.
Environmental Effects:	Due to the mixing of oil into sediments, this method could further expose organisms that live below the original layer of oil. Repeated reworking could delay re-establishing of these organisms. Refloated oil from treated sites could contaminate adjacent areas.
Waste Generation:	None.

Vegetation Cutting/Removal

Objective:	To remove portions of oiled vegetation or oil trapped in vegetation to prevent oiling of wildlife or secondary oil releases.
Description:	Oiled vegetation is cut with weed trimmers, blades, etc., and picked or raked up and bagged for disposal.
Applicable Habitat Types:	Habitats composed of vegetation, such as wetlands, sea grass beds, kelp beds, which contain emergent, herbaceous vegetation or floating, aquatic vegetation.
When to Use:	When the risk of oiled vegetation contaminating wildlife is greater than the value of the vegetation that is to be cut, and there is no less-destructive method that removes or reduces the risk to acceptable levels.
Biological Constraints:	Operations must be strictly monitored to minimize the degree of root destruction and mixing of oil deeper into the sediments. Access in bird-nesting areas should be restricted during nesting seasons. Cutting only the oiled portions of the plants and leaving roots and as much of the stem as possible minimizes impacts to plants.
Environmental Effects:	Vegetation removal will destroy habitat for many animals. Cut areas will have reduced plant growth and, in some instances, plants may be killed. Cutting at the base of the plant stem may allow oil to penetrate the substrate, causing sub-surface contamination. Along exposed sections of shoreline, the vegetation may not recover, resulting in erosion and habitat loss. Trampled areas will recover much more slowly.
Waste Generation:	Cut portions of oiled plants must be collected and disposed.

Flooding

Objective:	To wash oil stranded on land to the water's edge for collection.
Description:	A perforated header pipe or hose is placed above the oiled shore or bank. Ambient-temperature water is pumped through the header pipe at low pressure and flows downslope to the water where any oil released is trapped by booms and recovered by skimmers or other suitable equipment. On porous sediments, water flows through the substrate, pushing loose oil ahead of it. On saturated, fine-grained sediments, the technique becomes more of a surface flushing.
Applicable Habitat Types:	All shoreline types where the equipment can be effectively deployed. Not effective in steep intertidal areas.
When to Use:	In heavily oiled areas when the oil is still fluid and adheres loosely to the substrate, and where oil has penetrated into gravel sediments. This method is frequently used with other washing techniques (low- or high-pressure, cold- to hot-water flushing).
Biological Constraints:	Special care should be taken to recover oil where nearshore habitats contain rich biological communities. Not appropriate for muddy substrates.
Environmental Effects:	Habitat may be physically disturbed by foot traffic during operations and smothered by sediments washed down the slope. If containment methods are not sufficient, oil and oiled sediments may be flushed into adjacent areas. Flooding may cause sediment loss and erosion of the shoreline and shallow rooted vegetation. Oiled sediment may be transported to nearshore areas, contaminating them and burying benthic organisms.
Waste Generation:	Depends on the effectiveness of the collection method.

Low-pressure, Ambient-Water Flushing

Objective:	To remove fluid oil that has adhered to the substrate or man-made structures, pooled on the surface, or become trapped in vegetation.
Description:	Ambient-temperature water is sprayed at low pressures (<10 psi), usually from hand-held hoses, to lift oil from the substrate and float it to the water's edge for recovery by skimmers, vacuum, or sorbents. Usually used with a flooding system to prevent released oil from re-adhering to the substrate downstream of the treatment area.
Applicable Habitat Types:	On substrates, riprap, and solid, man-made structures, where the oil is still fluid. In wetlands and along vegetated banks where oil is trapped in vegetation.
When to Use:	Where fluid oil is stranded onshore or floating in shallow intertidal areas.
Biological Constraints:	May need to restrict use so that the oil/water effluent does not drain across sensitive intertidal habitats, and so that mobilized sediments do not affect rich subtidal communities. Use from boats will reduce the need for foot traffic in soft substrates and vegetation. Flushed oil must be recovered to prevent further oiling of adjacent areas.
Environmental Effects:	If containment methods are not sufficient, oil and oiled sediments may be flushed into adjacent areas. Flooding may cause sediment loss and erosion of the shoreline and shallow rooted vegetation. Some trampling of substrate and attached biota will occur.
Waste Generation:	Depends on the effectiveness of the collection method.

High-pressure, Ambient-Water Flushing

Objective:	To remove oil that has adhered to hard substrates or man-made structures.
Description:	Similar to low-pressure flushing, except that water pressure is 100-1,000 psi (720-7,200 kpa). High-pressure spray will more effectively remove sticky or viscous oils. If low water volumes are used, sorbents are placed directly below the treatment area to recover oil.
Applicable Habitat Types:	On bedrock, man-made structures, and gravel substrates.
When to Use:	When low-pressure flushing is not effective at removing adhered oil, which must be removed to prevent continued oil release or for aesthetic reasons. When a directed water jet can remove oil from hard-to-reach sites.
Biological Constraints:	May need to restrict flushing so that the oil does not drain across sensitive habitats. Flushed oil must be recovered to prevent further oiling of adjacent areas. Should not be used directly on attached algae nor rich, intertidal areas.
Environmental Effects:	All attached animals and plants in the direct spray zone will be removed, even when used properly. May drive oil deeper into the substrate or erode fine sediments from shorelines if water jet is improperly applied. If containment methods are not sufficient, oil and oiled sediments may be flushed into adjacent areas. Some trampling of substrate and attached biota will occur.
Waste Generation:	Depends on the effectiveness of the collection method.

Low-pressure, Hot-Water Flushing

Objective: To remove non-liquid/non-fluid oil that has adhered to the substrate or man-made structures, or pooled on the surface.

Description: Hot water (90°F [32°C] up to 171°F [77°C]) is sprayed with hoses at low pressures (<10 psi [<72 kpa]) to liquefy and lift oil from the substrate and float it to the water's edge for recovery by skimmers, vacuums, or sorbents. Used with flooding to prevent released oil from re-adhering to the substrate.

Applicable Habitat Types: On bedrock, sand to gravel substrates, and man-made structures.

When to Use: Where heavy, but relatively fresh, oil is stranded onshore. The oil must be heated above its pour point so it will flow. Less effective on sticky oils.

Biological Constraints: Avoid wetlands or rich intertidal communities so that the hot oil/water effluent does not contact sensitive habitats. Operations from boats will help reduce foot traffic in soft substrates and vegetation. Flushed oil must be recovered to prevent further oiling of adjacent areas. Should not be used directly on attached algae or in rich, intertidal areas.

Environmental Effects: Hot water contact can kill attached animals and plants. If containment methods are not sufficient, oil may be flushed into adjacent areas. Flooding may cause sediment loss and erosion of the shoreline and shallow rooted vegetation. Some trampling of substrate and biota will occur.

Waste Generation: Depends on the effectiveness of the collection method.

High-pressure, Hot Water Flushing

Objective:	To mobilize weathered and viscous oil strongly adhered to surfaces.
Description:	Hot water (90°F [32°C] up to 171°F [77°C]) is sprayed with hand-held wands at pressures greater than 100 psi (720 kpa). If used without water flooding, this procedure requires immediate use of vacuum or sorbents to recover the oil/water runoff. When used with a flooding system, the oil is flushed to the water surface for collection by skimmers, vacuum, or sorbents.
Applicable Habitat Types:	Gravel substrates, bedrock, and man-made structures.
When to Use:	When oil has weathered to the point that warm water at low pressure no longer effectively removes oil. To remove viscous oil from man-made structures for aesthetic reasons.
Biological Constraints:	Use should be restricted so that the oil/water effluent does not drain across sensitive habitats (damage can result from exposure to oil, oiled sediments, and hot water). Should not be used directly on attached algae nor rich, intertidal areas. Released oil must be recovered to prevent further oiling of adjacent areas.
Environmental Effects:	All attached animals and plants in the direct spray zone will be removed or killed, even when used properly. Oiled sediment may be transported to shallow nearshore areas, contaminating them and burying benthic organisms.
Waste Generation:	Depends on the effectiveness of the collection method.

Steam Cleaning

Objective:	To remove heavy residual oil from solid substrates or man-made structures.
Description:	Steam or very hot water (171°F [77°C] to 212°F [100°C]) is sprayed with hand-held wands at high pressure (2,000+ psi [14,400 kpa]). Water volumes are very low compared to flushing methods.
Applicable Habitat Types:	Man-made structures such as seawalls and riprap.
When to Use:	When heavy oil residue must be removed for aesthetic reasons, when hot water flushing is not effective, and no living resources are present.
Biological Constraints:	Not to be used in areas of soft substrates, vegetation, nor high biological abundance directly on, nor below, the structure.
Environmental Effects:	Complete destruction of all organisms in the spray zone. Difficult to recover all released oil. If containment methods are not sufficient, oil may be flushed into nearshore areas.
Waste Generation:	Depends on the effectiveness of the collection method. Usually sorbents are used, generating significant waste volumes.

Sand Blasting

Objective:	To remove heavy residual oil from solid substrates or man-made structures.
Description:	Use of sandblasting equipment to remove oil from the substrate. May include recovery of used (oiled) sand.
Applicable Habitat Types:	On heavily oiled bedrock, artificial structures such as seawalls and riprap.
When to Use:	When heavy oil residue must be cleaned for aesthetic reasons, and even steam-cleaning is not effective.
Biological Constraints:	Not to be used in areas of soft substrates, vegetation, nor high biological abundance directly below, nor adjacent to, the structures.
Environmental Effects:	Complete destruction of all organisms in the blast zone. Possible smothering of organisms in adjacent areas. Unrecovered, used sand will introduce oiled sediments into the adjacent habitat. Oiled sediment may be transported to shallow nearshore areas, contaminating them and burying benthic organisms.
Waste Generation:	Will need to recover and dispose of oiled sand used in blasting.

Dispersants

Objective:	To reduce impact to sensitive shoreline habitats and animals that use the water surface by chemically dispersing oil into the water column.
Description:	Dispersants reduce the oil/water interfacial tension, thereby decreasing the energy needed for the slick to break into small particles and mix into the water column. Specially formulated products containing surface-active agents are sprayed (at concentrations of 1-5 percent by volume of the oil) from aircraft or boats onto the slicks. Some agitation is needed to achieve dispersion.
Applicable Habitat Types:	Water bodies with sufficient depth and volume for mixing and dilution.
When to Use:	When the impact of the floating oil has been determined to be greater than the impact of dispersed oil on the water-column community.
Biological Constraints:	Use in shallow water could affect benthic resources. Consideration should be made to avoid directly spraying any wildlife, especially birds or fur-bearing marine mammals.
Environmental Effects:	Until sufficiently diluted, the dispersed oil can adversely impact organisms in the upper 30 feet (10 meters) of the water column. Because dispersion may be only partially effective, some water-surface and shoreline impacts could occur.
Waste Generation:	None.

Emulsion-treating Agents

Objective:	To break or destabilize emulsified oil into separate oil and water phases. Can be used to prevent emulsion formation, increasing oil recovery rates, extending the window for dispersant application, or making burning possible.
Description:	Emulsion-treating agents are surfactants that are applied to emulsified oil at low concentrations (0.1-2 percent). They can be injected into skimmer reservoirs to break the emulsion as it is skimmed from the water. They can be sprayed (similar to dispersants) directly onto slicks to break or prevent emulsions, although this type of application has not been successfully used in the field.
Applicable Habitat Types:	On all water environments where emulsified oil is present.
When to Use:	Where storage capacities are very limited, to separate the recovered, emulsified oil and water so that the water can be treated and discharged. On floating slicks, where emulsified oil can reduce skimmer efficiency and dispersant effectiveness.
Biological Constraints:	There is insufficient information to fully evaluate biological constraints. Use in shallow water could affect benthic resources. Responders should avoid directly spraying any wildlife, especially birds or fur-bearing marine mammals.

Emulsion-treating Agents (cont.)

Environmental Effects:	Because this is a new method, there are few data available to evaluate environmental effects. Effective dosages are one to two orders of magnitude lower than dispersants. Environmental concerns include the potential for increased oil content of separated water; whether the oil will be more readily dispersed; and how the treated oil will behave upon contact with skimming equipment, birds, mammals, and shorelines.
Waste Generation:	May enable recycling of oil/water mixtures by breaking down emulsions.

Elasticity Modifiers

Objective:	To impart visco-elastic properties to floating oil, thereby increasing skimming rates.
Description:	The product is applied as a liquid, slurry, or solid onto the oil. Some mixing is required and is usually provided by the water spray during application. Treated oil is gelatinous, or semi-solid, but still fluid; there is no chemical change in the oil. The primary purpose is to increase skimmer efficiency removal rates while minimizing water recovery amounts. Increases the efficiency of some skimmers, but may clog other skimmers and pumps.
Applicable Habitat Types:	On all water environments where oil can be contained for skimming. Not for use near wetlands nor debris because of increased adhesive properties of the treated oil.
When to Use:	When skimmer efficiency is low. Must be used with booming or other physical containment. Not for use on heavy oils, which are already highly viscous.
Biological Constraints:	Not suitable for vegetated shores nor where extensive debris is mixed in the oil. Should be avoided when birds or other wildlife cannot be kept away from the treated oil.
Environmental Effects:	May increase the smothering effect of oil on organisms; therefore, the treatment should be considered only where recovery of the treated oil is likely.
Waste Generation:	If skimming efficiency is increased, will reduce the volume of water in oil/water collections. Effects on recycling of oil treated with elasticity modifiers is unknown.

Herding Agents

Objective:	To collect or herd oil into a smaller area and thicker slick in order to increase recovery. Can be used to herd oil away from sensitive areas or to help contain oil when it is necessary to move a boom.
Description:	These agents, which are insoluble surfactants and have a high spreading pressure, are applied in small quantities (1-2 gallons per lineal mile) to the clean water surrounding the edge of a fresh oil slick. They contain the oil, prevent spreading, but do not hold the spill in place. Hand-held or vessel-mounted systems can be used. Must be applied early in spill, when oil is still fluid.
Applicable Habitat Types:	On all still-water environments.
When to Use:	Potential use for collection and protection. For collection, used to push slicks out from under docks and piers where it has become trapped, or in harbors where the equipment is readily accessible for use early in the spill. For protection in low-current areas, used to push slicks away from sensitive resources such as wetlands. Not effective in fast currents, rough seas, nor rainfall.
Biological Constraints:	Not suitable for use in very shallow water nor fish-spawning areas.
Environmental Effects:	Direct acute toxicity to surface-layer organisms possible, though available products vary greatly in their aquatic toxicity.
Waste Generation:	Same as for manual oil recovery.

Solidifiers

Objective:	To change the physical state of spilled oil from a liquid to a solid.
Description:	Chemical agents (polymers) are applied to oil at rates of 10-45 percent or more, solidifying the oil in minutes to hours. Various broadcast systems, such as leaf blowers, water cannons, or fire suppression systems, can be modified to apply the product over large areas. Can be applied to both floating and stranded oil. Can be placed in sorbent booms and used like sorbents.
Applicable Habitat Types:	All water environments, bedrock, sediments, and artificial structures.
When to Use:	To immobilize the oil or prevent refloating from a shoreline, penetration into the substrate, or further spreading. However, the oil may not fully solidify unless the product is well mixed with the oil, and may result in a mix of solid and untreated oil. Generally not used on heavy oil spills that are already viscous.
Biological Constraints:	Must be able to recover all treated material.
Environmental Effects:	Products are insoluble and have very low aquatic toxicity. Unrecovered solidified oil may have longer impact because of slow weathering rates. Physical disturbance of habitat is likely during application and recovery.
Waste Generation:	If skimming efficiency is increased, solidifiers may reduce the volume of water collected during oil recovery. Oil treated with solidifiers is typically disposed of in landfills.

Shoreline Cleaning Agents (Surface Washing Agents)

Objective:	To increase the efficiency of oil removal from contaminated substrates.
Description:	Special formulations are applied to the substrate, as a presoak and/or flushing solution, to soften or lift weathered or heavy oils from the substrate to enhance flushing methods. The intent is to lower the water temperature and pressure required to mobilize the oil from the substrate during flushing. Some agents will disperse the oil as it is washed off the beach, others will not.
Applicable Habitat Types:	On any habitat where water flooding and flushing procedures are applicable.
When to Use:	When the oil has weathered to the point where it cannot be removed using ambient water temperatures and low pressures. This approach may be most applicable where flushing effectiveness decreases as the oil weathers.
Biological Constraints:	When the product does not disperse the oil into the water column, the released oil must be recovered from the water surface. Use may be restricted where suspended sediment concentrations are high, near wetlands, and near sensitive nearshore resources.
Environmental Effects:	The toxicity and effects on dispersability of treated oil vary widely among products. Selection of a product should consider its toxicity.
Waste Generation:	Because treated oil must be recovered, waste generation is a function of recovery method, which often includes sorbents.

Nutrient Enrichment (Biostimulation)

Objective: To accelerate the rate of oil hydrocarbon degradation due to natural microbial processes by adding nutrients (generally nitrogen and phosphorus) that stimulate microbial growth.

Description: If nutrients are a limiting factor (as measured using the interstitial pore water) in an area where shoreline oiling has occurred, water-soluble nutrients can be applied by a spray irrigation system. Nutrients should be applied daily if the impacted area gets completely submerged by tides and waves and if maximum biostimulation is desired. If the impacted area gets submerged only during spring tides, the frequency of nutrient addition will be determined by the intertidal zone water coverage. Slow-release granular or encapsulated nutrients or oleophilic fertilizer (which adheres to the oil residue on the surface) should require less frequent addition, but time-series monitoring of interstitial pore water nutrient levels is needed to ensure target levels are being maintained, especially throughout the depth of the impacted intertidal zone.

Applicable Habitat Types: Could be used on any shoreline habitat type where access is allowed and nutrients are deficient.

When to Use: On moderate- to heavily-oiled substrates, after other techniques have been used to remove free product; on lightly-oiled shorelines, where other techniques are destructive or ineffective; and where nutrients limit natural attenuation. Most effective on light to medium crude oils and fuel oils (asphaltenes tend to inhibit rapid biodegradation). Less effective where oil residues are thick. Not considered for gasoline spills, which evaporate rapidly.

Nutrient Enrichment (Biostimulation) (cont.)

Biological Constraints: Avoid using ammonia-based fertilizers at highly elevated concentrations because un-ionized ammonia is toxic to aquatic life. Nitrate is an equally good nitrogen source, minus the toxicity. Sodium tripolyphosphate is a better phosphorus source than orthophosphates because it is more soluble in seawater. If nutrients are applied properly with adequate monitoring, eutrophication should not be a problem. Only nutrient additives proven to be nontoxic and effective in either the laboratory or the field should be used in the environment. Contact toxicity of oleophilic nutrients may restrict their use, as other chemicals in the product could be more toxic to aquatic organisms in the presence of oil.

Environmental Effects: Detrimental effects to shoreline from foot or vehicle traffic caused by workers applying nutrients (unless nutrients are sprayed from a vessel or aircraft).

Waste Generation: None.

Natural Microbe Seeding (Bioaugmentation)

Objective: A form of bioremediation used to accelerate natural microbial degradation of oil by adding high numbers of oil-degrading microorganisms.

Description: Formulations containing specific hydrocarbon-degrading microbes are added to the oiled area because there are few indigenous hydrocarbon degraders, or those that are present cannot degrade the oil effectively. Since microbes require nitrogen and phosphorus to convert hydrocarbons to biomass, formulations containing these oil degraders must also contain adequate nutrients. Research studies conducted with bioengineered organisms or organisms enriched from different environments, grown in the laboratory to high numbers, and applied to an oiled beach to stimulate rapid biodegradation, have failed to prove conclusively that seeding is effective.

Bioaugmentation appears less effective than biostimulation because: 1) hydrocarbon degraders are ubiquitous in nature and, when an oil spill occurs, the influx of oil will cause an immediate increased response in the hydrocarbon-degrading populations; but, 2) if nutrients are in limited supply, the rate of oil biodegradation will be less than optimal; thus, 3) supplying nutrients will enhance the process initiated by the spill, but adding microorganisms will not, because they still lack the necessary nitrogen and phosphorus to support growth.

The maximum number of microbial organisms achievable will determine the maximum biodegradation rate. If nutrient supplementation is sufficient to maximize that rate, bioaugmentation will not further increase the biodegradation rate.

Natural Microbe Seeding (Bioaugmentation) (cont.)

Applicable Habitat Types:	There is insufficient information on impacts or effectiveness of this method to make a judgment on applicable habitat.
When to Use:	There is insufficient information on impacts or effectiveness of this method to make a judgment on when to use it.
Biological Constraints:	Avoid using products containing ammonia-based fertilizers at elevated concentrations because un-ionized ammonia is toxic to aquatic life. Nitrate is an equally good nitrogen source, minus the toxicity. If the product containing nutrients is applied properly with adequate monitoring, eutrophication should not be a problem, but toxicity tests should be evaluated carefully, as other chemicals in the product could be toxic to aquatic organisms.
Environmental Effects:	Detrimental physical effects to shoreline from foot or vehicle traffic caused by workers applying bioaugmentation products (unless nutrients are sprayed from a vessel or aircraft).
Waste Generation:	None.

In-situ Burning

Objective:	To remove oil from the water surface or habitat by burning it in place.
Description:	Oil floating on the water surface is collected into slicks at least 2-3 mm thick and ignited. The oil can be contained in fire-resistant booms, or by natural barriers such as ice or the shore. On land, oil can be burned when it is on a combustible substrate such as vegetation, logs, and other debris. Oil can be burned from non-flammable substrates using a burn promoter. On sedimentary substrates, it may be necessary to dig trenches for oil to accumulate in pools to a thickness that will sustain burning. Heavy oils are hard to ignite but can sustain a burn. Emulsified oils may not ignite nor sustain a burn when the water content is greater than 30 to 50 percent.
Applicable Habitat Types:	On most habitats, except dry, muddy substrates where heat may impact the biological productivity of the habitat. May increase oil penetration in permeable substrates. Not suitable for woody vegetation such as mangroves.
When to Use:	On floating slicks, early in the spill event when the oil can be kept thick enough (2-3 mm). On land, where there is heavy oil in sites neither amenable nor accessible to physical removal and the oil must be removed quickly. In wetlands and mud habitats, a water layer will minimize impacts to sediments and roots. Many potential applications for spills in ice. There are many operational and public health limitations.
Biological Constraints:	The possible effects of large volumes of smoke on nesting birds and populated areas should be evaluated.

In-situ Burning (cont.)

Environmental Effects:	Temperature and air quality effects are likely to be localized and short-lived. Toxicological impacts from burn residues have not been evaluated. On water, burn residues may sink. On land, removal of burn residues is often necessary for crude and heavy oils. Residue removal can physically disrupt sensitive habitats such as wetlands. There are few studies on the relative effects of burning oiled wetlands compared to other techniques or natural recovery. Limited data indicate recovery of wetland vegetation will depend on season of burn, type of vegetation, and water level in the marsh at time of burn.
Waste Generation:	Any residues remaining after burning will need to be collected and landfilled but, with an efficient burn, will be a small fraction of the original oil volume.

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