# AN INLAND OIL SPILL RESPONSE MANUAL TO MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS

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**ABSTRACT:** *Inland oil spills generally have received less attention than their coastal and marine counterparts. On the average, more than 2,000 spills occur on the inland waters of the continental United States each year. Recognizing the potential effects of these spills, the American Petroleum Institute has funded several studies in recent years to address issues associated with inland spills. One product of this activity is the preparation of a set of guidelines to be published as a manual for inland oil spill response. The manual focuses on the identification of techniques that would have minimal intrinsic ecological impacts (that is, to living resources) and would also minimize the total ecological and/or environmental impacts of the oil. The guidelines are intended to help decision makers assess whether the available response options can mitigate the effects of a spill and/or accelerate recovery from the oiling. The analysis and the recommendations are presented in a set of matrices that combine four oil types, more than 20 response techniques, and 10 inland freshwater habitats.*

Oil spills into inland waters differ from coastal and marine (salt or brackish water) spills in several respects.

- They are nearly always in freshwater habitats.
- Inland spills are more frequent than marine spills and usually involve smaller volumes of oil.
- Refined product (barge) spills are common in fresh water, whereas crude oil (tanker) spills comprise the majority of coastal and marine spills.
- Inland spills have a much higher potential to contaminate water supplies (surface or groundwater), to affect areas of concentrated population, and to affect man-made structures and activities.
- Wave and tidal action in coastal and marine environments are important mechanisms for the dispersal and transportation of oil, and in cleaning oil from shorelines. These mechanisms are less important in freshwater habitats; however, currents and floods are important factors in inland water habitats.

Freshwater spills are common, with an annual average of more than 2,000 in the continental United States, involving an average total on the order of 50,000 barrels (bbl) of oil a year.[6] Inland spills have rarely received as much attention as marine and coastal spills. Until a few years ago, the only publicly available comprehensive reference for spill response was a manual by CONCAWE.[4] The Ashland oil spill into the Monongahela River in 1988 showed that freshwater oil spills can be as dramatic, from the viewpoint of the general public, and at least as difficult to control, as marine or coastal spills. Reviews of the knowledge base for response to oil spills revealed the disparity of information available between marine spill response and freshwater response.[5] The lack of literature and guidelines for inland spills prompted several recent efforts by the American Petroleum Institute (API) to fill this gap. To date the efforts have involved the following projects.

- Reviews of Natural Resource Damage Assessments in Freshwater Environments by P. Lane and Associates[2] and Stone and Webster[3]
- Report on Oil Spill Response in Fresh Water Environments: Impact on the Environment of Clean-up Practices—Unpublished report by Vandermeulen and Ross[6]
- Workshop on the Environmental Effects of Response Technologies for Inland Waters, November 19 and 20, 1991, Dearborn, Michigan—sponsored by API's Inland Spills Work Group and the Spill Control Association of America (SCAA)
- Literature Review of Environmental and Human Health Effects from Inland Oil Spills—in preparation by Woodward-Clyde Consultants
- Spill Response Manual for Freshwater Environments—in preparation by Woodward-Clyde Consultants

This paper focuses on the last item, the preparation of a manual that contains guidelines for choosing among available oil spill protection and cleanup options. Its one primary goal is to minimize the ecological impacts (that is, to living resources) of a spill in inland waters. The main input for the manual came from the workshop on inland oil spills, sponsored by API and SCAA in Dearborn, Michigan, in November 1991. The workshop brought together those in the oil spill response community with experience and/or responsibility for responding to freshwater crude oil or petroleum product discharges. Its objective was to develop, through consensus, strategies for dealing with spills in different freshwater environments. Information from that workshop has been distilled, reviewed, revised, and put into a response manual with a format similar to the manual produced by API for marine oil spills.

## Scope of the manual

The (draft) manual contains guidelines for the selection of oil spill protection and cleanup techniques. The selection process focuses on the identification of techniques that themselves would have minimal intrinsic ecological impacts and that also would minimize the ecological impacts of the oil in inland waters. A secondary aspect of the manual is to provide this direction while recognizing potential human health risks of the spill and response methods. The manual can be used as an aid in contingency planning or as an aid to field response, when consensus decisions must be reached rapidly.

The manual is intended to present the ecologically preferred response options for a variety of freshwater habitats, oil types, and spill conditions. Seven habitats were identified in the original workshop discussions. In turn, these were subdivided during work sessions, which resulted in a total of ten primary habitats for the manual.

- large rivers
- small rivers and streams

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**Table 1. Relative sensitivity of freshwater habitats**

| |
|---|
| High |
| Wetlands, swamps, and marshes |
| Mud shorelines |
| Medium-high |
| Small rivers, streams |
| Medium |
| Large rivers |
| Inland lakes and ponds |
| Great Lakes, nearshore |
| Sand and gravel shorelines |
| Low-medium |
| Great Lakes, open water |
| Low |
| Rock shores and man-made structures |

- Great Lakes
  - open water
  - nearshore
- inland lakes and ponds
- marsh/wetlands
- rock shorelines or man-made structures
- gravel shorelines (coarse-grained beaches/river bars)
- sand shorelines
- mud shorelines

Note that the Great Lakes are considered in terms of open water and nearshore habitats.

**Table 2. Characteristics of the four representative oil types**

| |
|---|
| Type A1. Light fuel oils (No. 1, gasoline, kerosene) |
| spreads rapidly |
| low viscosity |
| very volatile, highly flammable (flash point: ~100° F/40° C) |
| specific gravity: 0.65 to 0.8 |
| high evaporation rates |
| highly toxic to biota; acute toxicity determined by content and concentration of aromatic fractions |
| emulsions are unstable |
| tends to penetrate substrate |
| Type A2. Medium grade fuel oils (No. 2, No. 4, diesel) |
| low to moderate viscosity |
| flash point: No. 2 fuel oil, 130° to 150° F; diesel fuel 1-D, 100° F; diesel fuel 2-D, 125° F |
| specific gravity: No. 2 fuel, 0.840 to 0.874; diesel fuel, 0.827 to 0.838 |
| toxicity varies depending on light ends |
| tends to form stable emulsions |
| variable substrate penetration |
| oil on shoreline tends to smother organisms |
| Type B. Medium grade crude oils |
| moderate viscosity |
| flash point: 20° to 90° F |
| specific gravity: >.70 to >.96 at 60° F/15° C |
| aromatic hydrocarbon content range: <0.5 to 1.0% by weight |
| variable toxicity depending on amount of light ends |
| sulfur content by weight: 0.1 to 5.5% |
| tends to form stable emulsions |
| variable substrate penetration |
| oil on shoreline tends to smother organisms |
| Type C. Heavy fuel oils (bunker C, No. 6) |
| moderate to high viscosity |
| flash point: >150° F |
| specific gravity: 0.964 to 0.986 |
| toxicity is low relative to other categories of oil |
| very little penetration of substrate |
| may become less viscous when exposed to sunlight, forms stable emulsions |
| oil on shoreline will smother organisms |

Response techniques are described for protection, cleanup, and treatment methods. Each technique was evaluated as a countermeasure for four oil types: gasoline, diesel/No. 2 fuel oil, medium grade crude, and bunker C/No. 6 fuel oil. Furthermore, each technique was evaluated for three degrees of impact from each oil type: low, moderate, and high oiling.

Specifically, the manual provides a description of protection and cleanup techniques, summary tables that indicate the intrinsic impact of a particular technique on habitats in the absence of oil, decision trees for protection and cleanup, and protection and cleanup summary matrices for habitats and for four oil types.

Sections for each habitat contain a description of the habitat, a relative sensitivity ranking, and a matrix of response options in terms of impact on the habitat and recommendation for use of each method for each of the four oil types.

## Assumptions and restrictions on use of techniques

During the course of the workshop, and in preparation of the manual, several assumptions were made.

**Proper application of techniques.** It is assumed that techniques 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 could render it ineffective or cause additional damage.

**Ranking of impact of techniques.** Techniques were evaluated as first response methods. In an actual response, however, the methods cannot be evaluated in isolation from each other. During any spill, a decision must be made regarding whether any protection or cleanup is advisable. The first comparison that must be made is between the probable ecological impacts of oil left untreated in the environment (natural recovery) and the probable impact of the oil plus the response technique(s). If the response reduces the impacts or accelerates the recovery, in comparison to leaving the oil alone, the technique would be considered appropriate.

**Relative effectiveness of techniques.** A response technique should be

**Table 3. Possible response activities**

| |
|---|
| Natural recovery |
| Protection methods |
| Barriers/berms |
| Booming |
| Dispersants |
| In situ burning |
| Skimming/vacuum recovery |
| Water-jet herding |
| Cleanup methods |
| Cleaning/washing |
| Flooding |
| High-pressure cold water flush |
| High-pressure hot water flush |
| Low-pressure cold water wash |
| Low-pressure hot water wash |
| Sand blasting |
| Steam cleaning |
| Physical removal |
| Manual removal |
| Sediment removal |
| Sorbents |
| Vegetation removal/cropping |
| Treatment |
| Beach cleaners |
| Dispersants |
| Land farming |
| Natural microbe seeding |
| Nutrient enrichment |
| Oil herders |
| Shoreline pretreatment |
| Visco-elastic agents |

effective—that is, it must remove a significant amount of oil from the environment or prevent or reduce contamination. Prolonged use of an inefficient technique may be more detrimental than short-term use of a potentially more damaging approach.

**Restrictions for use of techniques.** Restrictions related to weather, spill size, or regulatory status cover a wide spectrum of scenarios. It is not practical to discuss every possible situation or combination of factors in a set of guidelines or a manual. Some of this information, if appropriate, is included in the discussion under each habitat or in the general discussion of each technique in the protection and cleanup tables. The study focuses on environmental factors only and in a spill situation many other considerations come into play, such as aesthetic, social, and economic inputs.

## Ranking of oil response methods

The ranking used in the manual does not necessarily reflect the best way to clean up oil, but rather should be used as an indicator of the environmental impact expected as a result of implementing an effective method. Rankings follow the general format established for the marine oil spill response manual,[1] and use the same four categories.

- **Preferred**—causes the least habitat impact
- **Viable**—useful, but can cause some habitat impact
- **Not advisable**—could be applicable, but may cause significant adverse habitat impact
- **Avoid**—unacceptable or ineffective method, use would always cause significant adverse habitat impact

These rankings were discussed by the individual working groups for each oil type in each habitat, bearing in mind the potential impact of using a certain technique within the habitat. The following criteria were used to establish the impact of a technique.

- **Low**—restabilization or repopulation of the habitat would occur within 6 months, impact on the sediment is negligible, damage to substrate and vegetation is minimal
- **Moderate**—restabilization or repopulation of the habitat would take 6 to 12 months, obvious damage to the substrate or vegetation, erosion potential is increased by use of the technique
- **High**—restabilization or repopulation of the habitat would take more than 12 months, erosion potential is high for the technique, extensive damage to substrate or vegetation is expected from use of the method

**Table 4. Draft matrix of the impact of a technique in the absence of oil[1]**

| Cleanup method | Large rivers | Small rivers | Great Lakes: Open water | Great Lakes: Nearshore | Inland lakes | Rock | Gravel | Sand | Mud | Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|
| Protection | | | | | | | | | | |
| Booming | L | L | L | L | L | L | L | L | L | L |
| Skimming/vacuum | L | L | L | L | L | L | M | — | H | L |
| In-situ burning | L | H | L | L | H | H | H | H | H | M |
| Water-jet herding | L | — | L | L | — | — | — | — | — | — |
| Air blowers | L | — | — | — | L | — | — | — | — | — |
| Barriers/berms | M | H | — | — | M | H | H | L | H | M |
| Natural recovery | L | L | L | L | L | L | L | L | L | L |
| Cleaning/washing | | | | | | | | | | |
| Flooding | L | M | — | — | L | L | M | L | L | L |
| Low-pressure cold water flush | M | L | — | — | L | L | M | M | H | L |
| High-pressure cold water flush | H | M | — | — | H | L | H | H | H | H |
| Low-pressure hot water flush | H | H | — | — | M | M | H | H | H | H |
| High-pressure hot water flush | H | H | — | — | H | M | H | H | H | H |
| Steam cleaning | H | H | — | — | H | M | M | H | H | H |
| Sand blasting | H | M | — | — | H | H | H | — | — | H |
| Physical removal | | | | | | | | | | |
| Manual oil removal | M | M | — | — | H | M | M | L | H | H |
| Sorbents | L | L | L | L | L | L | L | L | M | L |
| Sediment removal | H | H | L | H | H | L | M | M | H | H |
| Vegetation removal | H | M | L | L | H | H | L | H | H | H |
| Subsurface collection | — | H | — | — | — | — | — | — | — | — |
| Excavation | H | H | — | — | — | — | — | — | — | — |
| Treatment | | | | | | | | | | |
| Land farming | H | H | — | — | H | L | M | L | H | H |
| Nutrient enrichment | L | L | L | L | M | L | L | L | L | L |
| Natural microbe seeding | L | L | L | L | L | L | L | M | M | L |
| Dispersants | L | H | L | L | H | H | H | H | H | L |
| Shoreline pre-treatment | H | H | — | — | H | H | H | — | — | — |
| Beach cleaners | M | H | — | — | H | M | M | M | M | — |
| Oil herders | L | H | L | L | M | H | H | — | — | — |
| Visco-elastic agents | H | L | L | L | M | M | M | — | — | — |

1. Entries defined in footnote to Table 5.

## Habitat Sensitivity

Habitats should not be considered in isolation. For example, if the use of booms around an opening into an enclosed bay would divert oil to a marsh, then the sensitivity of the marsh also should be considered. Biologically sensitive areas, such as marshes, should be identified and protected in preference to less sensitive areas. Based on published information and discussions during the workshop, a ranking of the relative sensitivity of each habitat was developed (Table 1).

## Human health effects

Effects of protection and cleanup methods on human health were flagged but not evaluated during the workshop. However, a companion API-sponsored literature review and report on state-of-the-art knowledge on inland spills (in preparation) includes assessments of response techniques and impacts on human health. Information from that study has been added to results of the workshop and is included in the manual.

## Oil types

Oil spills can involve a variety of crude oils and a wide range of refined products. Inland oil spills are more likely to involve refined product; however, inland pipeline spills could involve crude oils. Generally, refined products such as fuel oil or gasoline have greater concentrations of toxic components than crude oil; spills of lighter refined products would likely have a more acute ecological impact. The problem of persistence must be considered for heavier products and crude oils.

Because of the volatility of lighter refined products, their visual impact may be less than their ecological impact. Conversely, spills of heavier products and crude oil may have a greater visual than ecological impact. A careful analysis of all factors is necessary during each oil spill response. The most important considerations are location, season, oil type, volume, toxicity, and the duration of exposure.

Four oil types are used in the manual (light fuel oils, medium grade fuel oils, medium grade crude oils, heavy fuel oils) as they are representative of the range of oils which may threaten inland habitats (Table 2). Weathering will tend to change the character of the oil being handled from a lighter to a more viscous material. Methods selected for

**Table 5. Draft matrix of protection/cleanup methods and habitat impact for wetlands**

| Method | Habitat impact$_2$ | Method evaluation$_1$ Oil type A1 | Oil type A2 | Oil type B | Oil type C |
|---|---|---|---|---|---|
| Preferred methods (P)$_3$ | | | | | |
| Booming | L | V | P | P | P |
| Skimming/vacuum | L | V | V | P | P |
| Natural recovery | L | P | P | P | P |
| Flooding | L | P | P | P | P |
| Low pressure cold water flush | L | V | P | P | V |
| Viable methods (V)$_3$ | | | | | |
| In-situ burning | M | V | V | V | V |
| Barriers/berms | M | V | V | V | V |
| Sorbents | L | V | V | V | V |
| Nutrient enrichment | L | V | V | V | N |
| Non-advisable methods (N)$_3$ | | | | | |
| High pressure cold water flush | H | A | A | N | N |
| Manual oil removal | H | A | N | N | N |
| Sediment removal | H | N | N | N | N |
| Vegetation removal | H | N | N | N | N |
| Land farming | H | N | N | A | A |
| Natural microbe seeding | L | N | N | N | N |
| Dispersants | L | A | N | N | A |
| Visco-elastic agents | — | N | N | N | A |
| Avoid—unacceptable method (A)$_3$ | | | | | |
| Low-pressure hot water flush | H | A | A | A | A |
| High-pressure hot water flush | H | A | A | A | A |
| Steam cleaning | H | A | A | A | A |
| Sand blasting | H | A | A | A | A |
| Shoreline pre-treatment | — | A | A | A | A |
| Beach cleaners | — | A | A | A | A |
| Oil herders | — | A | A | A | A |

*Notes:* (1) The four Oil types are defined in Table 2.
(2) The following Cleanup Method vs. Habitat Impact definitions apply to this matrix: L (Low)—Restabilization and/or repopulation of the habitat will occur within 6 months, impact of cleanup method on sediment erosion is negligible, damage to substrate and vegetation is minimal; M (Moderate)—Restabilization and/or repopulation of the habitat will take 6 to 12 months, obvious damage to substrate and/or vegetation, erosion potential from cleanup method is increased; H (High)—Restabilization and/or repopulation of the habitat will take more than 12 months, erosion potential high due to selected cleanup method, extensive damage to substrate and/or vegetation
(3) The following are four recommendations to be used (1 ea.) in every box of the matrix. They describe the comparison of cleanup method impact vs. type of oil (given the variable of low/mod/high oil impact): P—Preferred method, causes the least habitat impact; V—Viable method, useful, but can cause some habitat impact; N—Not an advisable method, may cause significant adverse habitat impact; A—Avoid, unacceptable method, use could always cause significant adverse habitat impact

use during an initial response should be reevaluated as time elapses and as the material being handled changes in character. To some extent this may be achieved by using the four tables on oil type in sequence, simulating the weathering process.

## Inland oil spill response methods

Prior to the API inland spills workshop, a list of available techniques to consider for protection and cleanup of oil spills in inland environments was identified (Table 3). The methods listed may be considered, under various conditions, for both protection and cleanup aspects. Protection means keeping oil out of a habitat or reducing the amount that enters. Cleanup involves removal and/or treatment of oil. In most spill response situations, protection should be the primary goal. It would be noted, however, that cleanup of one habitat may represent protection of another, more sensitive habitat. Combinations of protection and cleanup techniques are used commonly, though the guidelines described in this manual treat each technique separately. Interactive impacts of combined techniques are not discussed; for example, the link between booms and skimmers or booms and vacuum systems.

Although the list is not necessarily inclusive, it represents most technologies under consideration at the time of publication, recognizing that certain technologies are not approved, or require special authorization for their use. Sinking agents were initially included in the discussions, but subsequently dropped from the list of methods. Each technique was discussed for suitability to habitat and ranked according to its potential ecological effects.

## Summary matrices of response techniques and habitats

In the manual, a set of matrices provides overviews of (1) the recommended protection and cleanup methods for (2) the four different oil types on (3) each of the ten habitats. These matrices form the body of the manual. At the time of writing, these matrices are in review and, therefore, do not necessarily represent the final recommendations. As such, the results and findings do not necessarily represent the opinions or views of either API or Woodward-Clyde. Table 4 presents one example of the matrices which relates protection and cleanup methods to habitat sensitivity without the presence of oil. The manual contains four additional matrices that relate the impact of the response methods to the ten habitats for each of the four oil types. This relationship should be taken into consideration in deciding whether the response activities would be more harmful than the oil alone, and whether the response activities could mitigate the effects of the oil and/or accelerate the rate of recovery from the oiling.

Table 5 is a draft version of one of the ten matrices in the manual (one for each primary habitat). The four oil types are defined in Table 2. Habitat impact evaluation and method evaluation definitions have been discussed earlier in this text.

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