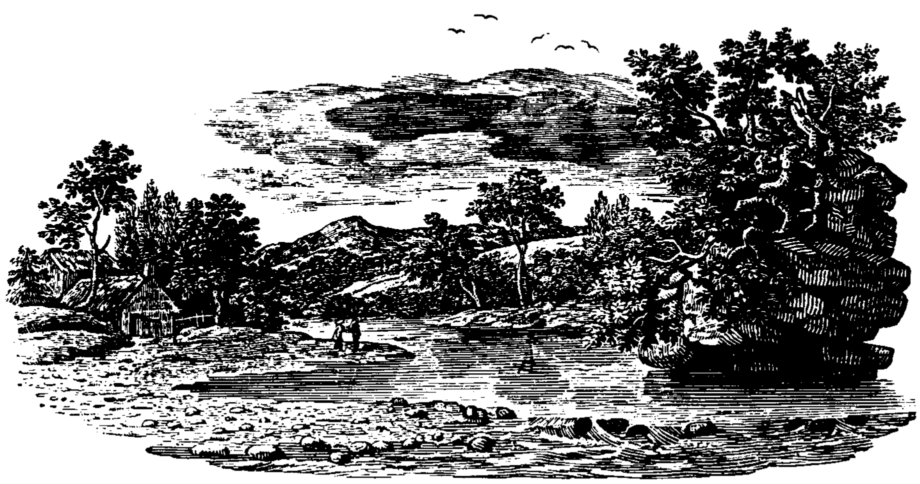
INLAND
OIL
SPILLS

Options for Minimizing Environmental Impacts of Freshwater Spill Response



NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
HAZARDOUS MATERIALS RESPONSE & ASSESSMENT DIVISION

AMERICAN PETROLEUM INSTITUTE

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ABSTRACT

Selecting appropriate protection, response, and cleanup techniques, both before and following an oil spill, affects the ultimate environmental impact and cost resulting from a spill. The American Petroleum Institute (API) and the National Oceanic and Atmospheric Administration (NOAA) jointly developed this guide as a tool for contingency planners and field responders to identify response techniques that have minimal ecological impacts and also minimize the impact of the oil. The guide provides information on 29 response methods and classifies their relative environmental impact for combinations of four oil types and twelve freshwater environments and habitats. Spill topics of special concern in freshwater settings are also discussed, including public health, conditions under which oil might sink in freshwater, oil behavior in ice conditions, permafrost, and use of firefighting foams.

ACKNOWLEDGMENTS

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This document has been reviewed by spill response professionals, including contractors, industry, consultants, and government whose efforts are appreciated. API and NOAA wish to acknowledge the additional contributions made by David Bell (BP America) and Dr. Ron Goodman (Imperial Oil Resources, Ltd.). The successful completion of this project is due in large part to the energy, leadership, and perseverance of David Fritz (Amoco Oil), Lt Kenneth Barton (NOAA), Jay Rodstein (formerly of NOAA), and Alexis Steen (API).

1.0 INTRODUCTION

1.1 SCOPE AND PURPOSE

Selecting appropriate oil spill protection, recovery, and cleanup techniques, before and following an oil spill, is a critical element affecting the ultimate environmental impact and cost resulting from a spill. It is important to identify techniques that in themselves have minimal intrinsic ecological impact and are also effective in reducing the impact of the oil. Furthermore, these response techniques should be considered before a spill, so that little time needs to be spent preparing for the response during a spill.

The American Petroleum Institute (API) and the National Oceanic and Atmospheric Administration (NOAA) jointly developed this guide as a tool to help contingency planners and field responders evaluate response techniques and choose those that will most effectively prevent or minimize adverse ecological impact. Information is provided to help select response techniques for specific combinations of habitat and oil types. Each technique is evaluated individually for a specific habitat; however, during spill response more than one technique may be used at the same time on one or more habitats.

The discussions in this guide reflect primarily the assessment of the environmental impact of the response methods. This guide also recognized that the selected techniques should be effective. They must remove a significant amount of oil from the environment or prevent or reduce oil impact, and they must have acceptable impact on the habitat as compared to leaving the oil alone (natural recovery). Prolonged use of an inefficient technique may be more ecologically detrimental than short-term use of a potentially more intrusive approach (e.g., frequent entry into a marsh to replace sorbents rather than vacuuming pooled oil).

Reducing the overall ecological impact of a spill event is the primary concern of this guide, and it is applicable for inland, freshwater environments and habitats only. This guide does not address land-only, chemical, or marine spills. It also does not discuss legal or regulatory issues; safety considerations; or guidance on planning, organizing, and conducting a spill response effort. The manual may be customized for specific geographic areas to address special priorities and concerns.

Specific spill conditions will often dictate the response techniques used, and selection always involves tradeoffs. For example, a potentially ecologically damaging, but efficient, cleanup technique could be used to meet site-specific response goals. Also, techniques may be used early in response simply because they can be implemented immediately, rather than waiting until ones with lower impact can be mobilized. A method that has a significant short-term ecological impact, such as in-situ burning, may actually produce the lowest long-term ecological impact because it removes the oil quickly.

1.2 BACKGROUND

Oil spills into inland waters differ from coastal or marine spills from several perspectives. For instance, inland spills are usually in freshwater habitats. Inland spills are also more frequent than marine spills, and they often involve smaller volumes of oil. Refined product spills are more common in freshwater, while crude oil spills comprise the majority of marine spills. Inland spills have a much higher potential to contaminate water supplies (surface as well as groundwater), to affect areas of concentrated populations, and to impact manmade structures and human activities. In coastal and marine environments, wave and tidal action are important mechanisms for dispersion and transport of oil and in removing oil from shorelines. These mechanisms are less important in freshwater habitats, where currents and floods are more important factors.

The knowledge base for response to oil spills reflects the disparity of information available between marine spill response and freshwater response. The lack of literature and guidelines for inland spill response prompted several efforts to improve this shortcoming. Preparation of this guide began with a workshop sponsored by API on Inland Oil Spills, conducted in Dearborn, Michigan, November 19-21, 1991. The objective of the workshop was to bring together the oil spill response community experienced and / or responsible for responding to freshwater crude oil or petroleum product spills, and to develop strategies through consensus for dealing with spills in different freshwater environments and shoreline habitats. The information from that workshop was the basis for development of this guide. However, the final guidelines presented here are based on the educated and experienced opinions of oil spill experts in industry and government.

1.3 ORGANIZATION OF GUIDELINES

The guide identifies response methods for twelve primary freshwater habitats (Table 1), which represent various waterways and shoreline types. Each habitat is treated separately in the guide, although the spill responder will be confronted with a variety of habitats.

Table 1. Primary freshwater environments and habitats included in this guide.

Water Environments	***Shoreline Habitats***
Open Water	Bedrock
Large Rivers	Manmade Structures
Small Lakes and Ponds	Sand
Small Rivers and Streams	Mixed Sand and Gravel
	Gravel
	Vegetated Shorelines
	Mud
	Wetlands

Section 2 of the guide includes:

- Response method summary matrices for the four primary water environments and eight shoreline habitats for four general oil types.

Section 3, arranged by water environment and shoreline habitat, contains:

- A detailed description of the environment or habitat; and
- Matrices of response methods in terms of recommended use for each of the four general oil types.

Section 4 of the guide contains detailed descriptions of the response methods listed in the matrices. The following headings are used:

- Objective;
- Description;
- Applicable habitats;
- When to use;
- Biological constraints; and
- Environmental impact.

Section 5 discusses the following special issues of concern in freshwater settings:

- Public health concerns;
- Conditions under which oil might sink;
- Oil behavior under ice conditions;
- Oil behavior and response in permafrost habitats; and

- Firefighting foam.

1.4 SENSITIVITY OF ENVIRONMENTS AND HABITATS

Habitat sensitivity is a function of several factors, including degree of exposure to natural removal processes, biological productivity and ability to recover following oil exposure, human use of the habitat, and ease of oil removal. These factors are used to rank the overall sensitivity of shoreline habitats to spilled oil as part of the Environmental Sensitivity Index (ESI). This guide focuses on one element of environmental sensitivity, namely the sensitivity of habitats to impacts resulting from oil removal. ESI shorelines are grouped according to the oil removal considerations used in this guide. The correlation between the shoreline habitat groupings in this guide and the shoreline rankings in the ESI atlases published for the U.S. Great Lakes is shown in Table 2, the summary tables, and Chapter 3. It should be noted that some groupings include both low and high sensitivity habitats, particularly where both sheltered and exposed habitats are grouped, such as bedrock and manmade structures.

Table 2. Correlation of the shoreline habitats discussed in this guide with the Environmental Sensitivity Index (ESI) shoreline rankings for the Great Lakes.

Shoreline Habitats	ESI Ranking and Description	
Bedrock	ESI = 1A	Exposed Rocky Cliffs
	ESI = 2	Shelving Bedrock Shores
	ESI = 8A	Sheltered Rocky Shores
Manmade Structures	ESI = 1B	Exposed Solid Seawalls
	ESI = 6B	Riprap Structures
	ESI = 8B	Sheltered Solid Manmade Structures
Sand	ESI = 4	Sand Beaches
Mixed Sand and Gravel Sediment	ESI = 3	Eroding Scarps in Unconsolidated
	ESI = 5	Mixed Sand and Gravel Beaches
Gravel	ESI = 6A	Gravel Beaches
Vegetated Shorelines	ESI = 9A	Sheltered Low Vegetated Banks/Bluffs
Mud	ESI = 9B	Sheltered Sand/Mud Flats

Wetlands	ESI = 10A	Fringing Marshes
	ESI = 10B	Extensive Marshes

The differences in oil behavior, persistence, and need for cleanup between sheltered and exposed sites are addressed in the discussion of these habitats.

Sensitivity issues of special concern to inland areas include strong seasonal variations in biological productivity and exposure to physical processes, urban areas with extensive manmade structures along the shoreline, and populated areas that are very near shorelines and bodies of water when human-health concerns can dominate cleanup issues. Important seasonal considerations include presence of ice in winter; variations in water level, which greatly influence habitats likely to be exposed to oil, flooding of stranded oil, and natural removal rates; sensitivity of vegetation to direct oiling impact; and use of habitats by migratory birds.

1.5 IMPACT OF RESPONSE METHODS IN THE ABSENCE OF OIL

The following criteria were used to evaluate the *relative impact* of each technique in the absence of oil, primarily due to physical disturbances of mechanical methods and toxic impacts from chemical and biological methods. The results are shown in Table 3. Impacts from use of individual products and equipment types vary. The information provided to evaluate impacts in the absence of oil addresses generic characteristics of the response techniques and does not consider those variations. Additional information on environmental impacts is provided in the discussions of each technique in Section 4.

- *Low* Physical damage to the substrate and vegetation is minimal. Toxic impact is likely to be of limited areal extent and short duration. Restabilization or repopulation of the habitat is likely within six months.
- *Moderate* Physical damage to the substrate and vegetation may occur, with increased erosion potential in sedimentary habitats. Toxic impact is such that restabilization or repopulation of the habitat may take six to twelve months.
- *High* Physical damage to the substrate and vegetation is expected. Erosion potential may be high for the technique. The ecosystem may be adversely affected. Restabilization or repopulation of the habitat may take more than twelve months.

Those techniques that are clearly ineffective or inapplicable for a habitat are indicated with a dash (—). For cases where there is insufficient information to evaluate impact in the absence of oil, an “I” is used.

Table 3. Relative impact of response methods in the absence of oil.

Response Method	WATER ENVIRONMENT				SHORELINE HABITAT							
	Open Water	Small Lakes/Ponds	Large Rivers	Small Rivers/Streams	Bedrock	Man-Made	Sand	Vegetated Shores	Sand and Gravel	Gravel	Mud	Wetlands
PHYSICAL RESPONSE METHODS												
Natural Recovery	–	–	–	–	–	–	–	–	–	–	–	–
Booming	L	L	L	L	–	–	–	–	–	–	–	–
Skimming	L	L	L	L	–	–	–	–	–	–	–	–
Barriers/Berms	–	–	–	H	–	–	–	–	–	–	–	–
Physical Herding	L	L	L	L	–	–	–	–	–	–	–	–
Manual Oil Removal/Cleaning	L	H	L	M	L	L	L	H	M	M	H	H
Mechanical Removal	L	H	H	H	–	M	M	H	M	M	H	H
Sorbents	L	L	L	L	L	L	L	L	L	L	M	M
Vacuum	L	L	L	L	L	L	L	M	L	L	H	M
Debris Removal	–	L	L	L	L	L	L	L	L	L	M	M
Sediment Reworking	–	H	–	H	–	–	M	H	M	M	H	H
Vegetation Removal	L	H	M	H	–	–	–	H	–	–	–	H
In-Situ Burning	L	M	L	M	L	L	M	M	M	M	H	M
Flooding	–	–	–	–	L	L	L	L	M	L	L	L
Low-Pressure, Cold-Water Flushing	–	–	–	–	L	L	M	L	L	M	H	L
High-Pressure, Cold-Water Flushing	–	–	–	–	L	L	H	H	H	H	H	H
Low-Pressure, Hot-Water Flushing	–	–	–	–	M	L	H	H	M	M	H	H
High-Pressure, Hot-Water Flushing	–	–	–	–	M	L	H	H	H	H	H	H
Steam Cleaning	–	–	–	–	M	L	H	H	M	M	H	H
Sand Blasting	–	–	–	–	H	M	–	–	–	–	–	–
CHEMICAL RESPONSE METHODS												
Dispersants	L	H	L	H	–	–	–	–	–	–	–	–
Demulsifiers	L	L	L	M	–	–	–	–	–	–	–	–
Visco-Elastic Agents	L	M	L	L	–	–	–	–	–	–	–	–
Herding Agents	L	M	L	H	–	–	–	–	–	–	–	–
Solidifiers	L	L	L	L	L	L	M	M	M	L	M	M
Chemical Shoreline Pretreatment	–	–	–	–	I	I	I	I	I	I	I	I
Shoreline Cleaners	–	–	–	–	M	L	M	I	M	M	M	I
BIOLOGICAL RESPONSE METHODS												
Nutrient Enrichment	L	M	L	L	L	L	L	L	L	L	L	L
Natural Microbe Seeding	I	I	I	I	I	I	I	I	I	I	I	I

L = Low; M = Moderate; H = High; I = Incomplete Information; "-" = Not applicable for this oil type

1.6 CLASSIFICATION OF OIL RESPONSE METHODS

The classifications developed for this guide compare the relative environmental impact of specific response methods for a given environment or habitat and oil type. It should be noted that the methods were compared among themselves, and no one method was used as a standard. The relative effectiveness of a response technique's ability to protect a habitat or remove oil is not explicitly considered. Relative effectiveness is only incorporated into the classification where less effective methods could result in longer application and thus greater ecological impacts, or leave higher oil residues in the habitat.

The classification categories are defined as follows:

A May cause the least adverse habitat impact

B May cause some adverse habitat impact

C May cause significant adverse habitat impact

D May cause the most adverse habitat impact

I Insufficient Information - impact or effectiveness of the method could not be evaluated at this time

Those techniques that are clearly ineffective (e.g., herding agents on heavy oils) or inapplicable for an oil type or habitat (e.g., sand blasting of mud habitats) are indicated with a dash (—).

1.7 ASSUMPTIONS USED IN THE DISCUSSION OF METHODS

This guide was prepared with several assumptions:

Proper Application of Methods

It is assumed that methods will be properly applied by trained personnel. For example, if booms are recommended, these guidelines assume that the booms will be effectively located and correctly deployed. Improper application of almost any technique can render it ineffective or cause additional damage. For general guidance on application, see the publications listed in Appendix A. In cases where instruction for using a protection or cleanup method may be habitat-specific, see Section 4.

Evaluation of Relative Impact of Methods

Each method was evaluated independently for each habitat. In an actual response, however, the methods cannot be evaluated in isolation from each other. Specific spill conditions will often dictate the need for different techniques for the same water environment or shoreline habitat. For example, a high degree of oiling or low exposure to natural removal processes may require a more intrusive technique to accelerate recovery in specific areas. The sensitivity of adjacent habitats may lead to the decision not to use an appropriate method because of the likelihood of secondary impact caused by cleanup of nearby sites. Finally, from an operational perspective, it may be necessary to use available methods early during a spill, rather than waiting for equipment or materials to arrive or teams to be trained in use of a less damaging technique.

Relative Effectiveness of Methods

The relative effectiveness of response methods to protect habitats and remove oil is a key consideration when selecting from various response methods. Although this guide attempts to consider only the environmental impact, effectiveness was incorporated into the discussion of methods in three ways.

First, those methods thought to be totally ineffective or inapplicable for an environment or habitat were not even listed in the habitat-specific matrices. For example, barrier/berms are not listed on the open-water matrices, and mechanical removal is not listed on the bedrock matrices.

Second, those methods that were clearly ineffective or inapplicable for a specific oil type within a habitat matrix were designated with a dash (—). Examples include using solidifiers on heavy oils in open water and emulsion-treating agents on gasoline products.

Third, those methods that are feasible, but likely to leave a significant amount of oil at the end of treatment, are given a lower classification. Often this change in effectiveness is associated with oil type, e.g., low-pressure, cold-water flushing is given a lower classification for heavy oil than medium oil because of its lower efficiency at oil removal. Similarly, methods such as manual and mechanical oil removal and sediment reworking that would have little effect on gasoline, which tends to evaporate quickly, are given lower classifications because the impact of the methods are not balanced by benefits from removing the oil.

Restrictions for Using Response Methods

Restrictions related to safety, weather, spill size, or regulatory constraints cover a wide spectrum of scenarios. It is thus impractical to discuss every possible situation or combination of factors in a set of guidelines. Some of this information, if appropriate, is included in the discussion under each habitat (Section 3) or in the descriptions of each method (Section 4). Many other considerations can come into play, such as worker safety and aesthetic, social, and economic impacts. Specific safety issues dealing with responding to gasoline spills are reflected in the tables. It should be noted that using chemical methods will require approvals from state and/or Federal regulatory agencies.

1.8 CLASSIFICATION OF OIL TYPES

Inland oil spills can involve a wide range of crude oils and refined products. The type of oil spilled is a key consideration in developing response and cleanup strategies. Oil properties important in characterizing oil types include:

Flash point Highly volatile oils, which evaporate rapidly after a release, may pose significant fire risks to responders. Often, the safest option is to allow the product to evaporate. Evaporation is an important mechanism for removing the spill from the water or shore because it lessens the need for cleanup and concern for associated impacts. Highly volatile oils completely evaporate in one to two days.

Specific gravity/API gravity Oils with a specific gravity greater than 1.00 (API gravity of less than 10) will sink in freshwater. However, those with a specific gravity of 0.95 or higher (API gravity less than 17.5) are also at risk of sinking once they become mixed with suspended sediments. When these oils have stranded on a shoreline, sediment incorporated from the shoreline can cause sinking if it is eroded from the shoreline.

Viscosity Viscosity controls both the rate that oil spreads on water and its likely depth of penetration into the substrate once on shore. Low-viscosity oils spread rapidly into thin sheens, increasing the surface area and making recovery difficult. They readily penetrate into sediments and debris. Viscous oils can be so thick that they do not spread, particularly when spilled on cold water. They are more likely to coat rather than penetrate shorelines.

Emulsion formation Under certain conditions, oil slicks will form a water-in-oil emulsion often called “chocolate mousse.” This material can contain up to 80 percent water and can be many orders of magnitude more viscous than the spilled oil. There is no simple qualitative measure of the tendency to form emulsions. Emulsions are stabilized by natural or added surfactants, or compounds that act like surfactants, in the spilled oil. Gasoline does not emulsify, while diesel can quickly emulsify. Many crude oils can form stable emulsions. When an emulsion is formed, the oil changes in appearance and viscosity, becoming much more difficult to address from a spill-response perspective: the fluid is more viscous and hard to pump, and the volume has increased by a factor of four to five.

Adhesion The ease with which spilled oil can be physically removed from surfaces, usually by water flushing or vacuum, is an important factor in planning cleanup operations. The range of response methods needed for shoreline cleanup will depend largely on whether stranded oil adheres to substrate and response equipment. However, adhesion is a poorly defined parameter that is difficult to predict.

We use an oil classification scheme based on these properties to define four categories of oil. Characteristics of the four general types are provided below (Table 4), along with representative oils. Weathering tends to change the physical and chemical properties of oil, usually making it more viscous and cleanup techniques less effective. Methods used during the initial response should be re-evaluated as time elapses and as the oil changes in character. To some extent, this re-evaluation may be achieved by using the four tables for oil types in sequence, thus simulating the weathering process. Extremely heavy oils or those that are solid at ambient temperatures, such as asphalt, are not addressed below but are discussed as a special consideration in Section 5.

Table 4. The four types of oil used in this guide and their characteristics.

Gasoline Products

¥ Very volatile and highly flammable (flash point near 100¡F/40¡C)
¥ High evaporation rates
¥ Narrow cut fraction with no residues
¥ Low viscosity; spread rapidly to a thin sheen
¥ Specific gravity less than 0.80
¥ High acute toxicity to biota
¥ Do not emulsify
¥ Will penetrate substrate; nonadhesive

Diesel-like Products and Light Crude Oils (No. 2 fuel oil, jet fuels, kerosene, West Texas crude, Alberta crude)

¥ Moderately volatile (flash point varies 100-150¡F/40-65¡C)
¥ Refined products can evaporate to no residue
¥ Crude oils do have a residue after evaporation is completed
¥ Low- to moderate viscosity; spread rapidly into thin slicks
¥ Specific gravity of 0.80-0.85; API gravity of 35-45
¥ Moderate to high acute toxicity to biota; product-specific toxicity related to type and concentration of aromatic compounds
¥ Can form stable emulsions
¥ Tend to penetrate substrate; fresh spills are not adhesive
¥ Stranded light crudes tend to smother organisms

Medium-grade Crude Oils and Intermediate Products (North Slope crude, South Louisiana crude, No. 4 fuel oil, IFO 180, lube oils)

¥ Moderately volatile (flash point higher than 125¡F/50¡C)
¥ Up to one-third will evaporate in the first 24 hours
¥ Moderate to high viscosity
¥ Specific gravity of 0.85-0.95; API gravity of 17.5-35
¥ Variable acute toxicity, depending on amount of light fraction
¥ Can form stable emulsions
¥ Variable substrate penetration and adhesion
¥ Stranded oil tends to smother organisms

Heavy Crude Oils and Residual Products (Venezuela crude, San Joaquin Valley crude, Bunker C, No. 6 fuel oil)

¥ Slightly volatile (flash point greater than 150¡F/65¡C)
¥ Very little product loss by evaporation
¥ Very viscous to semisolid; may become less viscous when warmed
¥ Specific gravity of 0.95-1.00; API gravity of 10-17.5
¥ Low acute toxicity relative to other oil types
¥ Can form stable emulsions

- ¥ Little penetration of substrate likely, but can be highly adhesive
- ¥ Stranded oil tends to smother organisms

2.0 SUMMARY OF RESPONSE METHODS AND HABITATS

Tables 6 through 13 provide overviews of the physical, chemical, and biological response methods for four different oil types as applied to all water environments and shoreline habitats. Detailed information regarding specific habitats is provided in Section 3. Users of this guide should consult the matrices and summaries in Section 3 for descriptions of assumptions and circumstances applicable to the various methods. We encourage you to refer to Section 4 for more information on each response method. Also, the references listed in Appendix A can provide valuable, detailed information on specific topics or applications.

It is important to note that the classifications primarily reflect the likely relative environmental impact resulting from properly implementing a response method within each habitat. However, when there are overriding effectiveness or safety issues associated with a specific oil type or habitat, these methods have been classified as "not applicable" and are denoted with a dash (—) on the matrices. In the case of response to gasoline-type spills, many methods have been classified as "not applicable" because of the fire hazard to the responders. Although responders have used many of these methods at gasoline spills to protect resources or clean up the spill, discussion of the spill-specific circumstances that made their use possible are beyond the scope of this document.

Natural recovery is included in the tables since natural processes can be adequate, on their own, to remediate impact from an oil spill. It also presents no added environmental stress due to human spill response activities. Therefore, natural recovery is often classified as having the least adverse habitat impact in the summary tables.

Since there is little information regarding the environmental impact of in-situ burning, chemical treatment, and biodegradation enhancement in freshwater habitats, the evaluation and discussion are based on the best available knowledge on how they work and any past use. In most cases this knowledge results from past experience with marine spills. Where there is too little information to evaluate a technique (e.g., chemical shoreline pretreatment), an "I", for insufficient information, is used in the tables.

Spill response techniques described in this guide for inland water habitats include protection, recovery, and cleanup methods. The main objective of protection is keeping oil out of a habitat, or reducing the amount of oil that enters. Recovery consists of removal of floating oil from the water surface. Cleanup consists of removal of stranded oil. Frequently, these methods may be used for several response phases, such as deploying boom for protection or for containing oil washed off a river bank during cleanup.

Table 5. Key to ESI codes used in Tables 7, 9, 11, and 13.

ESI No.	Shoreline Type
1A	Exposed rocky cliffs
1B	Exposed solid seawalls
2	Shelving bedrock shores
3	Eroding scarps in unconsolidated sediments
4	Sand beaches
5	Mixed sand and gravel beaches
6A	Gravel beaches
6B	Riprap structures
7	Exposed tidal flats (not present in Great Lakes)
8A	Sheltered rocky shores
8B	Sheltered, solid, manmade structures
9A	Sheltered vegetated low banks/bluffs
9B	Sheltered sand/mud flats
10A	Freshwater marshes (herbaceous vegetation)
10B	Freshwater swamps (woody vegetation)

Table 6. GASOLINE PRODUCTS: Summary of relative environmental impact from res
for spills in water environments.

Response Method	WATER ENVIRONMENT Open Water	Large Rivers	Small Lakes/Ponds	Small Rivers/Streams
PHYSICAL RESPONSE METHODS				
Natural Recovery	A	A	A	A
Booming - Containment	–	–	–	–
Booming - Deflection/Exclusion	A	A	A	A
Skimming	–	–	–	A
Barriers/Berms	–	–	–	B
Physical Herding	B	B	C	B
Manual Oil Removal/Cleaning	–	–	–	–
Mechanical Oil Removal	–	–	–	–
Sorbents	–	–	–	–
Vacuum	–	–	–	–
Debris Removal	–	–	–	–
Sediment Reworking	–	–	–	–
Vegetation Removal	–	–	–	–
In-Situ Burning	–	–	B	C
Flooding	–	–	–	–
Low-Pressure, Cold-Water Flushing	–	–	–	–
High-Pressure, Cold-Water Flushing	–	–	–	–
Low-Pressure, Hot-Water Flushing	–	–	–	–
High-Pressure, Hot-Water Flushing	–	–	–	–
Steam Cleaning	–	–	–	–
Sand Blasting	–	–	–	–
CHEMICAL RESPONSE METHODS				
Dispersants	D	D	D	D
Emulsion Treating Agents	–	–	–	–
Visco-Elastic Agents	–	–	–	B
Herding Agents	D	D	B	D
Solidifiers	D	D	D	B
Chemical Shoreline Pretreatment	–	–	–	–
Shoreline Cleaning Agents	–	–	–	–
BIOLOGICAL RESPONSE METHODS				
Nutrient Enrichment	–	–	–	–
Natural Microbe Seeding	–	–	–	–

The following categories are used to compare the relative environmental impact of each response me
for the specific environment or habitat for each oil type, using the following definitions:
A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this t

Table 7. GASOLINE PRODUCTS: Summary of relative environmental impact from response spills in shoreline habitats.

Response Method	Bedrock	Man-Made	Sand	Vegetated Shores	Sand and Gravel	Gravel	Mud	Wetlands
PHYSICAL RESPONSE METHODS	1,2,8*	1,8	3,4	9	5	6	7,9	10
Natural Recovery	A	A	A	A	A	A	A	A
Booming	–	–	–	–	–	–	–	–
Skimming	–	–	–	–	–	–	–	–
Barriers/Berms	–	–	–	–	–	–	–	–
Physical Herding	–	–	–	–	–	–	–	–
Manual Oil Removal/Cleaning	–	–	D	D	D	D	D	D
Mechanical Oil Removal	–	–	D	D	D	D	D	D
Sorbents	B	B	–	–	–	–	B	C
Vacuum	–	–	–	–	–	–	–	–
Debris Removal	–	–	–	–	–	–	–	–
Sediment Reworking	–	–	D	D	D	D	D	D
Vegetation Removal	–	–	–	D	–	–	–	D
In-Situ Burning	–	–	–	–	–	–	C	B
Flooding	B	B	B	B	A	A	B	B
Low-Pressure, Cold-Water Flushing	B	B	B	B	B	A	D	B
High-Pressure, Cold-Water Flushing	B	B	D	D	C	C	D	D
Low-Pressure, Hot-Water Flushing	–	–	D	D	D	D	D	D
High-Pressure, Hot-Water Flushing	–	–	D	D	D	D	D	D
Steam Cleaning	–	–	–	–	–	–	–	–
Sand Blasting	–	–	–	–	–	–	–	–
CHEMICAL RESPONSE METHODS								
Dispersants	–	–	–	–	–	–	–	–
Emulsion Treating Agents	–	–	–	–	–	–	–	–
Visco-Elastic Agents	–	–	–	–	–	–	–	–
Herding Agents	–	–	–	–	–	–	–	–
Solidifiers	–	B	–	–	–	–	D	D
Chemical Shoreline Pretreatment	–	–	–	–	–	–	I	I
Shoreline Cleaning Agents	–	–	–	–	–	–	–	–
BIOLOGICAL RESPONSE METHODS								
Nutrient Enrichment	–	–	–	–	–	–	–	–
Natural Microbe Seeding	–	–	–	–	–	–	–	–

*Key to ESI codes in Table 5 on page 12.

The following categories are used to compare the relative environmental impact of each response method f or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

Table 8. DIESEL-LIKE OILS: Summary of relative environmental impact from respon spills in water environments.

Response Method	WATER ENVIRONMENT Open Water	Large Rivers	Small Lakes/Ponds	Small Rivers/Streams
PHYSICAL RESPONSE METHODS				
Natural Recovery	A	A	B	B
Booming	A	A	A	A
Skimming	A	A	A	A
Barriers/Berms	–	–	–	A
Physical Herding	B	B	B	B
Manual Oil Removal/Cleaning	–	–	C	C
Mechanical Oil Removal	–	–	C	C
Sorbents	B	B	A	A
Vacuum	A	A	A	A
Debris Removal	–	B	B	B
Sediment Reworking	–	–	–	–
Vegetation Removal	B	B	B	B
In-Situ Burning	A	B	B	B
Flooding	–	–	–	–
Low-Pressure, Cold-Water Flushing	–	–	–	–
High-Pressure, Cold-Water Flushing	–	–	–	–
Low-Pressure, Hot-Water Flushing	–	–	–	–
High-Pressure, Hot-Water Flushing	–	–	–	–
Steam Cleaning	–	–	–	–
Sand Blasting	–	–	–	–
CHEMICAL RESPONSE METHODS				
Dispersants	B	C	D	D
Emulsion Treating Agents	B	B	I	I
Visco-Elastic Agents	B	B	B	B
Herding Agents	B	D	B	D
Solidifiers	B	B	B	B
Chemical Shoreline Pretreatment	–	–	–	–
Shoreline Cleaning Agents	–	–	–	–
BIOLOGICAL RESPONSE METHODS				
Nutrient Enrichment	–	–	I	I
Natural Microbe Seeding	–	–	I	I

The following categories are used to compare the relative environmental impact of each response m for the specific environment or habitat for each oil type, using the following definitions:
A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this
-" = Not applicable for this oil type.

Table 9. DIESEL-LIKE OILS: Summary of relative environmental impact from response metl shoreline habitats.

Response Method	Bedrock	Man-Made	Sand	Vegetated Shores	Sand and Gravel	Gravel	Mud	Wetlands
	SHORELINE HABITAT							
PHYSICAL RESPONSE METHODS	1,2,8*	1,8	3,4	9	5	6	7,9	10
Natural Recovery	A	A	A	A	A	A	A	A
Booming	–	–	–	–	–	–	–	–
Skimming	–	–	–	–	–	–	–	–
Barriers/Berms	–	–	–	–	–	–	–	–
Physical Herding	–	–	–	–	–	–	–	–
Manual Oil Removal/Cleaning	B	A	B	B	B	B	D	D
Mechanical Oil Removal	–	–	B	C	C	D	D	D
Sorbents	A	A	A	A	A	A	A	A
Vacuum	B	B	B	B	B	B	C	B
Debris Removal	A	A	A	B	A	A	B	B
Sediment Reworking	–	–	B	D	B	B	D	D
Vegetation Removal	–	–	–	B	–	–	–	C
In-Situ Burning	B	B	–	B	–	–	C	B
Flooding	A	A	A	A	A	A	A	A
Low-Pressure, Cold-Water Flushing	A	A	B	A	A	A	C	A
High-Pressure, Cold-Water Flushing	B	A	D	C	C	B	D	D
Low-Pressure, Hot-Water Flushing	C	B	C	D	C	C	D	D
High-Pressure, Hot-Water Flushing	D	B	D	D	D	D	D	D
Steam Cleaning	D	C	–	–	D	D	–	–
Sand Blasting	D	C	–	–	–	–	–	–
CHEMICAL RESPONSE METHODS								
Dispersants	–	–	–	–	–	–	–	–
Emulsion Treating Agents	–	–	–	–	–	–	–	–
Visco-Elastic Agents	–	–	–	–	–	–	–	–
Herding Agents	–	–	–	–	–	–	–	–
Solidifiers	B	B	B	D	–	–	D	D
Chemical Shoreline Pretreatment	I	I	I	I	I	I	I	I
Shoreline Cleaning Agents	–	B	–	I	–	–	D	I
BIOLOGICAL RESPONSE METHODS								
Nutrient Enrichment	C	C	B	B	B	B	I	I
Natural Microbe Seeding	I	I	I	I	I	I	I	I

*Key to ESI codes in Table 5 on page 12.

The following categories are used to compare the relative environmental impact of each response method fc habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-"= Not appliable for this oil type.

Table 10. MEDIUM OILS: Summary of relative environmental impact from response spills in water environments.

Response Method	WATER ENVIRONMENT Open Water	Large Rivers	Small Lakes/Ponds	Small Rivers/Streams
PHYSICAL RESPONSE METHODS				
Natural Recovery	B	B	C	C
Booming	A	A	A	A
Skimming	A	A	A	A
Barriers/Berms	–	–	–	A
Physical Herding	B	B	B	B
Manual Oil Removal/Cleaning	–	B	C	C
Mechanical Oil Removal	–	B	C	C
Sorbents	B	B	A	A
Vacuum	A	A	A	A
Debris Removal	–	B	B	B
Sediment Reworking	–	–	–	–
Vegetation Removal	B	B	B	B
In-Situ Burning	A	B	B	B
Flooding	–	–	–	–
Low-Pressure, Cold-Water Flushing	–	–	–	–
High-Pressure, Cold-Water Flushing	–	–	–	–
Low-Pressure, Hot-Water Flushing	–	–	–	–
High-Pressure, Hot-Water Flushing	–	–	–	–
Steam Cleaning	–	–	–	–
Sand Blasting	–	–	–	–
CHEMICAL RESPONSE METHODS				
Dispersants	B	C	D	D
Emulsion Treating Agents	B	B	I	I
Visco-Elastic Agents	B	B	B	B
Herding Agents	B	D	B	D
Solidifiers	B	B	B	B
Chemical Shoreline Pretreatment	–	–	–	–
Shoreline Cleaning Agents	–	–	–	–
BIOLOGICAL RESPONSE METHODS				
Nutrient Enrichment	I	I	I	I
Natural Microbe Seeding	I	I	I	I

The following categories are used to compare the relative environmental impact of each response me
for the specific environment or habitat for each oil type, using the following definitions:
A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this
-" = Not applicable for this oil type.

Table 11. MEDIUM OILS: Summary of relative environmental impact from response methods for spills in shoreline habitats.

Response Method	SHORELINE HABITAT Bedrock	Man-Made	Sand	Vegetated Shores	Sand and Gravel	Gravel	Mud	Wetlands
PHYSICAL RESPONSE METHODS	1,2,8*	1,8	3,4	9	5	6	7,9	10
Natural Recovery	A	B	B	B	B	B	A	A
Booming	–	–	–	–	–	–	–	–
Skimming	–	–	–	–	–	–	–	–
Barriers/Berms	–	–	–	–	–	–	–	–
Physical Herding	–	–	–	–	–	–	–	–
Manual Oil Removal/Cleaning	B	B	A	B	A	B	C	C
Mechanical Oil Removal	–	–	B	C	B	C	D	D
Sorbents	A	A	A	B	A	A	A	A
Vacuum	B	B	B	B	B	B	B	B
Debris Removal	A	A	A	B	A	A	B	B
Sediment Reworking	–	–	B	D	B	B	D	D
Vegetation Removal	–	–	–	B	–	–	–	C
In-Situ Burning	B	B	B	B	B	B	C	B
Flooding	B	B	A	A	A	A	A	A
Low-Pressure, Cold-Water Flushing	A	A	B	A	A	A	C	A
High-Pressure, Cold-Water Flushing	B	A	D	C	C	B	D	D
Low-Pressure, Hot-Water Flushing	B	B	C	D	C	C	C	D
High-Pressure, Hot-Water Flushing	C	B	D	D	D	D	D	D
Steam Cleaning	D	C	–	–	D	D	–	–
Sand Blasting	D	C	–	–	–	–	–	–
CHEMICAL RESPONSE METHODS								
Dispersants	–	–	–	–	–	–	–	–
Emulsion Treating Agents	–	–	–	–	–	–	–	–
Visco-Elastic Agents	–	–	–	–	–	–	–	–
Herding Agents	–	–	–	–	–	–	–	–
Solidifiers	B	B	B	D	B	B	C	D
Chemical Shoreline Pretreatment	I	I	I	I	I	I	I	I
Shoreline Cleaning Agents	B	B	B	I	B	B	D	I
BIOLOGICAL RESPONSE METHODS								
Nutrient Enrichment	C	C	B	B	B	B	I	I
Natural Microbe Seeding	I	I	I	I	I	I	I	I

*Key to ESI codes in Table 5 on page 12.

The following categories are used to compare the relative environmental impact of each response method f
or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
-" = Not applicable for this oil type.

Table 12. HEAVY OILS: Summary of relative environmental impact from response r spills in water environments.

Response Method	WATER ENVIRONMENT Open Water	Large Rivers	Small Lakes/Ponds	Small Rivers/Streams
PHYSICAL RESPONSE METHODS				
Natural Recovery	B	C	C	C
Booming	A	A	A	A
Skimming	A	A	A	A
Barriers/Berms	–	–	–	A
Physical Herding	B	B	B	B
Manual Oil Removal/Cleaning	B	B	B	B
Mechanical Oil Removal	B	B	C	C
Sorbents	B	B	A	A
Vacuum	A	A	A	A
Debris Removal	–	B	B	B
Sediment Reworking	–	–	–	–
Vegetation Removal	B	B	B	B
In-Situ Burning	A	B	B	B
Flooding	–	–	–	–
Low-Pressure, Cold-Water Flushing	–	–	–	–
High-Pressure, Cold-Water Flushing	–	–	–	–
Low-Pressure, Hot-Water Flushing	–	–	–	–
High-Pressure, Hot-Water Flushing	–	–	–	–
Steam Cleaning	–	–	–	–
Sand Blasting	–	–	–	–
CHEMICAL RESPONSE METHODS				
Dispersants	–	–	–	–
Emulsion Treating Agents	B	B	I	I
Visco-Elastic Agents	–	–	–	–
Herding Agents	–	–	–	–
Solidifiers	–	–	–	–
Chemical Shoreline Pretreatment	–	–	–	–
Shoreline Cleaning Agents	–	–	–	–
BIOLOGICAL RESPONSE METHODS				
Nutrient Enrichment	I	I	I	I
Natural Microbe Seeding	I	I	I	I

The following categories are used to compare the relative environmental impact of each response m for the specific environment or habitat for each oil type, using the following definitions:
A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this
-" = Not applicable for this oil type.

Table 13. HEAVY OILS: Summary of relative environmental impact from response method in shoreline habitats.

Response Method	Bedrock	Man-Made	Sand	Vegetated Shores	Sand and Gravel	Gravel	Mud	Wetlands
	SHORELINE HABITAT							
PHYSICAL RESPONSE METHODS	1,2,8*	1,8	3,4	9	5	6	7,9	10
Natural Recovery	B	B	B	B	B	B	B	B
Booming	–	–	–	–	–	–	–	–
Skimming	–	–	–	–	–	–	–	–
Barriers/Berms	–	–	–	–	–	–	–	–
Physical Herding	–	–	–	–	–	–	–	–
Manual Oil Removal/Cleaning	A	A	A	B	A	A	C	C
Mechanical Oil Removal	–	–	A	C	B	C	D	D
Sorbents	B	B	B	B	B	B	B	A
Vacuum	B	A	B	B	B	B	B	B
Debris Removal	A	A	A	B	A	A	B	B
Sediment Reworking	–	–	B	D	B	B	D	D
Vegetation Removal	–	–	–	B	–	–	–	C
In-Situ Burning	B	B	B	B	B	B	C	B
Flooding	C	C	B	B	C	C	A	B
Low-Pressure, Cold-Water Flushing	C	C	B	B	B	B	C	B
High-Pressure, Cold-Water Flushing	B	B	D	D	C	B	D	D
Low-Pressure, Hot-Water Flushing	B	B	B	D	B	B	C	D
High-Pressure, Hot-Water Flushing	C	B	D	D	D	D	D	D
Steam Cleaning	D	C	–	–	D	D	–	–
Sand Blasting	D	C	–	–	–	–	–	–
CHEMICAL RESPONSE METHODS								
Dispersants	–	–	–	–	–	–	–	–
Emulsion Treating Agents	–	–	–	–	–	–	–	–
Visco-Elastic Agents	–	–	–	–	–	–	–	–
Herding Agents	–	–	–	–	–	–	–	–
Solidifiers	–	–	–	–	–	–	–	–
Chemical Shoreline Pretreatment	I	I	I	I	I	I	I	I
Shoreline Cleaning Agents	B	B	B	I	B	B	D	I
BIOLOGICAL RESPONSE METHODS								
Nutrient Enrichment	D	D	C	B	C	C	I	I
Natural Microbe Seeding	I	I	I	I	I	I	I	I

*Key to ESI codes in Table 5 on page 12.
The following categories are used to compare the relative environmental impact of each response method f
habitat for each oil type, using the following definitions:
A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
-" = Not applicable for this oil type.

3.0 SPILL RESPONSE METHODS FOR SPECIFIC INLAND HABITATS

3.1 INTRODUCTION

Oil spill protection, recovery, and cleanup methods are described in the following sections for four water environments and eight shoreline habitats. Each section is organized in the following format:

- Description of the environment or habitat;
- Matrices of response methods for four oil types; and
- Short summaries of the key issues considered for each response method.

The inland habitats are presented in order of their sensitivity, from least to most sensitive to oil spill impact, first for water environments, then for shoreline habitats. Accordingly, water environments begin with large rivers and end with small lakes and ponds. Shoreline habitats begin with bedrock and end with wetlands.

Response methods in each matrix are listed in order, generally beginning with those that cause the least adverse habitat impact, to those that can cause the most adverse habitat impact. Methods for which insufficient information is available for some habitats are listed last. Methods that are not applicable for all four oil types are excluded from the tables.

The use of water environments and shoreline habitats generally reflects the distinction between oil on a water body versus oil that is stranded at the land-water interface. Water-based activities consist mostly of containment, protection, and collection methods while onshore response includes protection, recovery, and cleanup. A large spill will likely affect a wide range of habitats and require use of many different methods. However, large spills can be divided into a series of small spills for developing site-specific response strategies. Often, more than one response method can be used with minimal habitat impacts. Spill conditions may dictate selecting a specific method, or combination of methods, over other possible methods.

We encourage you to refer to Section 4 for more information on each response method. Also, the references listed in Appendix A can provide valuable, detailed information on specific topics or applications.

3.2 OPEN WATER

Habitat Description

Open-water environments exist in large water bodies, such as the Great Lakes, Lake Champlain, and Lake Mead. These large water bodies have ocean-like wave and current conditions; however, lake currents are generally weak (less than one knot). Local weather conditions commonly cause sudden changes in sea state. Suspended sediment loads are highly variable, both spatially and over time. River mouths are particularly problematic areas, with high suspended sediment and debris loads, shallow zones, and manmade structures, which create complex water circulation patterns.

Thermal stratification with an upper, warm layer over cool, denser water is a common feature of large lakes during the warmer months. In most temperate lakes, stratification ends in the autumn when surface cooling combines with water mixing from high winds. Ice formation is a common characteristic of interior and northern lakes in winter months. Although all inland waters are surrounded by land, response operations for open-water environments are water-based; that is, protection and recovery equipment must be deployed from vessels.

Sensitivity

Open waters are considered to have low to medium sensitivity to oil spill impact because physical removal rates are high, water-column concentrations of oil can be rapidly diluted, and most organisms are mobile enough to move out of the area affected by the spill. Enclosed and protected areas of large lakes are more sensitive than offshore and nearshore waters because of slower dilution rates. Oil spills can affect fish in the water column, with the early life stages at greatest risk. Also, many birds (waterfowl, raptors, gulls, terns, and diving birds) feed and rest on the water, and therefore are highly vulnerable. Human use of affected areas may be restricted for a period of time, potentially limiting access for navigation, transportation, water intakes, or recreational activities during the spill.

Free-floating flora or mats can occur in sheltered bays of nutrient-rich lakes. Such mats may be particularly susceptible to oil because of their location in bays where oil may accumulate. Moreover, the plants are at the water surface (where the oil is) and without underground roots to regenerate after being oiled.

Table 14. Relative environmental impact from response methods for OPEN WATER environments.

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	A	A	A	A
Booming - Containment	–	A	A	A
Skimming/Vacuum	–	A	A	A
In-Situ Burning	–	A	A	A
Natural Recovery	A	A	B	B
Physical Herding	B	B	B	B
Sorbents	–	B	B	B
Vegetation Removal	–	B	B	B
Emulsion Treating Agents	–	B	B	B
Visco-Elastic Agents/Solidifiers	–	B	B	–
Dispersants	D	B	B	–
Herding Agents	D	B	B	–
Manual Oil Removal/Cleaning	–	–	–	B
Mechanical Oil Removal	–	–	–	B
Nutrient Enrichment	–	–	I	I
Natural Microbe Seeding	–	–	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.

B = May cause some adverse habitat impact.

C = May cause significant adverse habitat impact.

D = May cause the most adverse habitat impact.

I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.

"-" = Not applicable for this oil type.

RESPONSE METHODS: OPEN WATER ENVIRONMENTS

Least Adverse Habitat Impact

Booming

- Most effective in low-wave conditions and slow currents
- Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources

Skimming/Vacuum

- Effectiveness limited by current velocities and widely spread, thin sheens
- Not applicable to gasoline spills because of safety concerns

In-Situ Burning

- Most appropriate in offshore, rather than nearshore, areas
- More difficult to ignite emulsified and heavy oils and sustain the burn
- Safety issues for workers, vessels, and aircraft must be addressed
- Not applicable to gasoline spills due to safety concerns and containment difficulties

Natural Recovery

- Low impact except for medium- to heavy-category oils, which are persistent and would eventually strand on shorelines

Some Adverse Habitat Impact

Physical Herding

- May be needed under calm conditions to move oil toward recovery devices
- Water spray onto gasoline likely to mix the product into the water column

Sorbents

- Not a stand-alone technique except for very small spills
- Inhibit the evaporation of gasoline spills

Vegetation Removal

- May be appropriate if oil is trapped in floating vegetation

Emulsion-Treating Agents

- Not applicable to oils that do not form emulsions, such as gasoline

Visco-Elastic Agents/Solidifiers

- Not appropriate to gasoline spills because of safety concerns during application and inhibition of evaporation
- The recovery of treated oil must be considered
- Most are not very effective on heavy oils, which are too viscous to allow the product to mix into the oil

Dispersants

- Inhibit the evaporation of gasoline spills
- Use requires comparing the impact of dispersed versus undispersed oil
- Not effective on heavy or weathered oils

Herding Agents

- Most effective under calm conditions
- Not applicable to heavy oils because oil must be fluid
- Inhibit the evaporation of gasoline spills

Manual Oil Removal/Cleaning and Mechanical Oil Removal

- Effective only when heavy oils have solidified into large masses
- Complete removal of heavy oil is rarely achieved

Insufficient Information

Nutrient Enrichment and Natural Microbe Seeding

- Not applicable to gasoline and diesel-like oils because they rapidly evaporate
- There is insufficient information on impact and effectiveness for other oil types, particularly for open-water applications in freshwater

3.3 LARGE RIVERS

Habitat Description

Large rivers have varying salinities, meandering channels, and high flow rates (currents usually greater than one knot). These rivers are not necessarily navigable to large vessels. If they are, the environment can include associated locks, dams, pools, and other manmade structures. Examples of large rivers include the Mississippi River and its major tributaries, the Hudson River, the Delaware River, and the Columbia River. Water levels vary seasonally, with potential for reversal of water flow up tributaries and into backwater lakes during high water. Floodplains are common characteristics of large rivers. Floods generate high suspended sediment and debris loads. In northern regions, ice covers the surface in winter. River banks or bars are discussed in the sections on shore habitats (Sections 3.6 to 3.13), and backwater lakes are discussed in Section 3.4.

Sensitivity

Large rivers have medium sensitivity to oil spill impact because, even though they have high natural removal rates, they also have extensive biological and human use. Biological resources of concern include concentrations of migratory waterfowl and shorebirds, fish, and endangered mussel beds. Under flood conditions, river floodplains contain highly sensitive areas that are important habitats for many valuable species. Floating vegetation is present in areas of low flow. Recreational use of rivers is very high, and many are major transportation corridors. Drinking, industrial, and cooling water intakes are quite vulnerable to oil spills in this environment because of turbulent mixing, and they often shut down when slicks are present.

High currents, eddies, mid-river bars, ice formation, and flooding may complicate response measures in this habitat. Water flow across weirs and dams is of special concern because it is often turbulent and likely to emulsify oil slicks as they pass over these structures. Emulsified oil has a density close to water; it can readily suspend beneath the surface and remain in the water column as it moves through a series of locks and dams. Also, oil can adsorb onto sediment particles, which then settle out in quiet backwaters, potentially contaminating these habitats.

LARGE RIVER

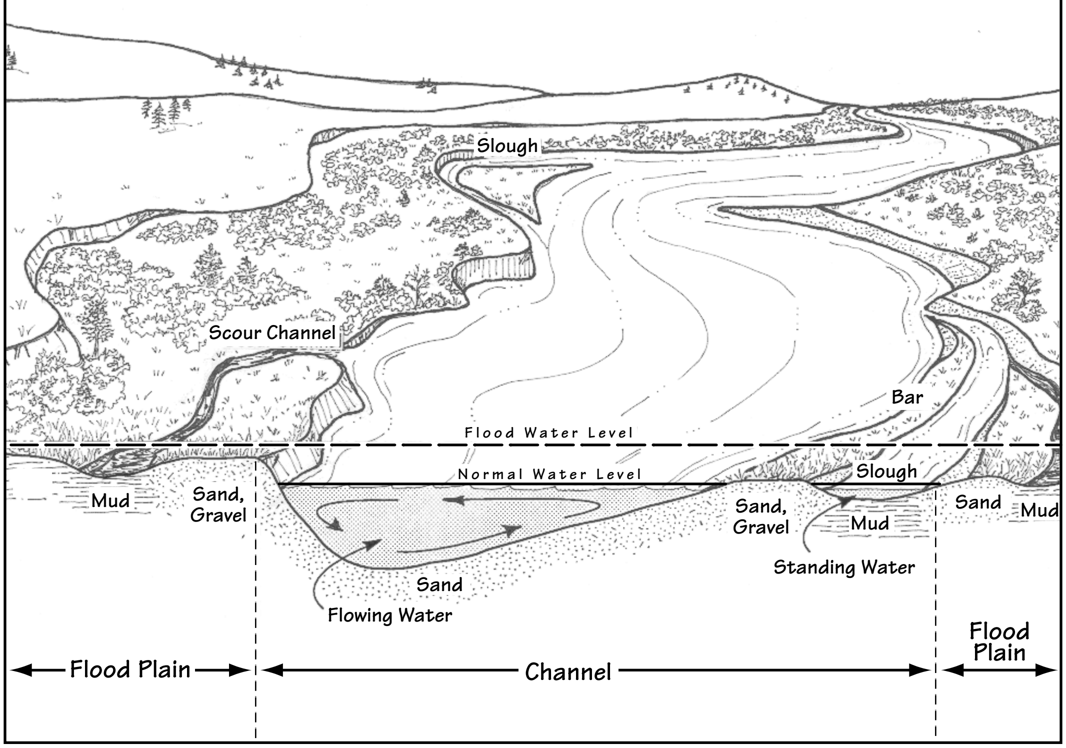

Slough
Scour Channel
Bar
Flood Water Level
Normal Water Level
Slough
Mud
Sand,
Gravel
Sand,
Gravel
Mud
Sand
Mud
Sand
Standing Water
Flowing Water
Flood Plain
Channel
Flood
Plain

Table 15. Relative environmental impact from response methods for LARGE RIVER environments.

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	A	A	A	A
Booming - Containment	–	A	A	A
Skimming/Vacuum	–	A	A	A
Natural Recovery	A	A	B	C
Physical Herding	B	B	B	B
Sorbents	–	B	B	B
In-Situ Burning	–	B	B	B
Emulsion Treating Agents	–	B	B	B
Vegetation Removal	–	B	B	B
Debris Removal	–	B	B	B
Visco-Elastic Agents/Solidifiers	–	B	B	–
Manual Oil Removal/Cleaning	–	–	B	B
Mechanical Oil Removal	–	–	B	B
Dispersants	D	C	C	–
Herding Agents	D	D	D	–
Nutrient Enrichment	–	–	I	I
Natural Microbe Seeding	–	–	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: LARGE RIVER ENVIRONMENTS

Least Adverse Habitat Impact

Booming

- Used primarily for diverting slicks towards collection points in low-current areas
- Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources

Skimming/Vacuum

- Not applicable to gasoline spills because of safety concerns

Some Adverse Habitat Impact

Natural Recovery

- For small gasoline and diesel-like spills, evaporation and natural dispersion would rapidly remove surface slicks
- For all other types and sizes of spills, oil recovery and / or protection of sensitive resources should be attempted

Physical Herding

- May be needed to flush oil trapped in debris, eddies, etc. toward recovery devices
- Water spray onto gasoline spills will likely enhance mixing of the product into the water column

Sorbents

- Not applicable to gasoline spills because of safety concerns and inhibition of evaporation
- May not be practical for large rivers because oil will spread and drift rapidly
- Overuse results in excess waste generation

In-Situ Burning

- May not be practical in rivers because oil will spread rapidly
- Containment and maintenance of minimum thickness for burning (1-3 millimeters) is difficult in fast currents

Emulsion-Treating Agents

- Not applicable for gasoline products, which do not emulsify

Vegetation Removal

- May be considered where oil is trapped in floating vegetation along shore and in eddies
- Removal of oiled vegetation may be required to prevent secondary oiling of wildlife or chronic sheening

Debris Removal

- River debris can trap persistent oils, causing chronic sheening and exposure of aquatic resources

Visco-Elastic Agents/Solidifiers

- Not applicable to gasoline spills because of safety concerns during application and inhibition of evaporation
- Recovery of treated oil may be difficult
- May not be practical in rivers because oil will spread and drift rapidly
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

Manual Oil Removal/Cleaning

- Concentrations of heavy oils that have hardened into solid or semi-solid masses can be manually picked up, from boat or shore
- Hand tools can be used to pick up small accumulations of oiled debris
- Operations conducted from boats minimize potential for habitat disruption by trampling onshore

Mechanical Oil Removal

- May be needed to recover large amounts of oil / oily debris trapped in booms or along shore
- Equipment can be operated from barges with less impact; shore-based operations are likely to cause localized disruption of shoreline habitat

Probable Adverse Habitat Impact

Dispersants

- Inhibit the evaporation of gasoline spills
- Not effective on heavy or weathered oils
- For large spills, limited dilution of dispersed oil in rivers likely to raise toxicity concerns

- Impacts on water intakes downstream would have to be evaluated

Most Adverse Habitat Impact

Herding Agents

- High currents make proper application difficult and carry product away
- Not applicable to heavy oils because oil must be fluid

Insufficient Information

Nutrient Enrichment and Natural Microbe Seeding

- Not applicable to gasoline and diesel-like oil spills because they rapidly evaporate
- There is insufficient information on impact and effectiveness for other oil types, particularly for applications in rivers

3.4 SMALL LAKES AND PONDS

Habitat Description

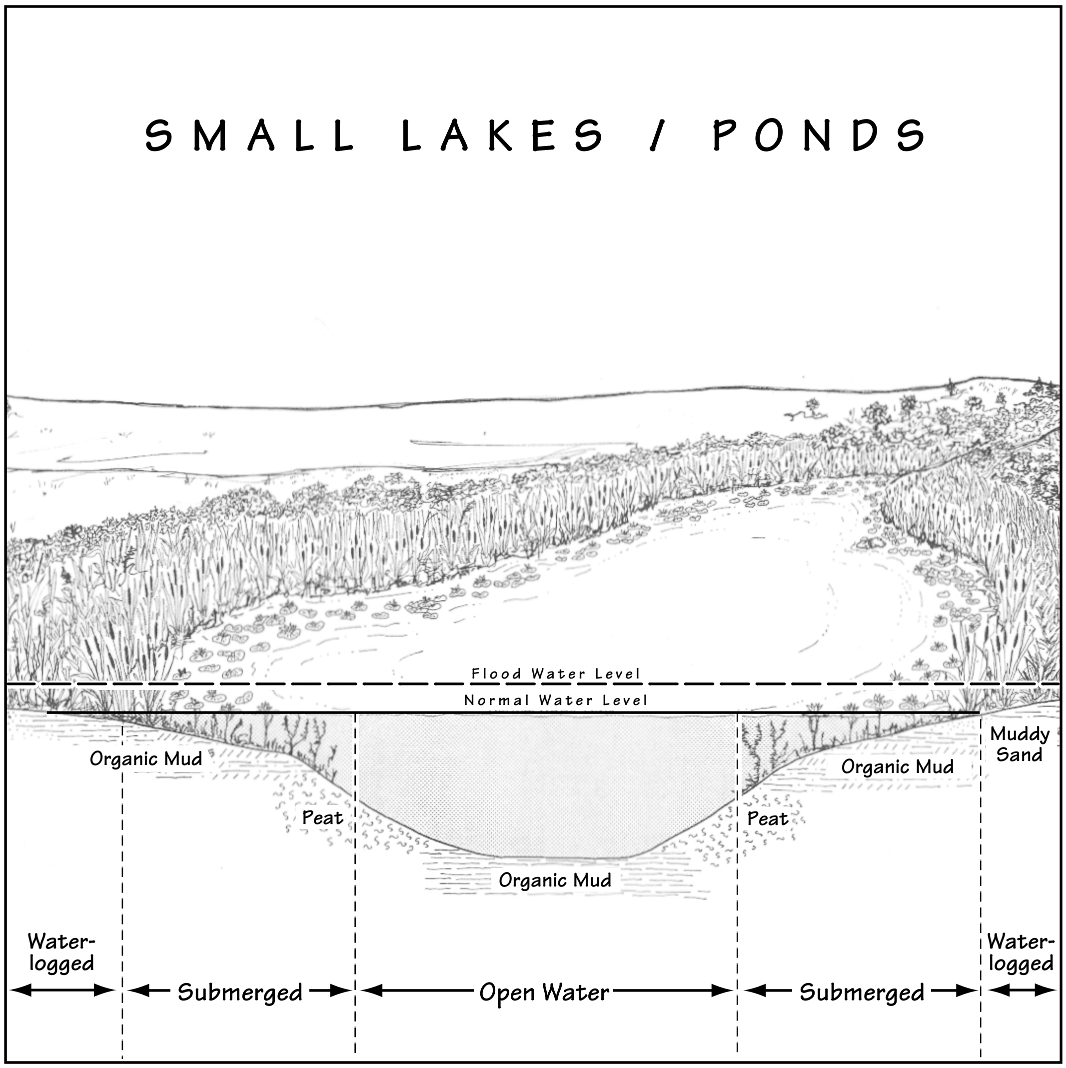
Lakes and ponds are standing bodies of water of variable size and water depth. Waves and currents are generally very low, although the water surface can become choppy. Water levels can fluctuate widely over time, particularly on manmade lakes. Smaller ponds can completely freeze over in winter. The bottom sediments close to shore can be soft and muddy, and the surrounding land can include wet meadows and marshes. Floating vegetation can be common.

The rate of water exchange is highly variable within this group, ranging from days to years. These water bodies can include sections of a river with low flow rates (e.g., behind diversion dams) or that are somewhat isolated from regular flow (e.g., backwater lakes or oxbow lakes). Isolated water bodies, such as kettle lakes, are unique members of this category because they have no surface water outflow, and therefore have very low flushing rates. In shallow water, boat operations would be limited and most response operations would be conducted from shore.

Sensitivity

Small lakes and ponds have medium to high sensitivity to oil spill impact because of low physical removal rates, limited dilution and flushing of oil mixed into the water column, and high biological and human use. They provide valuable habitat for migrating and nesting birds and mammals, and support important fisheries. Small lakes can be the focus of local recreational activities. Associated wetlands have higher sensitivities and are discussed in Section 3.13.

Wind will control the distribution of slicks, holding the oil against a lee shore or spreading it along shore and into catchment areas. Wind shifts can completely change the location of slicks, contaminating previously clean areas. Thus, early protection of sensitive areas is important. The inlet and outlet are key areas for focusing protection efforts. Oil impacts on floating vegetation depend to a large degree on dose, with possible elimination of plants at high doses. Section 5 addresses sinking oils and response under ice conditions.



SMALL LAKES / PONDS
Flood Water Level
Normal Water Level
Organic Mud
Organic Mud
Muddy Sand
Peat
Peat
Organic Mud
Water-logged
Submerged
Open Water
Submerged
Water-logged

Table 16. Relative environmental impact from response methods for SMALL LAKE and POND environments.

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	A	A	A	A
Booming - Containment	–	A	A	A
Skimming/Vacuum	–	A	A	A
Sorbents	–	A	A	A
Natural Recovery	A	B	C	C
In-Situ Burning	B	B	B	B
Herding Agents	B	B	B	–
Debris Removal	–	B	B	B
Vegetation Removal	–	B	B	B
Physical Herding	C	B	B	B
Visco-Elastic Agents/Solidifiers	–	B	B	–
Manual Oil Removal/Cleaning	–	C	C	B
Mechanical Oil Removal	–	C	C	C
Dispersants	D	D	D	–
Emulsion Treating Agents	–	I	I	I
Nutrient Enrichment	–	I	I	I
Natural Microbe Seeding	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: SMALL LAKE AND POND ENVIRONMENTS

Least Adverse Habitat Impact

Booming

- Use containment booms to keep oil from spreading
- Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources

Skimming/Vacuum

- Not applicable to gasoline spills because of safety concerns
- Land-based operations need site-specific restrictions and monitoring to minimize physical destruction

Sorbents

- Overuse results in excess waste generation
- Inhibit the evaporation of gasoline spills

Some Adverse Habitat Impact

Natural Recovery

- Low impact for light oils but may have significant impact for medium crudes and heavier fuel oils because they persist and affect shoreline habitats

In-Situ Burning

- Less environmental impact in winter when snow and ice provide some protection, plants are dormant, and fewer animals are present
- Safety concerns limit containment of gasoline, but may be safely used with natural containment, such as gasoline trapped in ice

Herding Agents

- Most effective under calm conditions
- Should be coupled with recovery when used to protect sensitive habitats
- Not effective on heavy oils because oil must be fluid

Debris Removal

- Debris may be associated with nests or living areas (e.g., beaver lodges), so impacts on resident animal habitat may need consideration
- Operate from small boats to minimize substrate disruption

Vegetation Removal

- If oil is trapped in floating vegetation, may be only way to recover the oil in the absence of water currents
- May be appropriate to prevent secondary oiling of wildlife

Physical Herding

- Care should be taken not to drive oil into the water column or sediment

Visco-Elastic Agents/Solidifiers

- Visco-elastic agents, by improving overall oil recovery from the water surface, reduce secondary shoreline oiling
- Not applicable to gasoline spills because of safety concerns during application and inhibition of evaporation
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

Probable Adverse Habitat Impact

Manual Oil Removal/Cleaning

- Inherent inefficiency of manual removal of fluid oils would require large crews or repeated entries, resulting in disruption to substrate and wildlife
- Not applicable for gasoline spills because of safety concerns

Mechanical Oil Removal

- May be needed where oil has heavily contaminated bottom sediments
- May require very intrusive recovery techniques

Most Adverse Habitat Impacts

Dispersants

- Inhibit the evaporation of gasoline spills
- Shallow water depths and low dilution rates may result in high aquatic toxicity from oil / dispersant mixtures

Insufficient Information

Emulsion-Treating Agents

- Not applicable to oils that do not form emulsions, such as gasoline
- Insufficient toxicity data to evaluate environmental impact of shallow freshwater environment use

Nutrient Enrichment and Natural Microbe Seeding

- Not applicable to gasoline spills because they rapidly evaporate
- There is insufficient information on impact and effectiveness for other oil types
- There are special concerns about nutrient overloading in small, restricted water bodies

3.5 SMALL RIVERS AND STREAMS

Habitat Description

Small rivers and streams are characterized by shallow water (generally 1-2 meters) and narrow channels. Water flow can be highly variable, both throughout the seasons and with distance downstream. This grouping includes a wide range of waterbodies, from fast-flowing streams with low falls and numerous rapids over bedrock and gravel, to slow-moving bayous bordered by low muddy banks and fringed with vegetation. Sections of the channel may be choked with log jams and debris, and mid-channel bars and islands can divide water flow into multiple channels. Both boat and vehicular access can be very limited; often the only access will be at bridge crossings. Ice may further complicate response measures in this habitat.

Sensitivity

Small rivers and streams have medium to high sensitivity to oil spill impact. Oil spills may have more of an impact on small rivers and streams than on large rivers due to a variety of conditions, such as lower flow conditions, lower dilution rates, lower overall energy, and greater range of natural habitats. Fish spawn in streams and the tributaries of larger rivers; thus, the most sensitive, early life stages can be present. Fringing wetlands and adjacent floodplains are closely connected to small rivers and streams, and they are areas of high biological use and low natural removal rates.

Slicks usually contaminate both banks, and non-viscous oils are readily mixed into the entire water column in shallow streams, potentially exposing both aquatic and benthic organisms to oil. Initial weathering rates may be slower because spreading and evaporation are restricted in narrow channels and heavy vegetation cover. Fish kills are possible for spills ranging from gasoline to medium crude oils. Many different kinds of mammals, birds, reptiles, and amphibians use the stream bank habitats, and there can be localized high mortality rates of these animals. Spills can cause closure of water intakes for drinking water, irrigation, or industrial use along small rivers. A more aggressive response may be appropriate to prevent contamination of downstream habitat, particularly if water intakes, populated areas, or special habitat resources are present.

SMALL RIVERS / STREAMS

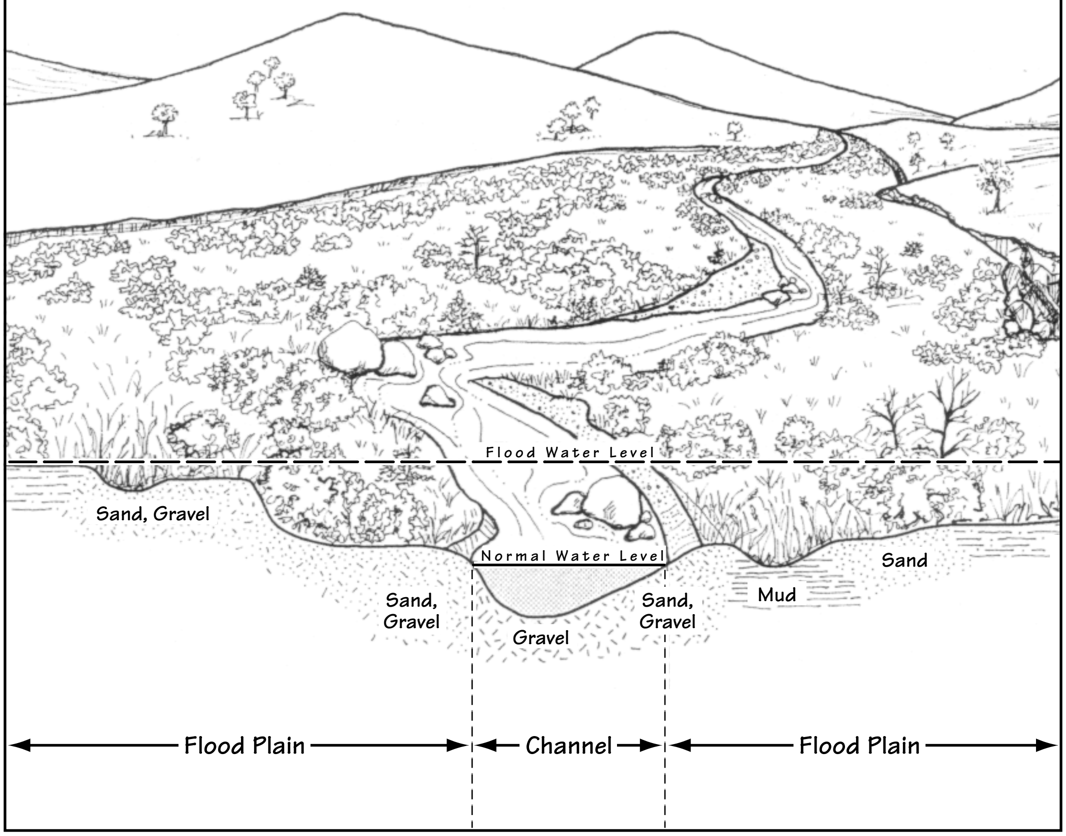


Table 17. Relative environmental impact from response methods for SMALL RIVER and STREAM environments.

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	A	A	A	A
Skimming	A	A	A	A
Booming - Containment	–	A	A	A
Vacuum	–	A	A	A
Sorbents	–	A	A	A
Barriers/Berms	B	A	A	A
Physical Herding	B	B	B	B
Natural Recovery	A	B	C	C
Debris Removal	–	B	B	B
Visco-Elastic Agents/Solidifiers	B	B	B	–
Vegetation Removal	–	B	B	B
In-Situ Burning	C	B	B	B
Manual Oil Removal/Cleaning	–	C	C	B
Mechanical Oil Removal	–	C	C	C
Dispersants	D	D	D	–
Herding Agents	D	D	D	–
Emulsion Treating Agents	–	I	I	I
Nutrient Enrichment	–	I	I	I
Natural Microbe Seeding	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = **I**nsufficient **I**nformation **-** impact or effectiveness of the method could not be evaluated at this time.
"**-**" = Not applicable for this oil type.

RESPONSE METHODS: SMALL RIVER AND STREAM ENVIRONMENTS

Least Adverse Habitat Impact

Booming

- Used primarily to divert slicks towards collection points in low-current areas
- Safety concerns limit the containment of gasoline spills; however, booms can exclude or deflect the spill away from sensitive resources
- Expect low effectiveness with fast currents, shallow water, and steep banks

Skimming/Vacuum

- To protect public health and downstream resources where spreading is limited, recovery of large gasoline spills could be attempted with firefighting foam to suppress vapors and respiratory protection for workers

Sorbents

- Deploy in booms to recover sheens in low-current areas and along shore
- Trampling of stream bank and bed habitats during deployment and recovery of sorbents can disrupt streamside vegetation and drive oil into the sediment
- Overuse results in excess waste generation

Barriers/Berms

- Potential for physical disruption and sediment contamination in immediate area of the barrier / berm
- If all or most of the flow is diverted, may need to monitor water requirements to habitats downstream of the barrier to mitigate potential impacts
- Safety concerns limit actions at gasoline spills, although berms built ahead of the slick could be used to exclude oil from sensitive areas, such as side channels

Some Adverse Habitat Impact

Physical Herding

- May be only means to flush oil trapped in log jams, beaver dams, behind rocks, and in vegetation / debris along banks to downstream collection areas
- Spraying of gasoline spills can mix the oil into the water column

Natural Recovery

- For small gasoline and diesel-like oil spills, evaporation and natural dispersion would rapidly remove surface slicks
- For all other types and sizes of spills, recovery of free or pooled oil and / or protection of sensitive resources should be attempted

Debris Removal

- Will release trapped oil and speed natural flushing rates

Visco-Elastic Agents/Solidifiers

- Visco-elastic agents may speed recovery of contained oil when time is critical
- Solidifiers may immobilize even gasoline spills, preventing their transport downstream and further impact
- Ineffective on heavy oils, which are too viscous to allow the product to mix into the oil

Vegetation Removal

- May be needed to remove oil trapped in floating and fringing vegetation
- Remove oiled vegetation to prevent chronic sheening in sensitive areas or secondary oiling of wildlife
- Monitor crews to minimize physical disturbance, which can be severe

In-Situ Burning

- May be difficult to protect stream-side vegetation
- Safety concerns limit containment of gasoline, but may be safely used if natural containment is present
- Less impact in winter when snow / ice provide some protection, plants are dormant, and fewer animals are present
- May not be practical in fast flowing streams where containment and maintenance of minimum slick thickness (1-3 millimeters) may be difficult

Probable Adverse Habitat Impact

Manual Oil Removal/Cleaning

- Viable for heavy oils that have solidified versus fluid oils that have spread
- Stream bank disruption likely from movement of work crews

Mechanical Oil Removal

- Only consider when large amounts of solidified oil have accumulated in the stream channel and need to be removed quickly

Most Adverse Habitat Impact

Dispersants

- Enhanced mixing of oil into the water column with restricted dilution will increase acute toxicity to aquatic organisms

Herding Agents

- Toxicity concerns when early life stages are present
- May not be practical due to fast currents and rough water surface
- Oil must be fluid, so not appropriate to heavy oils

Insufficient Information

Emulsion-Treating Agents

- Insufficient toxicity data to evaluate environmental impact of shallow freshwater environment use
- Not applicable to oils that do not form emulsions, such as gasoline

Nutrient Enrichment and Natural Microbe Seeding

- Not applicable to gasoline spills because they rapidly evaporate
- There is insufficient information on impact and effectiveness, particularly for applications in small rivers and streams

3.6 BEDROCK HABITATS (ESI = 1A, 2, 8A)

Habitat Description

This shoreline type is characterized by an impermeable rocky substrate. The rock surface can be highly irregular, with numerous cracks and crevices. The slope of the shoreline varies from vertical rocky cliffs to shelving bedrock shores where flat or gently dipping rock layers have been cut by waves into wide platforms. Bedrock habitats are exposed to wide ranges in wave energy; headlands in the Great Lakes and other large lakes are the most exposed and bedrock shorelines in sheltered lakes are the least exposed. There can be a thin veneer of sand and gravel sediments on the rock platforms, although storm waves will strip these sediments off exposed shorelines. Boulder-sized debris can accumulate at the base of exposed rocky cliffs.

Sensitivity

Bedrock shoreline habitats have a range of sensitivities to oil spills, depending upon their degree of exposure to natural removal processes. They have few attached organisms and plants, and rocky shore productivity is typically low. However, they may provide shelter to fish and nesting sites for birds which can be present in large numbers in nearshore waters.

In *exposed* settings, oil may be partially held offshore by wave reflection off steep cliffs and platforms. Any oil that is deposited will be rapidly removed from exposed faces, although oil persistence on any specific shoreline segment is related to the incoming wave energy during, and shortly after, a spill. The most resistant oil would occur as a patchy band at or above the high water line, or deposited in any surface sediments.

In *sheltered* settings, oil will readily adhere to the rough rocky surface, forming a distinct band along the water line. Cracks and crevices will be sites of oil pooling and persistence. Oil will also penetrate and persist in any surface sediments. Medium to heavy oils can be very sticky and form thick black bands, while lighter oils are more readily removed by wave action, evaporation, and response efforts.

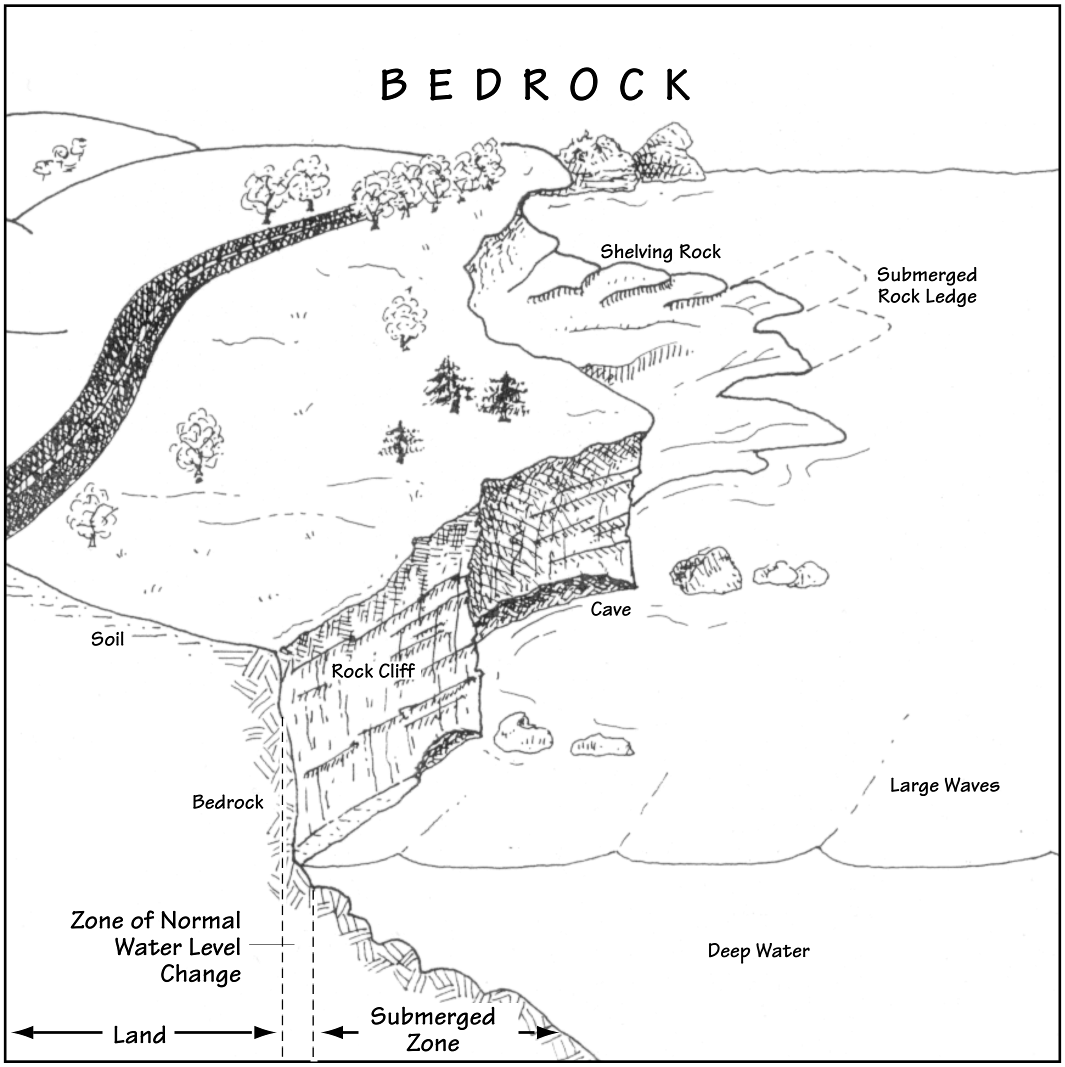

BEDROCK
Shelving Rock
Submerged
Rock Ledge
Cave
Soil
Rock Cliff
Bedrock
Large Waves
Zone of Normal
Water Level
Change
Deep Water
Land
Submerged
Zone

Table 18. Relative environmental impact from response methods for BEDROCK habitats (ESI = 1A, 2, 8A).

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Natural Recovery	A	A	A	B
Debris Removal	–	A	A	A
Sorbents	B	A	A	B
Flooding	B	A	B	C
Low-Pressure, Cold-Water Flushing	B	A	A	C
High-Pressure, Cold-Water Flushing	B	B	B	B
Manual Oil Removal/Cleaning	–	B	B	A
Vacuum	–	B	B	B
In-Situ Burning	–	B	B	B
Shoreline Cleaning Agents	–	–	B	B
Solidifiers	–	B	B	–
Low-Pressure, Hot-Water Flushing	–	C	B	B
Nutrient Enrichment	–	C	C	D
High-Pressure, Hot-Water Flushing	–	D	C	C
Steam Cleaning	–	D	D	D
Sand Blasting	–	D	D	D
Natural Microbe Seeding	–	I	I	I
Chemical Shoreline Pretreatment	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: BEDROCK HABITATS

Least Adverse Habitat Impact

Natural Recovery

- Sheltered bedrock may need cleanup because of slow natural removal rates
- Cleanup of larger spills may be needed because of the amount of oil present
- Heavy oils may persist on all but the most exposed shores

Debris Removal

- Degree of oiling that warrants debris removal and disposal depends on human and sensitive resource use of the site

Sorbents

- Overuse generates excess waste
- Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents

Some Adverse Habitat Impact

Flooding and Low-Pressure, Cold-Water Flushing

- Most effective on fresh, fluid oils
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

High-Pressure, Cold-Water Flushing

- Primarily applicable to medium-crude oils while still fresh and liquid
- Can be effective in removing oil from crevices and pockets of sediment on bedrock

Manual Oil Removal/Cleaning

- Expect significant residues of diesel and medium oils with only manual removal because of their fluidity and difficulty of manual pickup
- Useful for heavy oils in patches or crevices

Vacuum

- Not applicable to gasoline spills because of safety concerns

In-Situ Burning

- Can effectively remove heavy oil accumulations
- Concerns about air pollution, thermal impact on biota, and physical nature of the residue

Shoreline Cleaning Agents

- May be only technique to remove sticky oils without hot-water, high-pressure washing
- Individual products vary in their toxicity and recoverability of the treated oil

Solidifiers

- Prevent the oil from being washed back into the water and are most appropriate for heavy accumulations of pooled oil on shelving bedrock
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

Low-Pressure, Hot Water Flushing

- Any organisms in the application area would be adversely affected by hot water
- Most effective on heavy crudes where heat would make oil more fluid

Probable Adverse Habitat Impact

Nutrient Enrichment

- Not applicable to gasoline spills because they rapidly evaporate
- Concerns about nutrient overloading in poorly flushed areas or where nutrient toxicity, especially ammonia, might be significant
- Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues

High-Pressure, Hot-Water Flushing

- Will likely kill any attached organisms; use is appropriate in limited areas only when oil removal is needed for aesthetic reasons

Most Adverse Habitat Impact

Steam Cleaning And Sand Blasting

- Highly intrusive techniques that will kill any organisms present
- Use only for aesthetic reasons in very limited areas

Insufficient Information

Natural Microbe Seeding

- There is insufficient information on impact and effectiveness

Chemical Shoreline Pretreatment

- There is insufficient information on available products, their effectiveness, or impact

3.7 MANMADE STRUCTURES (ESI = 1B, 6B, 8B)

Habitat Description

Manmade structures include vertical shore protection structures such as seawalls, piers, and bulkheads, as well as riprap revetments and groins, breakwaters, and jetties. Vertical structures can be constructed of concrete, wood, and corrugated metal. They usually extend below the water surface, although seawalls can have beaches or riprap in front of them. Riprap revetments are constructed of boulder-sized pieces of rock, rubble, or formed concrete pieces (e.g., tetrapods), placed parallel to the shoreline for shore protection. Riprap groins are oriented perpendicular to shore to trap sediment; jetties are designed to protect and maintain channels; and breakwaters are offshore structures constructed to protect an area from wave attack. Riprap structures have very large void spaces and are permeable, while seawalls and bulkheads have impermeable, solid substrates. These structures are very common along developed shores, particularly in harbors, marinas, and residential areas. The range in degree of exposure to waves and currents varies widely, from very low in dead-end canals, to very high on offshore breakwaters. Boat wakes can generate wave energy in otherwise sheltered areas.

Sensitivity

Manmade structures have a range of sensitivities to oil spills, depending on the degree of exposure to natural removal processes. Biological communities and use are sparse. Often, there are sources of pollutants or habitat degradation nearby, such as urban runoff, chronic small oil spills in marinas, poor water quality, and limited water circulation. More intrusive cleanup techniques are often conducted due to their lower biological use, higher public demand for oil removal for aesthetic reasons, and need to minimize human exposure to oil in populated areas. It is acknowledged that manmade structures can vary in permeability, cohesion, and mobility and, in turn, how they are affected by oiling. In this document, however, manmade structures have been grouped together so that the higher degree of cleanup often required can be adequately addressed.

Vertical structures are generally impermeable to oil penetration, but oil can heavily coat rough surfaces, forming a band at the water line. During storms, oil can splash over the top and contaminate terrestrial habitats. Riprap poses significant cleanup problems because of large void spaces between the riprap and heavy accumulations of debris. Large amounts of oil can become trapped in the riprap, where it is difficult to remove and a potential source of sheening.

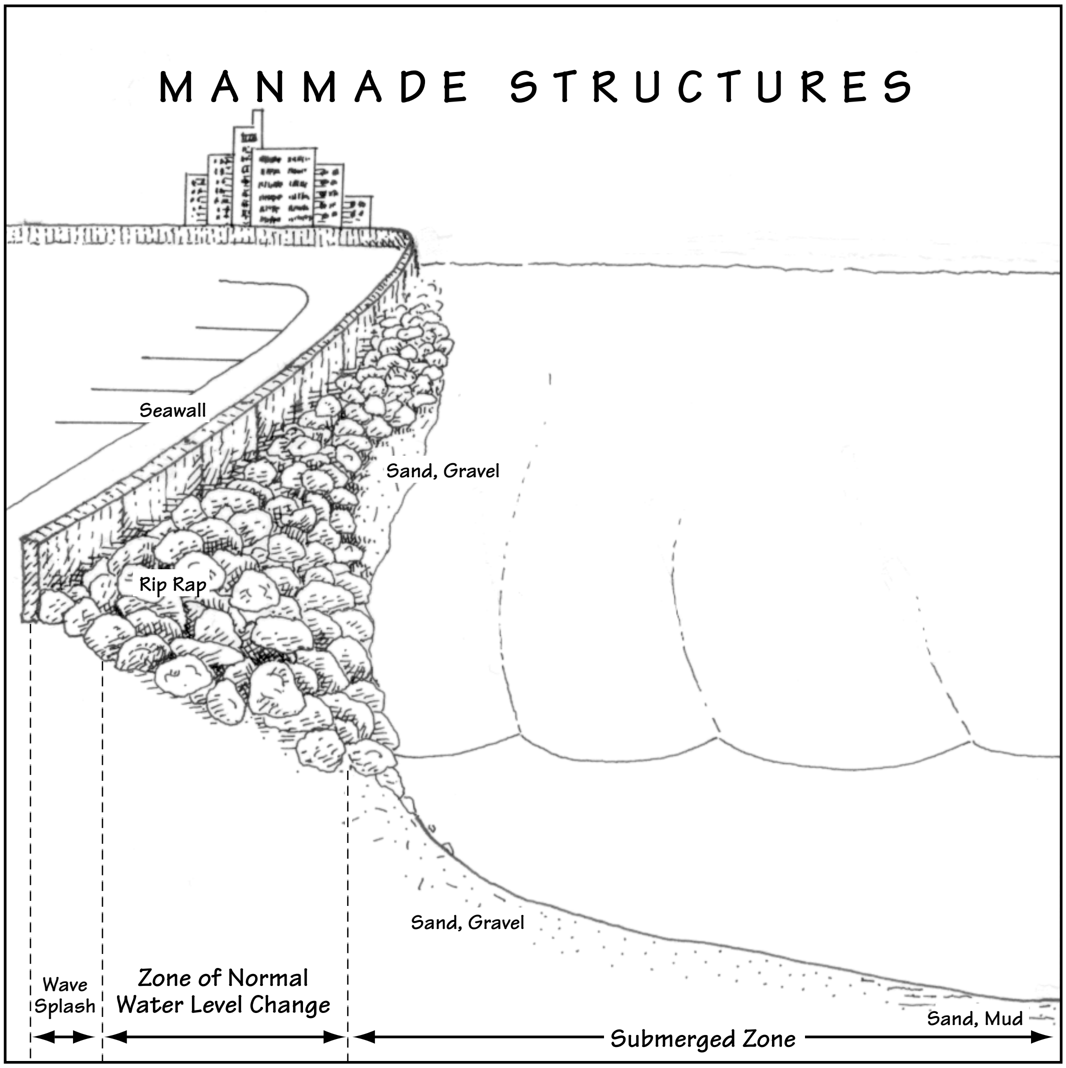

MANMADE STRUCTURES
Seawall
Sand, Gravel
Rip Rap
Sand, Gravel
Wave
Splash
Zone of Normal
Water Level Change
Submerged Zone
Sand, Mud

Table 19. Relative environmental impact from response methods for MANMADE structures (ESI = 1B, 6B, 8B).

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Manual Oil Removal/Cleaning	–	A	A	A
Debris Removal	–	A	A	A
High-Pressure, Cold-Water Flushing	B	A	A	B
Sorbents	B	A	A	B
Vacuum	–	B	A	A
Natural Recovery	A	A	B	B
Flooding	B	A	A	C
Low-Pressure, Cold-Water Flushing	B	A	A	C
Low-Pressure, Hot-Water Flushing	–	B	B	B
High-Pressure, Hot-Water Flushing	–	B	B	B
Shoreline Cleaning Agents	–	B	B	B
Solidifiers	B	B	B	–
In-Situ Burning	–	B	B	B
Nutrient Enrichment	–	C	C	D
Steam Cleaning	–	C	C	C
Sand Blasting	–	C	C	C
Chemical Shoreline Pretreatment	–	I	I	I
Natural Microbe Seeding	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: MANMADE STRUCTURES

Least Adverse Habitat Impact

Manual Oil Removal/Cleaning and Debris Removal

- Effective for removing debris and small, persistent pockets of oil

High-Pressure, Cold-Water Flushing

- Effective for removing sticky oils from solid surfaces and flushing pooled oil from riprap crevices, even for gasoline in populated areas
- May flush oiled sediments (if present) into nearshore bottom habitats
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Sorbents

- Use along riprap structures to recover residual sheening oil after other cleanup methods have been conducted, even for gasoline
- Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents
- Overuse results in excess waste generation

Vacuum

- Early use of vacuum on pooled oil in crevices can increase the oil recovery rate and minimize oil losses during flushing
- Can only remove thick oil from accessible areas, so high residual oil likely

Natural Recovery

- Most effective for lighter oils and more exposed settings
- Heavier oils may necessitate removing persistent residues

Some Adverse Habitat Impact

Flooding

- Not applicable to seawalls; on riprap, only effective when the oil is fluid
- May be used on riprap in developed areas, even for gasoline spills, where pockets of the spilled product pose human health concerns
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Low-Pressure, Cold-Water Flushing

- Only effective when the oil is fluid
- Directed water spray can help remove trapped oil, even for gasoline
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Low-Pressure, Hot-Water Flushing and High-Pressure, Hot-Water Flushing

- Assumes that there are no biological communities in or immediately downslope from treatment area
- High water temperatures are often needed to liquefy heavy oils
- High water pressures are often needed to remove weathered oils from solid substrates and riprap

Shoreline Cleaning Agents

- Individual products vary in their toxicity and ability to recover the treated oil

Solidifiers

- Appropriate to recover and control chronic sheening, even for gasoline
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

In-Situ Burning

- Thick oil likely to occur as isolated pockets that are difficult to access and burn
- There will be concerns about air pollution and physical nature of the residue
- Public safety issues for burning in developed areas will be of special concern

Probable Adverse Habitat Impact

Nutrient Enrichment

- Not applicable to gasoline spills because they rapidly evaporate
- Concerns about nutrient overloading in poorly flushed areas or where nutrient toxicity, especially ammonia, might be significant
- Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues

Steam Cleaning and Sand Blasting

- Used when removing persistent oil is required for aesthetic reasons

Insufficient Information

Chemical Shoreline Pretreatment

- There is insufficient information on available products, their effectiveness, and impact

Natural Microbe Seeding

- There is insufficient information on impact and effectiveness, particularly for applications on manmade structures

3.8 SAND HABITATS (ESI = 4)

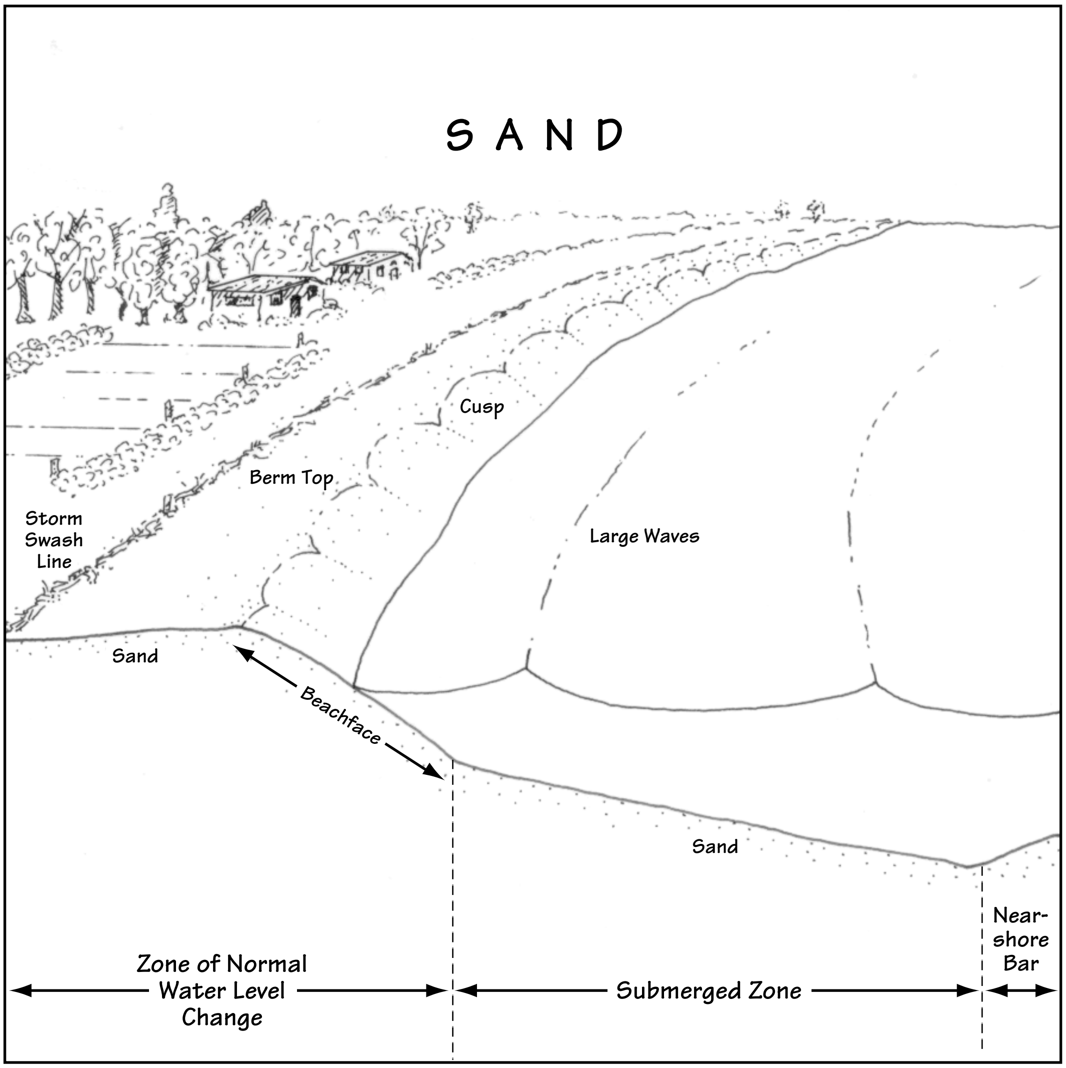
Habitat Description

Sand habitats have a substrate composed of sediments that are predominantly finer than 2 millimeters but greater than silt or clay-sized material (see Appendix B for grain sizes). The shoreline may consist of well-sorted sands of one principal size, or of poorly sorted mixtures of muddy sand, gravelly sand, or a combination of these two. When the sediments are fine-grained sand, beaches may be wide and flat; where the sediments are coarse-grained sand, they usually are steeper and narrower. Sandy shorelines may be naturally eroding, accreting, or stable, and groins or breakwaters may be placed to trap sand and maintain some beaches. Exposed sand beaches can undergo rapid erosional or depositional changes during storms. In developed areas, sand beaches can be artificially created by man and are commonly used for recreation. Sand bars and banks along rivers are also included in this habitat.

Sensitivity

Sand habitats have low to medium sensitivity to oil spills. They generally do not have sizable biological communities except where the habitat tends to be protected and consists of poorly sorted muddy sediments. Thus, ecological effects are likely to be of limited extent because of the low natural biological productivity. In developed areas, sand beaches are considered sensitive because of their high recreational use.

During small spills, oil will concentrate in a band along the swash line. Maximum penetration into fine-grained sand will be less than 15 centimeters; penetration in coarse sand can reach 25 centimeters or greater. Clean sand can bury oiled layers quickly, creating more difficult cleanup issues. On heavily used recreational beaches, extensive cleanup is usually required to remove as much of the oil as possible. When large amounts of sediment must be removed, it may be necessary to replace these sediments with clean material. Traffic on sand can push oil deeper.



SAND
Cusp
Berm Top
Storm Swash Line
Large Waves
Sand
Beachface
Sand
Near-shore Bar
Zone of Normal Water Level Change
Submerged Zone

Table 20. Relative environmental impact from response methods for SAND habitats (ESI = 4).

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Debris Removal	–	A	A	A
Natural Recovery	A	A	B	B
Flooding	B	A	A	B
Sorbents	–	A	A	B
Manual Oil Removal/Cleaning	D	B	A	A
Mechanical Oil Removal	D	B	B	A
Low-Pressure, Cold-Water Flushing	B	B	B	B
Vacuum	–	B	B	B
Sediment Reworking	D	B	B	B
Nutrient Enrichment	–	B	B	C
Shoreline Cleaning Agents	–	–	B	B
Solidifiers	–	B	B	–
In-Situ Burning	–	–	B	B
Low-Pressure, Hot-Water Flushing	D	C	C	B
High-Pressure, Cold-Water Flushing	D	D	D	D
High-Pressure, Hot-Water Flushing	D	D	D	D
Chemical Shoreline Pretreatment	–	I	I	I
Natural Microbe Seeding	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: SAND HABITATS

Least Adverse Habitat Impact

Debris Removal

- Degree of oiling that warrants debris removal and disposal depends on use by humans and sensitive resources

Natural Recovery

- Lower impact for small spills, lighter oil types, and remote areas

Flooding

- Only effective when the oil is fluid and on the sand surface, rather than penetrated or buried
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Sorbents

- Not applicable to gasoline spills because they rapidly evaporate
- Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents
- Overuse results in excess waste generation

Some Adverse Habitat Impact

Manual Oil Removal/Cleaning

- Minimizes sediment removal and problems of erosion and waste disposal
- Effective when oil is mostly on the surface, not buried beneath clean sand
- Gasoline tends to quickly evaporate; therefore habitat disruption, worker safety concerns, and waste generated by manual cleanup are not balanced by benefits in removing oil

Mechanical Oil Removal

- Tends to remove large amounts of clean sand with the oiled sand
- Use on high-use beaches where rapid removal of oil is required and where long stretches of shoreline are heavily oiled

- Gasoline tends to quickly evaporate; therefore habitat disruption, worker safety concerns, and waste generated from mechanical cleanup are not balanced by benefits in removing oil

Low-Pressure, Cold-Water Flushing

- Only effective when the oil is fluid and adheres loosely to the sediments
- Optimize pressure to minimize the amount of sand washed downslope

Vacuum

- Early use of vacuum on pooled, liquid oil can prevent deeper penetration
- Will minimize amount of sorbent waste when used with flushing efforts
- Can vacuum heavy, non-sticky oil from sand substrates completely, but slowly

Sediment Reworking

- Appropriate for lightly oiled and stained sediments, to speed removal rates, and as a final step to polish recreational beaches
- Because gasoline tends to quickly evaporate, habitat disruption, worker safety concerns, and waste generated from sediment reworking are not balanced by benefits in removing oil

Nutrient Enrichment

- Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues
- May be concern about nutrient overloading in poorly flushed areas
- Not applicable to gasoline spills because they rapidly evaporate

Shoreline Cleaning Agents

- May be only technique to remove viscous oils without removing sediment
- Individual products vary in their toxicity and ability to recover the treated oil

Solidifiers

- Not applicable to gasoline spills because they rapidly evaporate
- Early use may prevent pooled oil from penetrating deeper
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

In-Situ Burning

- Can effectively remove pooled surface oil accumulations
- Concerns about air pollution, physical nature of the residue, and thermal impact on biota
- May have to dig trenches to accumulate oil in pools
- Lighter oils will penetrate the sand, leaving insufficient surface concentrations to burn

Probable Adverse Habitat Impact

Low-Pressure, Hot-Water Flushing

- May be needed to soften and lift sticky oil off the sand surface
- Any organisms present will be adversely affected by hot water

Most Adverse Habitat Impact

High-Pressure, Cold-Water Flushing And High-Pressure, Hot-Water Flushing

- High-pressure water jets will fluidize sand-sized sediments, erode the beach, and wash the oiled sediment into nearshore habitats

Insufficient Information

Chemical Shoreline Pretreatment

- More information needed on available products, their effectiveness, and impact

Natural Microbe Seeding

- There is insufficient information on impact and effectiveness in freshwater habitats

3.9 MIXED SAND AND GRAVEL HABITATS (ESI = 3, 5)

Habitat Description

Mixed sand and gravel habitats are characterized by a substrate that is composed predominantly of a mixture of sand- to cobble-sized sediments (see Appendix B for grain sizes). These habitats may vary from a well-sorted cobble layer overlying finer-grained (sand-sized) sediments to mixtures of sand, pebble, and cobble. Typically, well-sorted beaches are exposed to some wave or current action that separates and transports finer-grained sediments; however, the sediment distribution does not necessarily indicate the energy at a particular shoreline. On depositional beaches multiple berms can be formed at the different water levels generated during storms. In glaciated areas, the gravel component can include very large boulders. Natural replenishment rates are very slow for gravel, compared to sand. Mixed sand and gravel habitats occur as beaches along the Great Lakes and as point bars along rivers and streams.

Sensitivity

Mixed sand and gravel habitats have medium sensitivity to oil spills. Biological communities are very sparse because of sediment mobility, desiccation, and low organic matter. Most invertebrates living in this habitat are deep burrowers, such as some oligochaete worms and insect larvae. Characteristic insects are mayflies, stoneflies, caddisflies, and midges, although mayflies and stoneflies are scarce or absent where silt is present. The nearshore habitat is used by fish for spawning and protects fry and larvae. There are also limited numbers of birds and mammals.

Viscous oils reaching these habitats may not penetrate into the sediments because the pore spaces between sediments are filled with sand. Therefore, deep oil penetration and long-term persistence are lower than on gravel substrates. However, oil can still occur at depths below those of annual reworking, particularly if the oil is deposited high on the beach out of the reach of normal wave activity or is rapidly buried. Erosion can be a concern when large quantities of sediment are physically removed. In more sheltered areas, asphalt pavements can form if heavy surface oil deposits are not removed. Once formed, these pavements are very stable and can persist for years.

MIXED SAND and GRAVEL

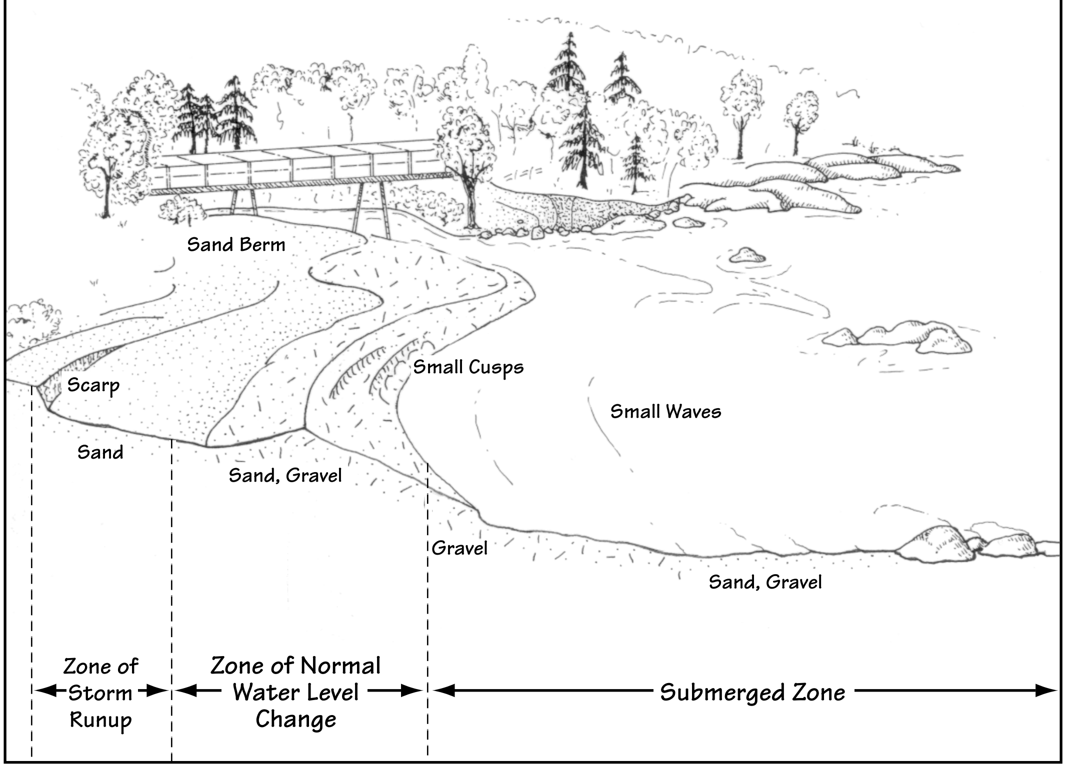


Table 21. Relative environmental impact from response methods for MIXED SAND and GRAVEL habitats (ESI = 3, 5).

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Debris Removal	–	A	A	A
Flooding	A	A	A	C
Natural Recovery	A	A	B	B
Low-Pressure, Cold-Water Flushing	B	A	A	B
Sorbents	–	A	A	B
Vacuum	–	B	B	B
Manual Oil Removal/Cleaning	D	B	A	A
Sediment Reworking	D	B	B	B
Mechanical Oil Removal	D	C	B	B
Shoreline Cleaning Agents	–	–	B	B
Nutrient Enrichment	–	B	B	C
In-Situ Burning	–	–	B	B
Solidifiers	–	–	B	–
High-Pressure, Cold-Water Flushing	C	C	C	C
Low-Pressure, Hot-Water Flushing	D	C	C	B
High-Pressure, Hot-Water Flushing	D	D	D	D
Steam Cleaning	–	D	D	D
Chemical Shoreline Pretreatment	–	I	I	I
Natural Microbe Seeding	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: MIXED SAND AND GRAVEL HABITATS

Least Adverse Habitat Impact

Debris Removal

- Degree of oiling that warrants debris removal and disposal depends on amount of use by humans and sensitive resources

Flooding

- Most effective when the oil is fluid and adheres loosely to the sediments
- Use on heavy oils is likely to leave large amounts of residual oil in the environment

Natural Recovery

- Least impact for small spills, lighter oil types, and remote areas

Low-Pressure, Cold-Water Flushing

- Most effective when the oil is fluid and adheres loosely to the sediments
- Excessive pressures can cause erosion
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Sorbents

- Overuse generates excess waste
- Useful for recovering sheens, even for gasoline spills
- Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents

Some Adverse Habitat Impact

Vacuum

- Early use of vacuum on pooled, liquid oil can prevent deeper penetration

Manual Oil Removal/Cleaning

- Gasoline tends to evaporate quickly; therefore manual cleanup causes habitat disruption, worker safety concerns, and generates waste with no benefits due to removing oil

- Minimizes sediment removal and problems of erosion and waste disposal
- Preferable when oil is mostly on the surface, not deeply penetrated or buried

Sediment Reworking

- Use to break up heavy surface oil or expose persistent subsurface oil deposits, particularly where sediment removal will cause erosion
- Use where there is sufficient exposure to waves to rework the sediments into their original profile and distribution
- Gasoline tends to evaporate quickly; therefore sediment reworking causes habitat disruption, worker safety concerns, and generates waste with no benefits due to removing oil

Mechanical Oil Removal

- Tends to remove large amounts of sediment with the oil
- Applicable for heavier oil types, which are difficult to remove otherwise
- Gasoline tends to evaporate quickly; therefore mechanical cleanup causes habitat disruption, worker safety concerns, and generates waste with no benefits from removing oil

Shoreline Cleaning Agents

- May be only technique to remove viscous oils without removing sediment
- Individual products vary in their toxicity and ability to recover the treated oil

Nutrient Enrichment

- Not applicable to gasoline spills because they rapidly evaporate
- Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues
- Most applicable as a secondary technique after gross oil removal
- Concerns about nutrient overloading in poorly flushed areas

In-Situ Burning

- Can effectively remove pooled surface oil accumulations
- Concerns about air pollution, physical nature of the residue, and thermal impact on biota
- May have to dig trenches to accumulate oil in pools
- Lighter oils will not remain on the sediment surface

Solidifiers

- Early use may prevent pooled oil from penetrating deeper
- Not applicable to gasoline spills because they rapidly evaporate
- May be useful in recovering sheens when deployed as booms and pillows
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil
- Could use for lighter oils with correct product and situation

Probable Adverse Habitat Impact

High-Pressure, Cold-Water Flushing

- High-pressure water jets will flush oiled sediments into nearshore habitats
- Excessive pressures can cause erosion if large amounts of sand are present

Low-Pressure, Hot-Water Flushing

- Any organisms present will be affected by hot water
- Use on gasoline spills may transport the oil to more sensitive habitats

Most Adverse Habitat Impact

High-Pressure, Hot-Water Flushing

- Will flush oiled sand into nearshore zone and affect any organisms present

Steam Cleaning

- Highly intrusive technique; will kill any organisms present
- Potential for released oil to penetrate deeper into the sediments

Insufficient Information

Chemical Shoreline Pretreatment

- Need more information on available products, their effectiveness, and impact

Natural Microbe Seeding

- There is insufficient information on impact and effectiveness in freshwater habitats

3.10 GRAVEL HABITATS (ESI = 6A)

Habitat Description

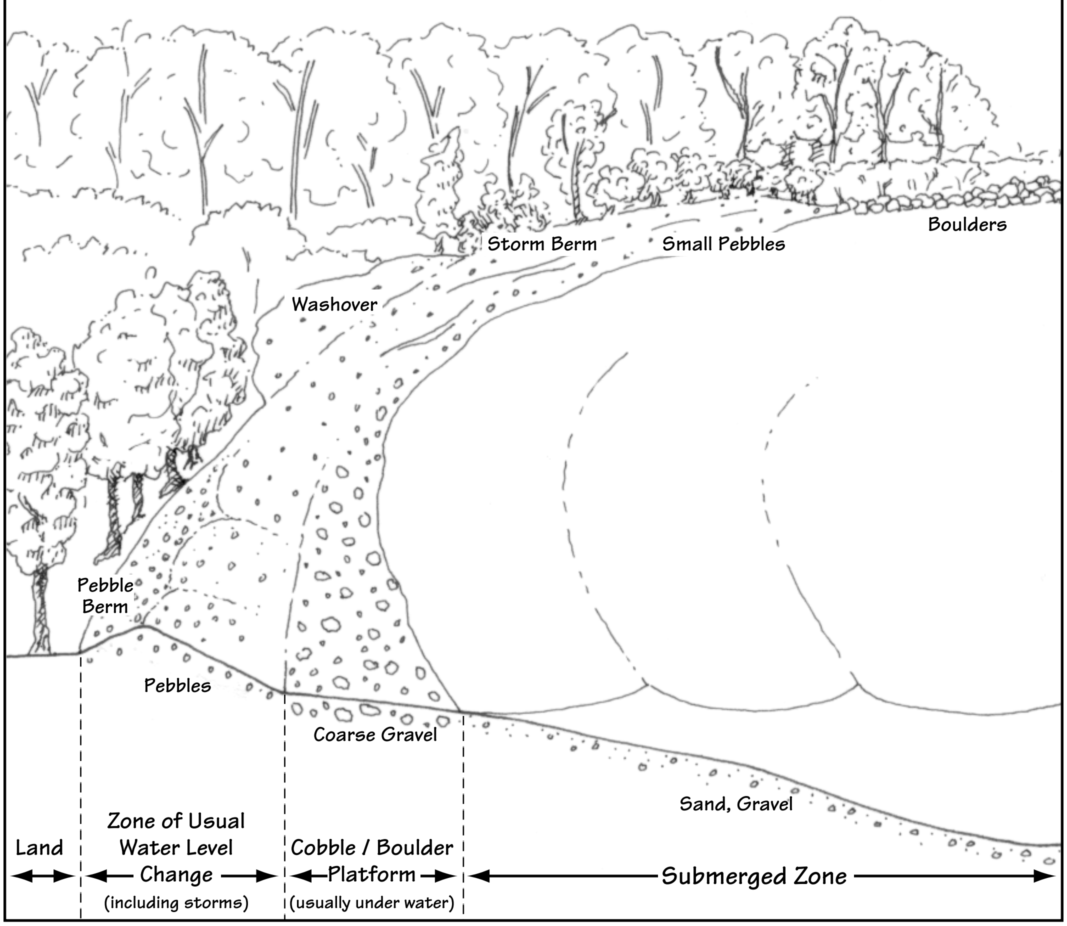
Gravel habitats are characterized by a substrate that is composed predominantly of gravel-sized sediments. By definition (see the grain-size chart in Appendix B), gravel includes sediments ranging in size from granules (greater than 2 millimeters) to boulders (greater than 256 millimeters). The sand fraction on the surface is usually less than ten percent, although the sand content can increase to 20 percent with depth. These sediments are highly permeable because there are few sand-sized sediments to fill the pore spaces between the individual gravel particles. Gravel substrates may also have low bearing capacity and, consequently, may not support vehicular traffic. Typically, well-sorted beaches are exposed to some wave or current action that reworks the sediments and removes the finer-grained sediments. However, the sediment distribution does not necessarily indicate the energy setting at a particular shoreline; sheltered beaches can still have a large gravel source. In glaciated areas, the gravel can include very large boulders. On depositional beaches, zones of pure pebbles or cobbles can form into multiple berms at the different water levels generated during storms. Gravel shorelines tend to be steeper than those composed of sand or mud. Natural replenishment rates are very slow for gravel compared to sand. Gravel habitats occur as beaches along the Great Lakes and as bars along rivers and streams.

Sensitivity

Gravel habitats have medium sensitivity to oil spills. Biological communities are very sparse because of sediment mobility, desiccation, and low organic matter. Characteristic insects are mayflies, stoneflies, caddisflies, and midges, all with larvae living among the sediments. Flatworms, leeches, and crustaceans may be found on the gravel undersides. The nearshore habitat is used by fish for spawning and provides protection for fry and larvae.

Gravel habitats are ranked higher in sensitivity than sand and gravel habitats because deep penetration of stranded oil into the permeable substrate is likely. Oil can penetrate to depths below those of annual reworking, resulting in long-term persistence of the oil. The slow replenishment rate makes removing oiled gravel highly undesirable. Also, formation of persistent asphalt pavements is likely where there is high accumulation of persistent oils.

G R A V E L



Storm Berm
Small Pebbles
Boulders
Washover
Pebble Berm
Pebbles
Coarse Gravel
Sand, Gravel
Land
Zone of Usual Water Level Change
(including storms)
Cobble / Boulder Platform
(usually under water)
Submerged Zone

Table 22. Relative environmental impact from response methods for GRAVEL habitats (ESI = 6A).

Response Methods	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Debris Removal	–	A	A	A
Low-Pressure, Cold-Water Flushing	A	A	A	B
Flooding	A	A	A	C
Natural Recovery	A	A	B	B
Sorbents	–	A	A	B
Vacuum	–	B	B	B
High-Pressure, Cold-Water Flushing	C	B	B	B
Nutrient Enrichment	–	B	B	C
Manual Oil Removal/Cleaning	D	B	B	A
Sediment Reworking	D	B	B	B
Shoreline Cleaning Agents	–	–	B	B
In-Situ Burning	–	–	B	B
Solidifiers	–	–	B	–
Low-Pressure, Hot-Water Flushing	D	C	C	B
Mechanical Oil Removal	D	D	C	C
High-Pressure, Hot-Water Flushing	D	D	D	D
Steam Cleaning	–	D	D	D
Chemical Shoreline Pretreatment	–	I	I	I
Natural Microbe Seeding	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: GRAVEL HABITATS

Least Adverse Habitat Impact

Debris Removal

- Degree of oiling that warrants debris removal and disposal depends on use by humans and sensitive resources

Low-Pressure, Cold-Water Flushing

- Only effective when the oil is fluid and loosely adheres to the sediments
- Usually used in conjunction with vacuum and sorbents
- Use on heavy oils is likely to leave large amounts of residual oil in the environment

Flooding

- Only effective when the oil is fluid and adheres loosely to the sediments
- Usually used with various flushing techniques
- Use on heavy oils is likely to leave large amounts of residual oil in the environment

Natural Recovery

- Least impact for small spills, lighter oil types, remote areas, and eroding areas

Sorbents

- Overuse generates excess waste
- Useful for recovering sheens, even for gasoline spills
- Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents

Some Adverse Habitat Impact

Vacuum

- Early use of vacuum on pooled, liquid oil can prevent deeper penetration

High-Pressure, Cold-Water Flushing

- High-pressure water jet is likely to flush finer sediments into nearshore submerged habitats
- Very viscous oils will require extremely high pressure to mobilize them

Nutrient Enrichment

- Not applicable to gasoline spills because they rapidly evaporate
- Concerns about nutrient overloading in poorly flushed areas or where nutrient toxicity, especially ammonia, might be significant
- Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues

Manual Oil Removal/Cleaning

- Gasoline tends to quickly evaporate; therefore manual cleanup causes habitat disruption, worker safety concerns, and generates waste with no benefits from removing oil
- Minimizes sediment removal and problems of erosion and waste disposal
- Deep penetration of oil in porous gravel reduces effectiveness

Sediment Reworking

- Used where gravel removal is not feasible because of erosion concerns
- Sufficient exposure to waves is required to rework the sediments into their original profile and distribution
- Gasoline tends to evaporate quickly; therefore sediment reworking causes habitat disruption, worker safety concerns, and generates waste with no benefits from removing oil

Shoreline Cleaning Agents

- May be only technique to remove viscous oils without removing sediment or using hot-water flushing
- Individual products vary in their toxicity and ability to recover the treated oil

In-Situ Burning

- Can effectively remove pooled surface oil accumulations
- May have to dig trenches to accumulate oil in pools
- Lighter oils will not remain on the sediment surface
- Concerns about air pollution, physical nature of the residue, and thermal impact on biota

Solidifiers

- Early use may prevent pooled oil from penetrating deeper

- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil
- May be useful in recovering sheens when deployed as booms and pillows

Probable Adverse Habitat Impact

Low-Pressure, Hot-Water Flushing

- May be needed to flush viscous or deeply penetrated oil
- Any organisms present will be adversely affected by hot water

Mechanical Oil Removal

- Likely to remove large amounts of gravel with the oil
- Foot and vehicular traffic on gravel could mix oil deeper into the sediments

Most Adverse Habitat Impact

High-Pressure, Hot-Water Flushing

- High-pressure water jets are likely to flush oiled sediments into nearshore submerged habitats
- Any organisms present will be adversely affected by hot water and high pressure

Steam Cleaning

- Highly intrusive technique; will kill any organisms present
- Potential for released oil to penetrate deeper into the porous sediments

Insufficient Information

Chemical Shoreline Pretreatment

- Need more information on available products, their effectiveness, and impact

Natural Microbe Seeding

- There is insufficient information on impact and effectiveness in freshwater habitats

3.11 VEGETATED SHORELINE HABITATS (ESI = 9A)

Habitat Description

Vegetated shoreline habitats consist of the non-wetland vegetated banks that are common features of river systems and lakes. Bank slopes may be gentle or steep, and the vegetation consists of grasses, bushes, or trees common to the adjacent terrestrial habitats. The substrate is not water-saturated and can range from clay to gravel. The banks may flood seasonally and are exposed to relatively high-energy removal processes, at least periodically. Along undeveloped shorelines, there can be leafy litter and woody debris trapped among the vegetation. In developed areas, yards and gardens may abut the lake or river.

Sensitivity

Vegetated shoreline habitats are considered to have medium to high sensitivity to oil spills. They are not particularly important habitats for sensitive animals and plants, although many animals use vegetated banks for drinking, washing food, crossing bodies of water, and feeding.

Bank plants oiled during a flood period could be susceptible, especially if the flood rapidly subsides, allowing oil to penetrate into bank sediments and to contact root systems. Small plants, particularly annuals, are likely to be most damaged. Stranded oil could remain in the habitat until another flood reaches the same level and provides a mechanism for natural flushing. On steep banks, the oil is likely to form a band, or multiple bands, at the waterline. On gentle banks, there is a greater potential for oil to accumulate in pools, penetrate the substrate, and coat large areas of vegetation, thus raising the issue of shoreline cleanup. In developed urban and suburban areas, human use and aesthetics would be the main reasons for cleanup.

VEGETATED RIVERBANKS

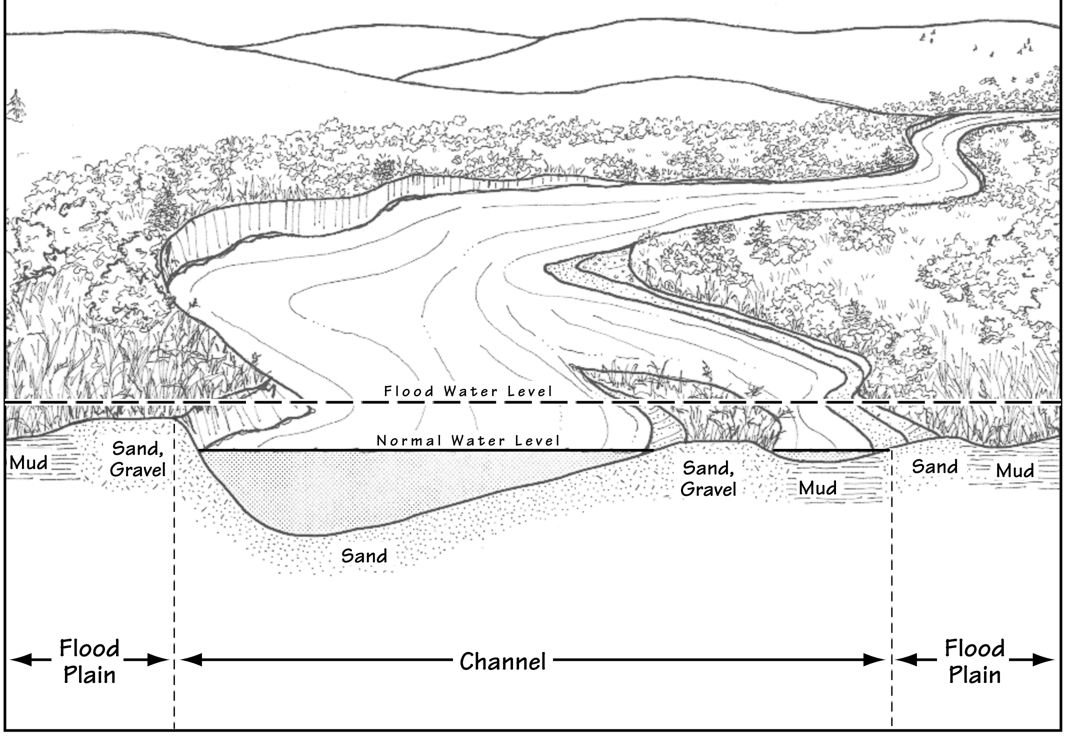


Table 23. Relative environmental impact from response methods for VEGETATED SHORELINE habitats (ESI = 9A).

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Natural Recovery	A	A	B	B
Flooding	B	A	A	B
Low-Pressure, Cold-Water Flushing	B	A	A	B
Sorbents	–	A	B	B
Manual Oil Removal/Cleaning	D	B	B	B
Debris Removal	–	B	B	B
Vacuum	–	B	B	B
Vegetation Removal	D	B	B	B
Nutrient Enrichment	–	B	B	B
In-Situ Burning	–	B	B	B
High-Pressure, Cold-Water Flushing	D	C	C	D
Mechanical Oil Removal	D	C	C	C
Low-Pressure, Hot-Water Flushing	D	D	D	D
High-Pressure, Hot-Water Flushing	D	D	D	D
Sediment Reworking	D	D	D	D
Solidifiers	–	D	D	–
Chemical Shoreline Pretreatment	–	I	I	I
Shoreline Cleaners	–	I	I	I
Natural Microbe Seeding	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: VEGETATED SHORELINE HABITATS

Least Adverse Habitat Impact

Natural Recovery

- Low impact for small or moderate-size spills and lighter oils
- More impact for large spills of medium- or high-viscosity oils

Flooding

- Operationally difficult and marginally effective for steep banks
- Appropriate for gentle banks where persistent oil has pooled, assuming that the released oil can be directed towards recovery devices or sorbents
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Low-Pressure, Cold-Water Flushing

- Effective for washing oil stranded on the banks into the water for recovery
- Vegetation cover minimizes the potential for sediment erosion from flushing
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Some Adverse Habitat Impact

Sorbents

- Useful for recovering sheens, even for gasoline spills
- Physical removal rates of medium and heavy oils will be slow, so less oil will be mobilized for recovery by sorbents
- Overuse generates excess waste

Manual Oil Removal/Cleaning

- Some mixing of oil into the substrate and trampling of vegetation is unavoidable with foot traffic in oiled areas
- Gasoline tends to quickly evaporate; therefore habitat disruption, worker safety concerns, and waste generated by manual cleanup are not balanced by benefits in removing oil

Debris Removal

- Degree of oiling that warrants debris removal and disposal depends on use by humans and sensitive resources
- Minimal concerns where substrate is firm or work is conducted from boats

Vacuum

- Potential damage where substrate will not support vehicular traffic
- Most effective where access is good and substrate can support vehicles
- Only useful when oil is pooled

Vegetation Removal

- Usually not necessary to reduce oil impact on vegetation
- May be required in areas used by sensitive animals

Nutrient Enrichment

- Applicable where nutrients are a limiting factor for oil degradation
- More effective after gross oil removal is completed
- Not applicable to gasoline spills because they rapidly evaporate

In-Situ Burning

- May be the least physically damaging means of oil removal from the banks
- Least impact for grassy areas versus banks covered with trees and shrubs

Probable Adverse Habitat Impact

High-Pressure, Cold-Water Flushing

- High-pressure water spray will disturb plants and erode sediments
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Mechanical Oil Removal

- Excessive physical disruption likely from use of equipment

Most Adverse Habitat Impact

Low-Pressure, Hot-Water Flushing

- Hot water could kill plants and potentially erode and degrade habitat

High-Pressure, Hot-Water Flushing

- Combination of high pressure and hot water poses high risk of sediment and vegetation loss

Sediment Reworking

- Will result in extensive habitat disruption

Solidifiers

- Not applicable to gasoline spills because they rapidly evaporate
- Application of loose particulates may impede removal of oil mixed with, and adhered to, vegetation, litter, and debris
- May be useful in recovering sheens when deployed as booms and pillows
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil or penetrate netting or fabric encasing the loose particulates

Insufficient Information

Chemical Shoreline Pretreatment

- There is insufficient information on impact and effectiveness in freshwater vegetation

Shoreline Cleaning Agents

- More information needed on available products, their effectiveness, and impact of use on vegetated bank habitats
- Individual products vary in their toxicity and ability to recover the treated oil

Natural Microbe Seeding

- There is insufficient information on impact and effectiveness in freshwater vegetated shorelines

3.12 MUD HABITATS (ESI = 9B)

Habitat Description

Mud habitats are characterized by a substrate composed predominantly of silt and clay sediments, although they may be mixed with varying amounts of sand or gravel (see Appendix B for grain-size chart). The sediments are mostly water saturated and have low bearing strength. In general, mud shorelines have a low gradient, although some steep banks also may consist of mud. The mud habitats generally are low energy and sheltered from wave action and high currents. Adjacent nearshore areas are usually shallow with muddy sediments. These fine-grained habitats often are associated with wetlands; Section 3.13 discusses habitats where aquatic vegetation dominates. Bare or sparsely vegetated mud substrates are rare along Great Lake shorelines. However, they commonly occur along river floodplains and lake bottoms, where they can be exposed during seasonal low water levels.

Sensitivity

Mud habitats are highly sensitive to oil spills and subsequent response activities. Shoreline sediments are likely to be rich in organic matter and support an abundance of infauna. Muddy habitats are important feeding grounds for birds and rearing areas for fish.

Oil will not penetrate muddy sediments because of their low permeability and high water content, except through decaying root and stem holes or animal burrows. There can be high concentrations and pools of oil on the surface. Natural removal rates can be very slow, chronically exposing sensitive resources to the oil. The low bearing capacity of these shorelines means that response actions can easily leave long-lasting imprints, cause significant erosion, and mix the oil deeper into the sediments. When subsurface sediments are contaminated, oil will weather slowly and may persist for years. Response methods may be hampered by limited access, wide areas of shallow water, fringing vegetation, and soft substrate.

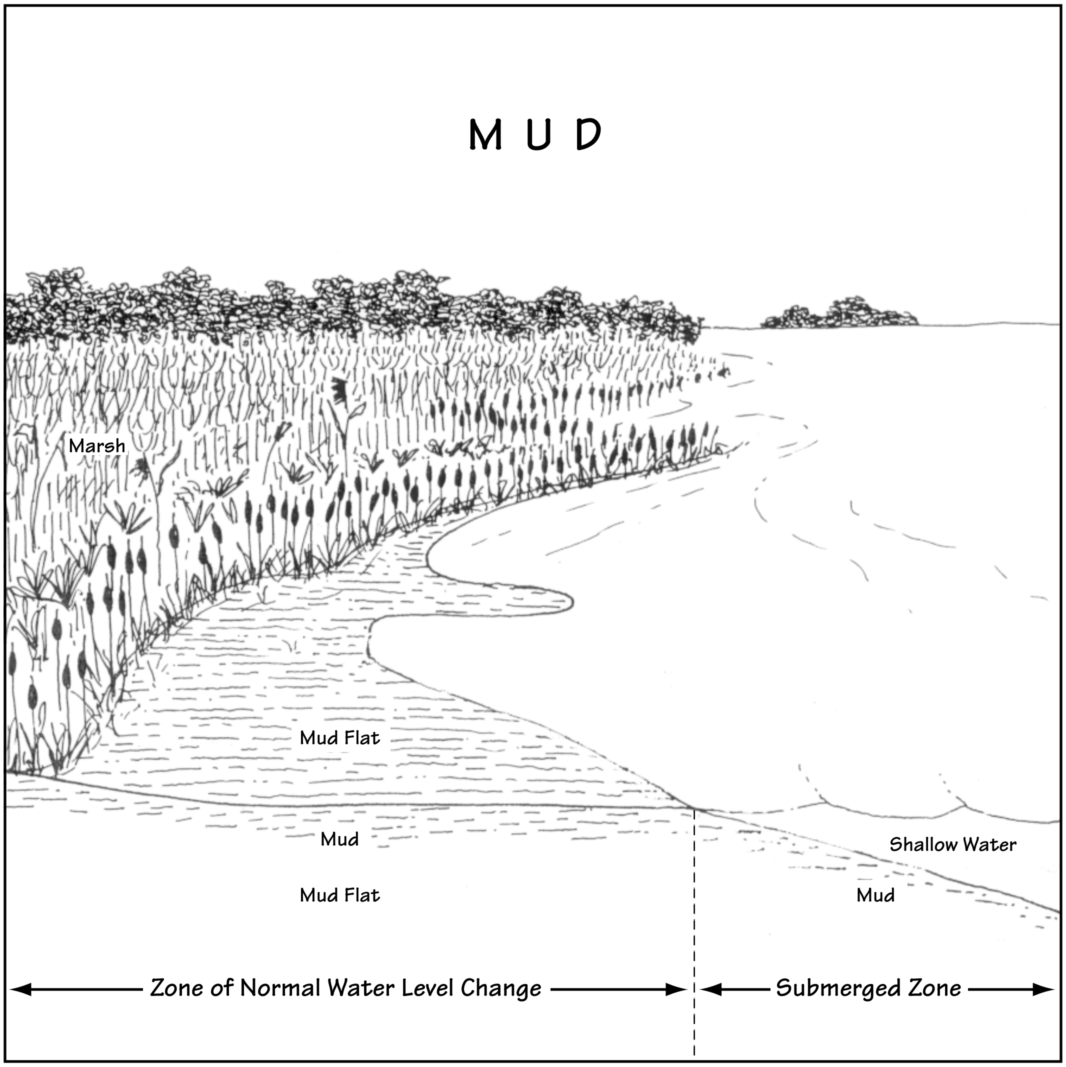

M U D
Marsh
Mud Flat
Mud
Mud Flat
Shallow Water
Mud
Zone of Normal Water Level Change
Submerged Zone

Table 24. Relative environmental impact from response methods for MUD habitats (ESI = 9B).

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Natural Recovery	A	A	A	B
Flooding	B	A	A	A
Sorbents	B	A	A	B
Debris Removal	–	B	B	B
Vacuum	–	C	B	B
In-Situ Burning	C	C	C	C
Low-Pressure, Cold-Water Flushing	D	C	C	C
Manual Oil Removal/Cleaning	D	D	C	C
Low-Pressure, Hot-Water Flushing	D	D	C	C
Solidifiers	D	D	C	–
Mechanical Oil Removal	D	D	D	D
High-Pressure, Cold-Water Flushing	D	D	D	D
High-Pressure, Hot-Water Flushing	D	D	D	D
Sediment Reworking	D	D	D	D
Shoreline Cleaning Agents	–	D	D	D
Natural Microbe Seeding	–	I	I	I
Nutrient Enrichment	–	I	I	I
Chemical Shoreline Pretreatment	I	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.
B = May cause some adverse habitat impact.
C = May cause significant adverse habitat impact.
D = May cause the most adverse habitat impact.
I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
"-" = Not applicable for this oil type.

RESPONSE METHODS: MUD HABITATS

Least Adverse Habitat Impact

Natural Recovery

- Least impact for small spills and lighter oils, to prevent disruptions associated with cleanup efforts
- For large spills or heavy oils, expect long-term persistence in low-energy settings

Flooding

- Effective only for fresh, fluid oils
- Local topography may limit the ability to control where the water and released oil flow and effectiveness of recovery
- Use on gasoline spills may transport the oil to more sensitive habitats

Sorbents

- Useful as long as the oil is mobilized and recovered by the sorbent
- Overuse generates excess waste
- Careful placement and recovery is necessary to minimize substrate disruption

Some Adverse Habitat Impact

Debris Removal

- Degree of oiling that warrants debris removal and disposal depends on use by sensitive resources
- Extensive disruption of soft substrate likely

Vacuum

- Not applicable to gasoline spills because of safety concerns
- Use to remove oil pooled on the surface
- Avoid digging trenches to collect oil because they can introduce oil deeper into the sediment
- Disruption of soft substrates can be limited by placing boards on the surface and controlling access routes

Probable Adverse Habitat Impact

In-Situ Burning

- Heat may impact biological productivity of habitat, especially where there is no standing water to act as a heat sink on top of the mud

Low-Pressure, Cold-Water Flushing

- Mud is readily suspended if substrate is not firm
- Not effective for higher-viscosity oils that will not move with low pressure
- Local topography may limit the ability to control where the water and released oil flow and effectiveness of recovery
- Use on gasoline spills may transport the oil to more sensitive habitats

Manual Oil Removal/Cleaning

- Use where persistent oil occurs in moderate to heavy amounts, or where sensitive resources must be protected
- Response crews may trample soft substrates, mix oil deeper into the sediments, and contaminate clean areas

Low-Pressure, Hot-Water Flushing

- Physical and thermal impacts to habitat likely

Most Adverse Habitat Impact

Solidifiers

- High likelihood of disruption and mixing of oil deeper into the substrate during application and retrieval
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

Mechanical Oil Removal

- Soft substrate will not support vehicular traffic
- Will probably cause extensive physical habitat disruption

High-Pressure, Cold-Water Flushing and High-Pressure, Hot-Water Flushing

- High-pressure water will cause extensive sediment suspension and erosion
- Potential for burial of oiled sediments and transport of oil to adjacent areas

Sediment Reworking

- Will extensively disrupt physical habitat
- Increases oil penetration, burial, and persistence

Shoreline Cleaning Agents

- Current products are designed for use with high-pressure flushing; since used with flushing, water pressure needs to be considered
- Individual products vary in their toxicity and ability to recover the treated oil

Insufficient Information

Natural Microbe Seeding and Nutrient Enrichment

- Not applicable to gasoline spills because they rapidly evaporate
- There is insufficient information on impact and effectiveness in mud habitats

Chemical Shoreline Pretreatment

- There is insufficient information about direct toxicity of the products, disturbances resulting from application and retrieval, effectiveness, and net benefit

3.13 WETLAND HABITATS (ESI = 10A, 10B)

Habitat Description

Wetlands are characterized by water, unique soils that differ from adjacent upland areas, and vegetation adapted to wet conditions. Wetlands include a range of habitats such as marshes, bogs, bottomland hardwood forests, fens, playas, prairie potholes, and swamps. Substrate, vegetation, hydrology, seasonality, and biological use of inland wetlands are highly variable, making characterization difficult. The surfaces of wetlands usually have a low gradient and vegetated areas are typically at or under the water level. There can be distinct channels or drainages with flowing water, except at the exposed outer fringe; however, natural physical processes are minimal. Water levels may vary seasonally, and the wetland may be simply a zone of water-saturated soils during the dry season. Where mud habitats dominate the wetland, refer to Section 3.12 for a discussion of applicable response methods.

Sensitivity

Wetlands are highly sensitive to oil spills. The biological diversity in these habitats is significant and they provide critical habitat for many types of animals and plants. Oil spills affect both the habitat (vegetation and sediments) and the organisms that directly and indirectly rely on the habitat. Surprisingly little is known about oil impact on freshwater plants, although there are likely differences between robust perennials with substantial underground systems and cycles of winter die-back, and annuals that lack underground nutrient reserves. Detritus-based food webs are fundamentally important in wetlands; oil could possibly affect these by slowing decomposition rates of plant material.

Wetlands support populations of fish, amphibians, reptiles, birds, and mammals, with many species reliant upon wetlands for their reproduction and early life stages when they are most sensitive to oil. Many endangered animals and plants occur only in wetlands, and spills in such areas would be of particular conservation concern. Migratory waterbirds depend heavily on wetlands as summer breeding locations, migration stopovers, and winter habitats. The threat of direct oiling of animals using the wetland often drives efforts to remove the oil. If oil and / or cleanup efforts causes a loss of the more sensitive plants or modifies the ecosystem structure, then feeding and breeding of dependent wildlife may be affected.

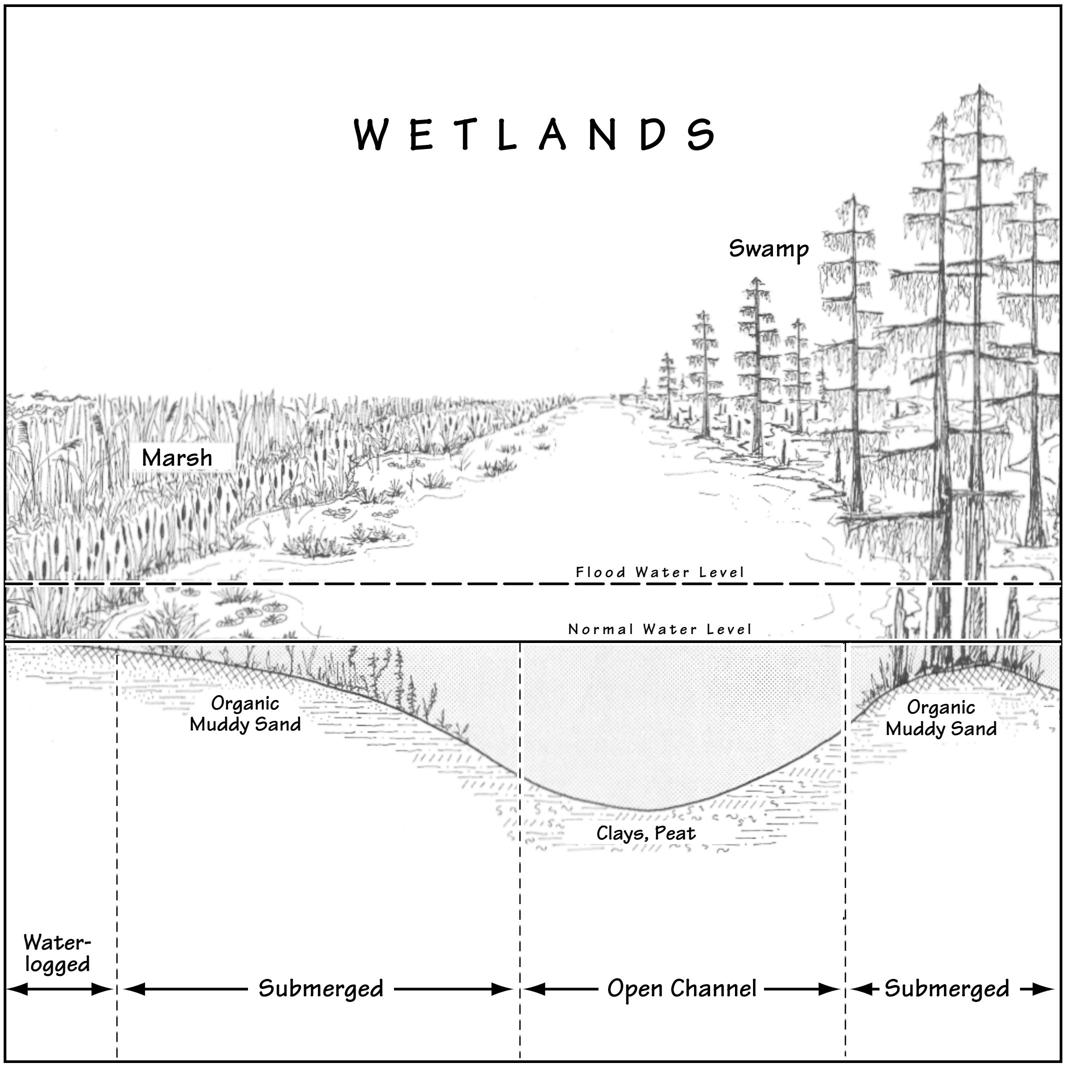

WETLANDS
Swamp
Marsh
Flood Water Level
Normal Water Level
Organic Muddy Sand
Organic Muddy Sand
Clays, Peat
Water-logged
Submerged
Open Channel
Submerged

Table 25. Relative environmental impact from response methods for WETLAND habitats (ESI = 10A, 10B).

Response Method	*Gasoline Products*	*Diesel-Like Oils*	*Medium Oils*	*Heavy Oils*
Natural Recovery	A	A	A	B
Sorbents	C	A	A	A
Flooding	B	A	A	B
Low-Pressure, Cold-Water Flushing	B	A	A	B
In-Situ Burning	B	B	B	B
Vacuum	–	B	B	B
Debris Removal	–	B	B	B
Vegetation Removal	D	C	C	C
Manual Oil Removal/Cleaning	D	D	C	C
High-Pressure, Cold-Water Flushing	D	D	D	D
Low-Pressure, Hot-Water Flushing	D	D	D	D
High-Pressure, Hot-Water Flushing	D	D	D	D
Mechanical Oil Removal	D	D	D	D
Sediment Reworking	D	D	D	D
Solidifiers	D	D	D	–
Shoreline Cleaning Agents	–	I	I	I
Nutrient Enrichment	–	I	I	I
Natural Microbe Seeding	–	I	I	I
Chemical Shoreline Pretreatment	–	I	I	I

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

A = May cause the least adverse habitat impact.

B = May cause some adverse habitat impact.

C = May cause significant adverse habitat impact.

D = May cause the most adverse habitat impact.

I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.

"-" = Not applicable for this oil type.

RESPONSE METHODS: WETLAND HABITATS

Least Adverse Habitat Impact

Natural Recovery

- Least impact for small to moderate spills and lighter oils; avoids damage often associated with cleanup activities
- Some cleanup may be warranted where large numbers of animals are likely to become oiled during wetland use

Sorbents

- Care is necessary during placement and recovery to minimize disturbance of substrate and vegetation
- Overuse generates excess waste

Flooding

- Erosion of substrate and vegetation may be a problem
- Can be used selectively to remove localized heavy oiling
- Can be difficult to direct water and oil flow towards recovery devices
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Low-Pressure, Cold-Water Flushing

- If water pressures are too high, the substrate and vegetation may be disturbed
- Use on heavy oils is likely to leave large amounts of residual oil in the environment
- Use on gasoline spills may transport the oil to more sensitive habitats

Some Adverse Habitat Impact

In-Situ Burning

- May be one of the least physically damaging means of heavy oil removal
- Presence of a water layer on marsh surface can protect roots
- Time of year (vegetation growth stage) is important consideration
- May be appropriate for gasoline spills trapped in ice

Vacuum

- Can be effective in removal of pooled oil from the marsh surface

- Trampling of vegetation and substrate can be limited by placing boards on the surface and limiting traffic

Debris Removal

- The removal of heavily oiled and mobile debris may reduce the tracking of oil off-site and contamination of wildlife

Probable Adverse Habitat Impact

Vegetation Removal

- Used to prevent oiling of sensitive animals using the wetland
- Most appropriate for oils that form a thick, sticky coating on the vegetation, such as medium and heavy oils
- May delay recovery of the vegetation due to both oil impact and physical destruction by cleanup crews
- Trampling of vegetation may be reduced by controlling access routes, using boards placed on surface, or conducting operations from boats

Manual Oil Removal/Cleaning

- Used where persistent oil occurs in heavy amounts and where sensitive resources using the wetlands are likely to be oiled
- Response crews may trample roots and mix oil deeper into the sediments

Most Adverse Habitat Impact

High-Pressure, Cold-Water Flushing

- High-pressure spray will disrupt sediments, root systems, and animals

Low-Pressure, Hot-Water Flushing and High-Pressure, Hot-Water Flushing

- Hot water will likely kill the vegetation

Mechanical Oil Removal

- Using vehicles in soft substrate will probably cause extensive physical disruption
- Can completely alter the marsh substrate, hydrology, and vegetation patterns for many years
- Use in heavily oiled wetlands when all other techniques have failed and there is an overriding reason for oil removal

Sediment Reworking

- No benefit from mixing oil deeper into fine-grained and organic soils

Solidifiers

- Not applicable to gasoline spills because they rapidly evaporate
- Use likely to increase adherence to vegetation and slow weathering/removal rates of residual oil
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

Insufficient Information

Shoreline Cleaning Agents

- More information needed on available products, their effectiveness, and impact of use on vegetated bank habitats
- Individual products vary in their toxicity and recoverability of the treated oil

Nutrient Enrichment and Natural Microbe Seeding

- Not applicable to gasoline spills because they rapidly evaporate
- Concerns include eutrophication and acute toxicity, particularly from ammonia, because of shallow waters and low mixing rates
- There is insufficient information on impact and effectiveness in wetlands

Chemical Shoreline Pretreatment

- There is insufficient information about product toxicity, disturbances resulting from application and retrieval, effectiveness, and net benefit

4.0 SPILL RESPONSE METHODS

This section describes methods previously categorized for use during response to oil spills in inland environments and habitats. The methods are used in the protection, recovery, and cleanup phases of a response. The main objective of *protection* is to keep oil out of a habitat or to reduce the amount that enters. *Recovery* consists of removing floating oil from the water surface. The *cleanup* phase consists of removing stranded oil from shoreline habitats via physical, chemical, and enhanced biological means. In most spill response situations, protection and oil recovery are the immediate goals. Combinations of protection, recovery, and cleanup methods are commonly used though these guidelines treat each method separately.

The following section includes a summary of the objective in using the method, a general description of the method, applicable habitat types, conditions under which the methods should be used, biological constraints commonly applied to the use of the method to protect sensitive resources, and the environmental effects expected from the proper use of the method. Some of the methods listed require special authorization for use during a spill; the appropriate agency must be contacted about the need for special approvals. We encourage you to refer to the references listed in Appendix A for further information.

Physical Response Methods

1 Natural Recovery
2 Booming
3 Skimming
4 Barrier/Berm
5 Physical Herding
6 Manual Oil Removal/Cleaning
7 Mechanical Oil Removal
8 Sorbents
9 Vacuum
10 Debris Removal
11 Sediment Reworking
12 Vegetation Removal
13 In-Situ Burning
14 Flooding
15 Low-Pressure, Cold-Water Flushing
16 High-Pressure, Cold-Water Flushing
17 Low-Pressure, Hot-Water Flushing
18 High-Pressure, Hot-Water Flushing
19 Steam Cleaning
20 Sand Blasting

Chemical Response Methods

21 Dispersants

22 Emulsion Treating Agents

23 Visco-Elastic Agents

24 Herding Agents

25 Solidifiers

26 Chemical Shoreline Pretreatment

27 Shoreline Cleaning Agents

Biological Response Methods

28 Nutrient Enrichment

29 Natural Microbial Seeding

1. Natural Recovery

Objective

No attempt to remove any stranded oil in order to minimize impact to the environment, or because there is no proven effective method for cleanup.

Description

No action is taken, although monitoring of the incident continues.

Applicable Habitat Types

Can be used on all habitat types.

When to Use

On remote or inaccessible habitats, when natural removal rates are very fast (e.g., the evaporation of gasoline), 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 where high numbers of mobile animals (birds, terrestrial mammals) or endangered species use the body of water or shoreline.

Environmental Effects

Same as from the oil alone.

2. Booming

Objective

To control the movement of floating oil by containment, diversion, deflection, or exclusion.

Description

Placement of a device (boom) on the water that forms a barrier to floating oil. *Containment* is deploying a boom to hold 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. The ultimate goal is to recover the oil.

Applicable Habitat Types

Can be used on all water environments. Booms begin to fail by entrainment when the effective current or towing speed exceeds 0.7 knots perpendicular to the boom.

When to Use

Nearly all types of response to spills on water involve deploying boom to assist in the recovery of floating oil. Booms must be properly deployed and maintained, including removing accumulated debris. Containment booming of gasoline spills is usually not attempted, because of both fire and inhalation hazards to responders. However, when public health is at risk, booming of gasoline can be attempted with use of foam and extreme safety procedures. Deflection or exclusion booming of sensitive areas to prevent exposure to oil, including gasoline, can be an important protection action.

Biological Constraints

Placement and maintenance of anchoring points should not cause excessive physical disruption. Boom must be maintained so that it does not trap oil improperly and cause more damage. Traffic to/from boom sites should not disturb wildlife.

Environmental Effects

Minimal if surface disturbance by cleanup work force traffic is controlled.

3. Skimming

Objective

To recover floating oil from the water surface.

Description

Mechanized equipment is placed at the oil / water interface. There are five different types of skimmers: weir, suction, centrifugal, submersion, and oleophilic. They may operate independently from shore, be mounted on vessels, or be completely self-propelled. All require collection and concentration of floating oil at the skimmer, usually using booms. Large amounts of water are often collected and must be handled. Adequate storage of recovered oil / water mixture must be available.

Applicable Habitat Types

Can be used on all water environments. Waves, currents, and debris reduce skimmer efficiencies.

When to Use

When sufficient amounts of floating oil can be contained. Skimming of gasoline spills is usually not feasible, because of both fire and inhalation hazards to responders. However, when public health is at risk, skimming of gasoline can be attempted using foam and extreme safety procedures.

Biological Constraints

Traffic to / from skimming sites should not disturb wildlife.

Environmental Effects

Minimal if surface disturbance by cleanup work force traffic is controlled.

4. Barriers/Berms

Objective

To prevent entry of oil into a sensitive area or to divert oil to a collection area.

Description

A physical barrier is placed across an area to prevent moving oil from passing. Barriers can consist of earthen berms, filter fences, air bubble barriers, or trenches. When it is necessary for water to pass, because of water volume or downstream needs, underflow dams (for low flow rates) or overflow dams are used.

Applicable Habitat Types

In streams and dry valleys, where the width and depth of the area to be closed off are relatively small. Also, at the mouths of small creeks along lake shorelines, to prevent oil from being blown upstream.

When to Use

When the flow of oil threatens sensitive habitats. If the barrier does not fail, it is the most effective strategy to exclude oil from an area.

Biological Constraints

Place barriers away from sensitive areas, such as spawning sites. Downstream water requirements should be monitored to prevent dewatering of sensitive areas.

Environmental Effects

May disrupt or contaminate sediments along banks or in channel. Dewatering or poor water quality downstream may affect aquatic organisms.

5. Physical Herding

Objective

To free oil trapped in debris or vegetation on water; to direct the movement of floating oil towards containment and recovery devices; or to push oil away from sensitive areas.

Description

Water or air streams and propeller wash generate a current to dislodge trapped oil and herd the released oil to containment and recovery area. May mix oil with water to form emulsified oil.

Applicable Habitat Types

In lakes and ponds where there are little or no currents, along rivers and streams where the channel or banks are accessible, and in and around manmade structures such as wharves and piers.

When to Use

In low-current or stagnant waterbodies, to herd oil in booms towards recovery devices. Along rivers and streams, when *mobile* oil has penetrated vegetated banks or accumulated in log jams or other debris, water spray and prop wash can mobilize the oil to flow downstream to collection points.

Biological Constraints

None.

Environmental Effects

May generate high levels of suspended sediments and mix them with the oil, resulting in deposition of contaminated sediments in benthic habitats.

6. Manual Oil Removal/Cleaning

Objective

To remove surface oil with hand tools and manual labor.

Description

Removal of surface oil by manual means (hands, rakes, shovels, buckets, rags, sorbent pads, etc.) and placing in containers. No mechanized equipment is used.

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 that have formed semi-solid to solid masses that can be picked up manually.

Biological Constraints

Foot traffic over sensitive areas (wetlands, floating vegetation, etc.) needs to be restricted or prevented. There may be periods when access should be avoided, such as during bird nesting.

Environmental Effects

Minimal if surface disturbance by crew movement and waste generation is controlled.

7. Mechanical Oil Removal

Objective

Removal of oil from water surface, bottom sediments, and shorelines with heavy equipment.

Description

Oil and oiled sediments are collected and removed using backhoes, dredges, graders, bulldozers, draglines, etc. On land, the oiled material is pushed into piles and transported offsite for treatment/disposal. On water, the equipment is operated from shore or barges to recover large amounts of heavy or solidified oil.

Applicable Habitat Types

On land, possible wherever there are surface sediments accessible to heavy equipment. On water, used in lakes, rivers, etc., where oil accumulates.

When to Use

When large amounts of oiled materials have to be collected and removed. Along shorelines, 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. Will need special permission to use in areas with known cultural resources.

Biological Constraints

Heavy equipment may be restricted in sensitive habitats (e.g., wetlands, soft substrate) or areas containing endangered plants and animals.

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. Runoff from exposed oil and fine-grained oily sediments can affect adjacent bodies of water.

8. Sorbents

Objective

To remove floating oil by adsorption onto oleophilic material placed in water or at the waterline.

Description

Sorbent material is placed *on the water surface*, allowing it to absorb oil as it is released by natural processes. Forms include sausage boom, rolls, sweeps, pads, and snares. Efficacy depends on the capacity of the particular sorbent, energy available for lifting oil off the substrate, and stickiness of the oil. Recovery of all sorbent material is mandatory.

Applicable Habitat Types

Can be used on any habitat or environment type.

When to Use

When the stranded oil is mobile and transport of oil is expected on or off the site. The oil must be viscous and thick enough to be released by the substrate and absorbed by the sorbent. Often used as a secondary treatment method after gross oil removal and in sensitive areas where access is restricted.

Biological Constraints

Access for deploying and retrieving sorbents should not affect soft or sensitive habitats or wildlife. Sorbent use should be monitored to prevent overuse and generating large volumes of waste.

Environmental Effects

Physical disturbance of habitat during deployment and retrieval. When the sorbents are no longer effective, oil may remain in critical habitats during sensitive periods.

9. Vacuum

Objective

To remove free oil pooled on the substrate or from the water in sheltered areas.

Description

A vacuum unit with a suction head recovers free oil. The equipment can range from small, portable units that fill individual 55-gallon drums to large supersuckers that are truck-mounted and can lift large rocks. Can be used with booms and flushing systems to move the oil toward the suction head. Removal rates from substrates can be extremely slow.

Applicable Habitat Types

Any accessible habitat type. May be mounted on barges for water-based operations, on trucks backed to the recovery area, or hand-carried to remote sites.

When to Use

When free, liquid oil is stranded on the substrate (usually in depressions), trapped in vegetation and is readily accessible, or concentrated on the water surface. Often used instead of skimmers for floating oil recovery. Usually requires shoreline access points. Used in recovery of gasoline spills only with special precautions such as: applying foam to suppress vapors, testing for flammable vapor, locating the vacuum truck a safe distance from spill, and venting the pump discharge safely.

Biological Constraints

Special restrictions should be identified for areas where foot traffic and equipment operation should be limited, such as soft substrates. Operations in wetlands need to be very closely monitored, with a site-specific list of restrictions.

Environmental Effects

Minimal if foot and vehicular traffic is controlled and minimal substrate is removed.

10. Debris Removal

Objective

To remove contaminated debris from the shoreline or water surface.

Description

Manual or mechanical removal of debris from the shore or water surface. Can include cutting up and removal of oiled logs.

Applicable Habitat Types

Can be used on any habitat or environment type where safe access is allowed.

When to Use

When driftwood and debris are heavily contaminated and provide a potential source of chronic oil release, an aesthetic problem, a source of contamination for other organisms in the area, or skimmer clogging problems.

Biological Constraints

Disturbance to adjacent areas should be minimized. Foot traffic over sensitive areas (wetlands, spawning grounds) needs to be restricted. May be periods when access should be restricted (spawning periods, large numbers of migratory waterbirds).

Environmental Effects

Physical disruption of substrate, especially when equipment must be deployed to recover a large quantity of debris.

11. Sediment Reworking

Objective

To rework oiled sediments to break up the oil deposits, increase its surface area, and mix deep subsurface oil layers, which will expose the oil to natural removal processes and enhance the rate of oil degradation.

Description

The oiled sediments are roto-tilled, disked, or otherwise mechanically mixed using heavy equipment. Along lake shores, oiled sediments may also be pushed lower on the shore to enhance natural cleanup from reworking by wave activity. The process may be aided with high-volume flushing of gravel.

Applicable Habitat Types

On any sedimentary substrate that can support heavy equipment.

When to Use

On sand to gravel beaches with subsurface oil, where sediment removal is not feasible (due to erosion concerns or disposal problems). Also where surface oil deposits have started to form pavements or crusts. Appropriate for sites where the oil is stranded above the normal water level.

Biological Constraints

Avoid use on shores near water intakes, fish-spawning areas, or near bird-nesting or concentration areas because of the potential for release of oil and oiled sediments into adjacent bodies of water.

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 mixing over time could delay re-establishing organisms. Runoff from treated sites could contaminate downslope areas.

12. Vegetation Removal

Objective

To cut and remove oiled vegetation to prevent oiling of wildlife or chronic oil releases.

Description

Manual cutting of oiled rooted vegetation using weed eaters. Cut vegetation is raked up. Floating vegetation is removed either manually or mechanically.

Applicable Habitat Types

Wetlands composed of emergent, herbaceous vegetation and 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.

Environmental Effects

Vegetation removal will destroy habitat for many animals. Cut areas will have reduced plant growth. Along exposed sections of shoreline, the vegetation may not regrow, eroding and destroying the habitat. Trampled areas will recover much more slowly.

13. In-Situ Burning

Objective

To remove oil from the water surface or habitat by burning.

Description

Oil floating on the water surface is collected into slicks at least 2-3 millimeters 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 in the habitat is burned, usually when it is on a combustible substrate such as vegetation, logs, and other debris. Oil can be burned off non-flammable substrates using a burn promoter. On sedimentary substrates, it may be necessary to dig trenches for oil to accumulate in pools thick enough to burn efficiently. Heavy and emulsified oils are harder to ignite and sustain an efficient burn, but are still burnable.

Applicable Habitat Types

On any habitat type except dry muddy substrates where heat may impact the biological productivity of the habitat.

When to Use

On floating slicks, early in the spill event when the oil can kept thick enough (2-3 millimeters). On land, where there is heavy oil in sites not amenable or accessible to physical removal and it is important to immobilize the stranded oil quickly. In wetlands and mud habitats, a water layer minimizes impacts to sediments and roots. Many potential applications for spills in ice.

Biological Constraints

Large volumes of smoke are generated, and its effect on nesting birds and populated areas should be evaluated.

Environmental Effects

Temperature and air quality effects are likely to be localized and short-lived. Toxicological impact from burn residues have not been evaluated. There are few studies on the relative effects of burning oiled wetlands compared to other techniques or natural recovery, but the limited data indicate little impact of burning relative to natural recovery when the soils are saturated.

14. Flooding

Objective

To wash oil stranded on the land surface to the water's edge for collection.

Description

A perforated header pipe or hose is placed above the oiled shore or bank. Ambient water is pumped through the header pipe at low pressures and flows downslope to the water. On porous sediments, water flows through the substrate, pushing loose oil ahead of it (or floats oil to the water's surface) then transports the oil down the slope for pickup. Flow is maintained to remove the majority of free oil. Oil is trapped by booms and is recovered by skimmers or other suitable equipment.

Applicable Habitat Types

All habitat types.

When to Use

In heavily oiled areas when the oil is still fluid and loosely adheres 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 water).

Biological Constraints

Not appropriate where nearshore sediments contain rich biological communities.

Environmental Effects

Habitat may be physically disturbed by foot traffic during operations and smothered by sediments washed down the slope. Oiled sediment may be transported to shallow nearshore areas, contaminating them and burying benthic organisms.

15. Low-Pressure, Cold-Water Flushing

Objective

To remove liquid oil that has adhered to the substrate or manmade structures, pooled on the surface, or become trapped in vegetation.

Description

Ambient water is sprayed at low pressures (<50 psi), usually from hand-held hoses, to lift oil from the substrate and direct it to the water's edge for pickup. Can be used with a flooding system to prevent released oil from re-adhering to the substrate.

Applicable Habitat Types

On heavily oiled substrates, riprap, and seawalls where the oil is still liquid. In wetlands and along vegetated banks where free oil is trapped in vegetation.

When to Use

Where free, liquid oil is stranded onshore or floating in very shallow areas.

Biological Constraints

Not appropriate where nearshore sediments contain rich biological communities. May need to restrict use so that the oil / water effluent does not drain across sensitive habitats. Use from boats will prevent foot traffic in soft substrates and vegetation. Released oil must be recovered to prevent further oiling of adjacent areas.

Environmental Effects

If containment methods are not sufficient, contamination may be flushed into downstream areas. Some trampling of substrate and vegetation is unavoidable.

16. High-Pressure, Cold-Water Flushing

Objective

To remove oil that has adhered to hard substrates or manmade structures.

Description

Similar to low-pressure flushing except that water pressure is 100-1,000 psi. High-pressure spray will more effectively remove sticky or viscous oils. If water volumes are low, sorbents are placed directly below the treatment area to recover oil.

Applicable Habitat Types

Bedrock, manmade structures, and gravel habitats.

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 / water effluent does not drain across sensitive habitats. Released oil must be recovered to prevent further oiling of adjacent areas.

Environmental Effects

May drive oil deeper into the substrate if water jet is improperly applied. If containment methods are not sufficient, contamination may be flushed into downstream areas. Some trampling of substrate and vegetation is unavoidable.

17. Low-Pressure, Hot-Water Flushing

Objective

To remove non-liquid oil that has adhered to the substrate or manmade structures, or pooled on the surface.

Description

Hot water (90°F up to 170°F) is sprayed with hoses at low pressures (<50 psi) to liquefy and lift oil from the substrate and direct it to the water's edge for pickup. Used with flooding to prevent released oil from re-adhering to the substrate.

Applicable Habitat Types

On heavily oiled bedrock, sand to gravel substrates, and manmade structures.

When to Use

Where heavy, but relatively fresh oil is stranded onshore. The strategy is to heat the oil to above its pour point, so it will flow. Less effective on sticky oils.

Biological Constraints

Avoid wetlands or nearshore sediments with rich biological communities. Use should be restricted so that the hot oil / water effluent does not contact sensitive habitats. Boat use will prevent foot traffic in soft substrates and vegetation. Released oil must be recovered to prevent further oiling of adjacent areas.

Environmental Effects

Hot water can kill all organisms in direct contact. If containment methods are not sufficient, contamination may be flushed into downstream areas. Some trampling of substrate and vegetation is unavoidable during the response.

18. High-Pressure, Hot-Water Flushing

Objective

To mobilize weathered and viscous oil adhered to surfaces.

Description

Hot water (90°F up to 170°F) is sprayed with hand wands at pressures greater than 100 psi. 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 or sorbents.

Applicable Habitat Types

Gravel habitats, bedrock, and manmade structures.

When to Use

When oil has weathered to the point that even warm water at low pressure no longer effectively removes oil, to prevent continued release of oil. To remove viscous oil from manmade 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). Released oil must be recovered to prevent further oiling of adjacent areas.

Environmental Effects

All attached organisms 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.

19. Steam Cleaning

Objective

To remove heavy residual oil from solid substrates.

Description

Steam or very hot water (170°F to 212°F) is sprayed with hand wands at high pressure. Water volumes are very low compared to flushing methods.

Applicable Habitat Types

Manmade structures such as seawalls and riprap.

When to Use

When heavy oil residue remaining on a shoreline needs to be cleaned for aesthetic reasons, and when hot-water wash is not effective.

Biological Constraints

Not to be used in areas of soft substrate, vegetation, or high biological abundance directly on or below the structure.

Environmental Effects

Complete destruction of all organisms in the spray zone. Difficult to recover all released oil.

20. Sand Blasting

Objective

To remove heavy residual oil from solid substrates.

Description

Use of sandblasting equipment to remove oil from the substrate. May include recovery of used (oiled) sand in some cases.

Applicable Habitat Types

Manmade structures such as seawalls and riprap.

When to Use

When heavy oil residue is remaining on the shoreline, which needs to be cleaned for aesthetic reasons, and even steam cleaning is not effective.

Biological Constraints

Not to be used in areas of soft substrate, vegetation, or high biological abundance directly below or adjacent to the structures.

Environmental Effects

Complete destruction of all organisms in the blast zone. Possible smothering of downstream organisms with sand. When the used sand is not recovered, introduces oiled sediments into the adjacent habitat.

21. Dispersants

Objective

To remove floating oil from the water surface and disperse it into the water column, to reduce impact to sensitive shoreline habitats and animals that use the water surface.

Description

Specially formulated products containing surface-active agents are sprayed at concentrations of about 5 percent by volume of the oil onto the slicks by aircraft or from boats. The products can be applied undiluted or mixed with water. The dispersants reduce the oil/water surficial tension and decrease the energy needed for the slick to break into small particles and mix into the water column. Some turbulence is needed to mix the dispersant into the oil and to mix the treated oil into the water.

Applicable Habitat Types

Open water and large rivers 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 mixing of oil into the water column.

Biological Constraints

Use in shallow water could affect benthic resources. The potential impact of dispersed oil on water intakes should be thoroughly considered prior to use.

Environmental Effects

May increase effects on water-column organisms, particularly plankton and larval fish. Dispersion will only be partially effective, so some water surface impact will still occur.

22. Emulsion-Treating Agents

Objective

To break or destabilize emulsified oil into separate oil and water phases. Can also be used to prevent emulsion formation.

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 to separate excess water from recovered oil. They also can be sprayed (similar to dispersants) directly onto slicks to break or prevent emulsions.

Applicable Habitat Types

On all water environments where emulsified oil is present.

When to Use

For recovered oil, where storage capacities are very limited, to separate the oil and water so that the water can be treated and discharged. On floating slicks, where emulsified oil can reduce skimmer efficiency.

Biological Constraints

There is insufficient information to evaluate at this time.

Environmental Effects

Because this is a new application approach, there are very few data available to evaluate environmental effects. Effective dosages are one to two orders of magnitude lower than dispersants. Environmental concerns regarding application to slicks are: how treatment might adversely change the physical or chemical properties of the oil; whether the oil will be more readily dispersed; and how the treated oil will behave upon contact with birds, mammals, and shorelines.

23. Visco-Elastic Agents

Objective

To impart visco-elastic properties to floating oil and increase skimming rates.

Description

Chemical agent is applied as a liquid spray or a slurry onto the oil in the proper dosage. Some mixing is required and is usually provided by the water spray during application. Treated oil is rendered visco-elastic, but still fluid, gelatinous, or semi-solid; there is no chemical change in the oil. The primary purpose is to increase the efficiency in skimmer removal rates while minimizing amount of water. Increases the recovery by drum skimmers, but can clog weir-type skimmers.

Applicable Habitat Types

On all water environments where oil can be contained for recovery with skimmers. Not for use near wetlands or debris because of an increase in adhesive behavior of the treated oil.

When to Use

When recovery efficiency of skimmers needs to be increased. 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 or where there is extensive debris mixed in the oil. Should be avoided when birds or other wildlife that may be more adversely affected by the treated oil cannot be kept away from the treated oil.

Environmental Effects

May enhance the smothering effect of oil on organisms. Therefore, the treatment should be considered only where recovery of the treated oil is likely.

24. Herding Agents

Objective

To collect or herd oil into a smaller area and thicker slick in order to increase recovery. Also can be used to herd oil away from sensitive areas or used inside containment booms when it is necessary to move the boom.

Description

Chemical 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, vessel-mounted, or aircraft systems can be used. Must be applied early in spill, when oil is still fluid.

Applicable Habitat Types

On all stillwater 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, use to push slicks away from sensitive resources such as wetlands. Not effective in fast currents, rough seas, or rainfall.

Biological Constraints

Not suitable for use in very shallow water or fish-spawning areas.

Environmental Effects

Direct acute toxicity to surface layer organisms possible, though available products vary greatly in their aquatic toxicity.

25. Solidifiers

Objective

To change the physical state of spilled oil from a liquid to a solid to reduce impact of oil to shorelines.

Description

Chemical agents (polymers) are applied to oil at rates of 10-45 percent, 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.

Applicable Habitat Types

All water environments, bedrock, sediments, and manmade structures.

When to Use

When immobilization of the oil is desired, to 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 spills of heavy oil because the product cannot be readily mixed into viscous oils.

Biological Constraints

Must be able to recover all treated material.

Environmental Effects

Available products are insoluble and have very low aquatic toxicity. Unrecovered solidified oil may have longer impact because of slow weathering rates. Physical disturbance is likely during application and recovery.

26. Chemical Shoreline Pretreatment

Objective

To prevent oil from adhering to or penetrating the substrate.

Description

Various types of film-forming agents or wetting agents are applied to habitats in advance of the oil to prevent oil adhesion and penetration. Application must occur just prior to stranding of the oil so timing is critical. It should be noted that there are no products now being sold as shoreline pretreatment agents.

Applicable Habitat Types

Bedrock, sand and gravel habitats, and manmade structures.

When to Use

When oil is projected to impact an applicable shoreline, particularly those that have high recreational or aesthetic value. However, lack of information on the availability, effects, and effectiveness of products greatly limits their use.

Biological Constraints

Unknown at this time but there are likely to be constraints based on product toxicity and persistence.

Environmental Effects

Unknown at this time since there are no commercially available products. There are concerns about toxicity and smothering since these products could be applied directly on clean substrates.

27. Shoreline Cleaning 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 to enhance flushing methods. The intent is to lower the water temperature and pressure required to mobilize the oil from the substrate during flushing.

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 warm to hot water. This approach may be most applicable where flushing effectiveness decreases as the oil weathers.

Biological Constraints

The released oil should be recovered rather than dispersed into the water column. Use may be restricted where suspended sediment concentrations are high, near wetlands, and near sensitive nearshore resources.

Environmental Effects

If more oil is dispersed into the water column, there could be more oil sorbed onto suspended sediments and transferred to nearshore habitats, particularly along sheltered shorelines. The toxicity of shoreline cleaners is similar to the toxicity of dispersants.

28. Nutrient Enrichment

Objective

To speed the rates of natural microbial degradation of oil by adding nutrients (generally nitrogen and phosphorus).

Description

Nutrients are applied to the habitat in one of several methods: soluble inorganic formulations, which are dissolved in water and applied as a spray, requiring frequent applications; slow-release formulations, which are applied as a solid; and oleophilic formulations, which adhere to the oil itself and are sprayed directly on the oiled areas.

Applicable Habitat Types

Could be used on any habitat type where safe access is allowed and nutrients are deficient.

When to Use

On moderately to heavily oiled substrates, after other techniques have been used to remove as much oil as possible; on lightly oiled shorelines where other techniques are destructive or not effective; and where nutrients limit natural degradation. Most effective on diesel-type and medium oils that do not have large amounts of high molecular weight, slowly degrading components. Less effective where oil residues are thick. Not considered for gasoline spills, which will be completely removed by evaporation at faster timeframes than by microbial degradation.

Biological Constraints

Not suitable in shallow water or restricted waterbodies where nutrient overloading may lead to eutrophication, or where toxicity of nutrients, particularly ammonia, is of concern. Contact toxicity of oleophilic formulations may restrict areas of direct application. Toxicity tests should be evaluated carefully, as other chemicals in the product could be toxic to aquatic organisms.

Environmental Effects

Very little information is available on effects in freshwater.

29. Natural Microbe Seeding

Objective

To speed the rates of microbial degradation of oil by adding live microbes with enhanced oil-degrading abilities.

Description

Formulations containing hydrocarbon-degrading microbes (usually with fertilizers) are added to the oiled area. The argument is made that indigenous microorganisms will be killed by the oil or will be slow to degrade the oil, so new microbial species need to be added to speed the process of biodegradation. Little information is currently available to show whether natural microbe seeding increases biodegradation more than nutrient enrichment alone.

Applicable Habitat Types

Could be used on any habitat type where safe access is allowed and additional microbes are needed.

When to Use

On moderate to heavily oiled substrates, after other techniques have been used to remove as much oil as possible; on lightly oiled shorelines where other techniques are destructive or not effective; and where existing microorganisms are not present or effective. Most effective on diesel-type and medium oils that do not have large amounts of high molecular weight, slowly degrading components. Less effective where oil residues are thick. Not considered for gasoline spills, which will evaporate faster than they would degrade.

Biological Constraints

If product contains fertilizers, not suitable in shallow water or restricted bodies of water where nutrient overloading may lead to eutrophication, or where toxicity of nutrients, particularly ammonia, is of concern. Toxicity tests should be evaluated carefully, as other chemicals in the product could be toxic to aquatic organisms.

Environmental Effects

Very little information is available on effects in freshwater.

5.0 SPECIAL CONSIDERATIONS

This section summarizes the following selected topics of special concern in freshwater habitats:

- Public health concerns;
- Conditions under which oil might sink;
- Oil behavior in ice conditions;
- Oil behavior and cleanup in permafrost; and
- Firefighting foam.

5.1 PUBLIC HEALTH CONCERNS

The human-health concerns associated with oil spills entail risks to the public from exposure to the oil and to responders during cleanup activities. In freshwater areas, the risks of exposure of the public are of special concern, because of the potential for contamination of public drinking water supplies and the proximity of populated areas to spill sites. Human-health risks from spilled oil occur along three potential pathways: ingestion, dermal contact, and inhalation. Ingestion pathways include drinking contaminated water and eating tainted food (e.g., fish, birds, and mammals).

Water intakes in relatively shallow lakes and rivers may be highly susceptible to contamination during oil spills. Response procedures may thus include temporarily closing the intakes, protectively booming the intake area, bringing on-line additional treatment equipment at the water-treatment plant, and / or monitoring water quality for the contaminants of concern. The low-molecular weight, aromatic compounds (benzene, ethylbenzene, toluene, and xylene) are usually of greatest concern, because of their much higher water solubility, compared to the other compounds in oil. These four compounds usually represent 70-95 percent of the water-soluble fraction (typically about 25-40 ppm) in crude oils. Water-treatment plants that have granular activated carbon filtration systems can remove low levels of oil contamination, especially the aromatic compounds, which can cause taste and odor problems at very low concentrations.

The potential for direct contact of oil on skin is greatest during cleanup, and measures should be taken to keep the public away from all spill response operations. Inhalation of volatile compounds from spills of crude oil and light, refined products poses a risk to the public in adjacent areas. However, these risks are greatest with long-term exposure.

Fire risks are mostly associated with volatile, refined products such as gasoline. Response operations at these spills must be conducted with caution. Often, the best response to spills of volatile products is to allow the product to evaporate, while diverting the slicks away from populated areas and sensitive habitats.

5.2 CONDITIONS UNDER WHICH OIL MIGHT SINK IN FRESH WATER

Most oil spills result in floating oil slicks. There are very specific conditions that can cause an oil spill to sink rather than float in freshwater settings.

1 The oil has a specific gravity greater than 1.00 at the ambient temperature.

Specific gravity is the ratio of the density of a material to freshwater. Although nearly all crude oils and most refined products have a specific gravity less than 1.00 and will therefore float, some of the residual refined products (e.g., very heavy fuel oils, asphalt) are so heavy that their specific gravity is greater than 1.00. Spills of these oils can sink immediately and flow along with the bottom currents or as droplets in the water column. However, very small changes in water density can refloat sinking oil. There have been several spills in the freshwater sections of a river where the oil originally sank and moved along the bottom. However, at the fresh / salt mixing zone, where the water density increased with salinity, some of the oil rose to the surface. In other spills, oil has been reported to sink with very cold temperatures at night, only to refloat after the water absorbs heat from the sun.

2 The oil has a specific gravity just under 1.00 but forms a very stable emulsion.

Water-in-oil emulsions can contain up to 80 percent water, which increases the specific gravity accordingly. Also, during the emulsification process, some sediment can be incorporated into the emulsion, either from the suspended sediments in the water mixed into the oil, or those adhered to the floating slick. Only a very small amount of sediment is needed to sink oil. Usually residual refined products (e.g., No. 6 fuel oil, Bunker C) have a specific gravity of 0.99 or greater.

3 The oil comes ashore, picks up sediment, and then is eroded from the shore.

Medium and heavy oils can adsorb to sediment when they strand, making the mixture heavier than water. However, the oil/sediment mixture must be eroded from the shoreline, usually by waves, which tend to break up the oil slicks. The oiled sediment can be deposited in the nearshore zone, but as small tarballs or widely scattered contaminated sediment, rather than a layer of sunken oil. In some instances, the tarballs can stick to each other, forming a tar mat just offshore.

4 The oil is a blend of light and heavy refined products, and the light fraction is lost by evaporation.

Many intermediate fuel oils are actually mixtures of No. 2 and No. 6 oils. If the spill conditions were such that the light oil component completely evaporated, and the heavy oil was particularly heavy, the weathered oil might sink.

5.3 OIL BEHAVIOR IN ICE CONDITIONS

Several important differences in the behavior of spilled oil in ice conditions greatly reduce the effectiveness of response methods. For spills in water colder than the oil's pour point, the oil will quickly become viscous or tar-like. Even lighter, refined products can lose the ability to disperse and become non-coalescing, semi-solid, smooth, spherical particles that are difficult to recover. Weathering and loss by evaporation are slowed by low temperature, thickness of the slick, restriction of spreading, entrapment below the ice, and encapsulation in ice.

When spilled on ice, oil may pool in depressions and cavities, or be transported across the ice by wind. In ice with a porous crystal structure, oil can penetrate the ice; diesel-like oils can penetrate freely and deeply, while heavy oils remain more on the surface. Oil on the ice surface can also be entrapped by growing ice. If a light cover of snow covers the oil on the ice, the increased absorption of solar radiation by the oil under the snow can result in daily melting and nightly re-freezing that can form an ice/oil/ice layer.

Oil spills trapped beneath the ice will collect in the rough underside areas of the ice sheet. Entrapped oil will spread until it reaches an equilibrium thickness. The oil can become encapsulated within the growing ice sheet, where it will remain until spring thaw or when leads in the ice sheet form. During breakup, decaying ice increases in porosity and decreases in strength. Oil spilled under or sandwiched between this ice will rise through the ice and collect on the ice surface.

For oil spilled under the ice, there are new infrared and imaging techniques available to assist in location of thick oil pockets. Holes can be drilled in the ice at these collection points, and the oil removed by vacuum. When the oil is encapsulated in the ice, there are two options: remove the contaminated ice or delay recovering the oil until the spring thaw. The largest logistical issue with contaminated ice is separating the oil from large quantities of ice during the winter. In-situ burning and certain types of skimmers have been shown to be effective for removing oil in broken ice.

5.4 PERMAFROST

In the polar regions of the world, where the average annual temperature is below 0°C, the soil freezes permanently and is known as "permafrost." Permafrost can range in thickness from a few centimeters for recently frozen soil, to hundreds of meters thick for old permafrost. In truly Arctic regions, all soils are in the form of permafrost; at its edges, the permafrost may be discontinuous and depend upon the soil type. In the United States, permafrost exists only in Alaska and at high altitudes in northern mountains. For oil spills, the major areas of concern are the Alaskan North Slope and the Trans-Alaskan pipeline route.

Ice is one of the most important components of permafrost. The continued existence of the frozen soil depends strongly on the insulating properties of the surface soil. During the summer months, the surface soil thaws, forming an active layer. The water in this layer remains in place, since the frozen subsurface is not permeable. Disturbing this surface-active layer (3-6 centimeters up to one meter in depth) can increase thawing of the subsurface and will result in surface slumping. It can take years for this disturbance to be healed.

The active layer of the permafrost supports a wide variety of specialized Arctic fauna and flora. Disturbing plants in this layer could affect this habitat for decades. While the data are limited, there is evidence that tundra plants are very sensitive to oil effects. This vegetation, particularly moss and lichen, forms the principal food sources for many of the animals in permafrost regions.

The sensitivity and issues of oil spill response in permafrost areas are similar to those for wetlands. It is best to allow the spill to recover naturally unless large areas have been affected. Appropriate response methods for summer spills would include installing berms to prevent continued spread of the oil, vacuuming pooled oil, applying sorbents to recover pooled oil in areas of limited access, and manually removing heavily oiled soils. Nutrient addition may be considered following gross oil removal. During summer, foot traffic in the permafrost should be highly controlled; structures such as board walkways should be used when possible to minimize physical disturbance. Vehicle traffic should be prohibited. It may be necessary to build a gravel road to the spill site to provide adequate insulation to prevent thawing of the permafrost. In winter, vehicular transport over snow-covered permafrost can be conducted without concern of physical disruption, and conventional land-based response techniques can be used, including in-situ burning.

5.5 FIREFIGHTING FOAM

When responding to spills involving petroleum and refined fuels such as gasoline, firefighters often apply foam to suppress vapors and reduce the potential of fire. If the spilled material is already burning, foams are used to extinguish petroleum-liquid fires because they separate the burning liquid from the air, effectively smothering the fire. There are five basic types of foam commonly used:

1. *Protein Foams* consist of hydrolyzed proteins plus stabilizing additives and inhibitors.
2. *Fluoroprotein Foams* (FP) are similar to protein foams but have a fluorinated surfactant additive to improve the resistance to fuel entrainment. They exclude air, and may form a thin film to suppress the evolution of fuel vapors.
3. *Aqueous Film-Forming Foams* (AFFF) are synthetic foams made from fluorocarbon surfactants with additional stabilizers. AFFFs also exclude air and form thin aqueous films to suppress the evolution of vapors.
4. *Film-Forming Fluoroprotein Foams* (FFFP) are combinations of protein and film-forming surfactants and combine the characteristics of AFFF and FP foams.

5> *Alcohol-Resistant Foams* are specially formulated foams for application on alcohols and water-miscible flammable liquids.

Each of these foams is created by mechanical action that fills the foam bubbles with air. A fourth type of foam, *Multipurpose Foam Compounds*, is being developed since many gasolines are required to contain alcohol or polar additives (such as methyl t-butyl ether) to decrease automobile emissions. These additives are water-soluble and reduce the effectiveness of conventional foams used on gasoline fires.

There are two environmental concerns with using firefighting foams. First, although the acute aquatic toxicity of these products is believed to be low, it has not been fully evaluated. Toxicity should be evaluated in terms of the likely dose expected from normal application rates and possible synergistic effects when combined with petroleum oils. Second, these products may alter the physical properties of the treated oil. Since most firefighting foams contain surfactants, the rate of dispersion of the oil may be increased if improperly applied or mixed due to currents, storms, or boat traffic.

APPENDIX A.

APPLICABLE OIL SPILL RESPONSE TECHNOLOGY BIBLIOGRAPHY

The following bibliography is not intended to be comprehensive, but instead provides a list of key references from which many other publications may be found dealing with spill response techniques, strategies, equipment, and effects.

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APPENDIX B.

GRAIN-SIZE SCALE

Wentworth Scale (Size Description)		Phi Units* ϕ	Grain Diameter d (millimeters)
Boulder		-8	256
			76.2
Cobble			
		-6	64.0
			19.0
			4.76
Pebble			
		-2	4.0
Granule			
		-1	2.0
	Very Coarse		
		0	1.0
	Coarse		
		1	0.5
	Medium		0.42
Sand			
		2	0.25
	Fine		
		3	0.125
	Very Fine		0.074
		4	0.0625
Silt			
		8	0.00391
Clay			
		12	0.00024
Colloid			

$*\phi = -\log_2 d$ (mm)

(From U.S. Army Coastal Engineering Center, Shore Protection Manual 1973)