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Manual of Practice for Protection and Cleanup of Shorelines:

Volume I
Decision Guide

Interagency Energy/Environment R&D Program Report

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MANUAL OF PRACTICE FOR PROTECTION AND CLEANUP OF SHORELINES

Volume I
Decision Guide

by

Carl R. Foget, Eric Schrier,
Martin Cramer, and Robert Castle
Woodward-Clyde Consultants
Three Embarcadero Center, Suite 700
San Francisco, California 94111

Contract No. 68-03-2542

Project Officer

Leo T. McCarthy, Jr.
Oil and Hazardous Materials Spills Branch
Industrial Environmental Research Laboratory
Edison, New Jersey 08817

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

FOREWORD

When energy and material resources are extracted, processed, converted and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This manual, a product of the above efforts, is structured to provide the field user, guidelines to determine which shoreline protection, clean-up and restoration techniques would be most effective for a given shoreline and oil spill situation. This project is part of the continuing program of the Oil & Hazardous Materials Spills Branch, IERL-Ci, to assess and mitigate the environmental impact of oil spills.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The purpose of this manual is to provide the On-Scene-Coordinator (OSC) with a systematic, easy to apply methodology that can be used to assess the threat of an oil spill and select the most appropriate protection and cleanup techniques.

This manual is structured to provide a decision-making guide to enable the user to determine, for a given oil spill situation, which protection and cleanup techniques would be most effective for a specific shoreline type. A detailed discussion of the factors involved in the decision-making process is also given and includes oil characteristics, behavior and movement of oil, shoreline characterization and sensitivity, protection and cleanup priorities and implementation requirements, and impacts associated with cleanup operations. The manual also presents criteria for terminating cleanup operations and a discussion on handling of oily wastes.

This manual was submitted in fulfillment of Contract No. 68-03-2542 by Woodward-Clyde Consultants under the sponsorship of the U.S. Environmental Protection Agency.

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SECTION 100

INTRODUCTION

Purpose

When a major oil spill occurs, it usually involves contamination of coastal or inland shorelines, which can result in serious environmental and economic damage. Such damage can be significantly reduced if proper protection and cleanup actions are taken promptly.

The purpose of this manual is to provide the on-scene coordinator (OSC) and his staff with a systematic, easy-to-apply methodology that can be used to assess the threat or extent of shoreline contamination and to choose the most appropriate shoreline protection/cleanup procedures for each shoreline contamination event.

Use of Manual

This manual of practice for protection and cleanup of shorelines is designed as a guide for determining the protection and restoration techniques that would be most effective for specific spill situations. The manual is divided into two volumes as illustrated below: Volume I, Decision Guide,

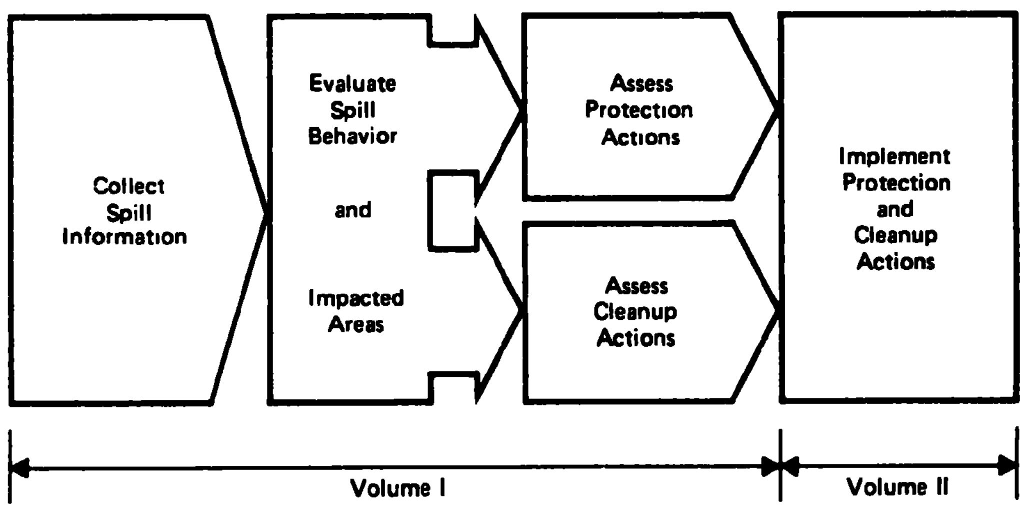

Figure 100-1. Manual organization.

gives instructions on how to gather information on a spill, assess the type and extent of a spill and decides which protection and cleanup actions are appropriate; Volume II, Implementation Guide, presents background information on oil characteristics and shoreline processes, and gives detailed instructions on how to implement various protection and cleanup procedures.

Figure 100-2 is a flow chart which illustrates the proper use of the manual. Starting with the initial information received concerning a spill, the user can progress through the various information and decision points indicated on the flow chart. Each of these points represents one or more subsections of the manual in which instructions are given for conducting a specific evaluation or decision making.

Section 200 provides information checklists that should be filled out for each discrete section of shoreline* threatened or contaminated by oil. The questions asked in the checklists are intended to provide information needed to make decisions in other sections of the manual.

Section 300 gives procedures for estimating the volume, nature, and character of the spilled oil and predicting where it will move and what shoreline it will threaten.

Once the nature and direction of the oil spill have been estimated, the next step is to determine the types and vulnerability of the threatened shorelines. In Section 400, information and decision guides are provided to classify coastal shorelines as to sediment type, energy level, exposure, access, and sensitivity to oil contamination. Section 700 discusses similar factors for shorelines on inland waters.

Protection of shorelines that are threatened but not yet contaminated by an oil spill is the next action to consider. Section 500 describes how to determine which shoreline areas need protection most (i.e., how to set priorities), how to select the protection technique most applicable to the particular spill situation, and how to implement the procedure selected.

Once protection measures are implemented, cleanup of oil-contaminated shorelines should commence. Through a series of decision guides, Section 600 describes the steps necessary to implement a shoreline cleanup program. First, priorities for cleaning each shoreline area are determined. Second, cleanup procedures for each shoreline area are selected, and those shorelines best left to natural cleaning are identified. Third, each cleanup procedure is evaluated to determine if the impacts associated with that cleanup technique are acceptable. Fourth, support requirements needed to implement each selected technique are assessed and compared with locally available equipment, personnel, and supplies. Finally, criteria are given to assist the user in determining when the cleanup is satisfactory and operations can be terminated. Guidelines are also given for establishing temporary waste-handling facilities.

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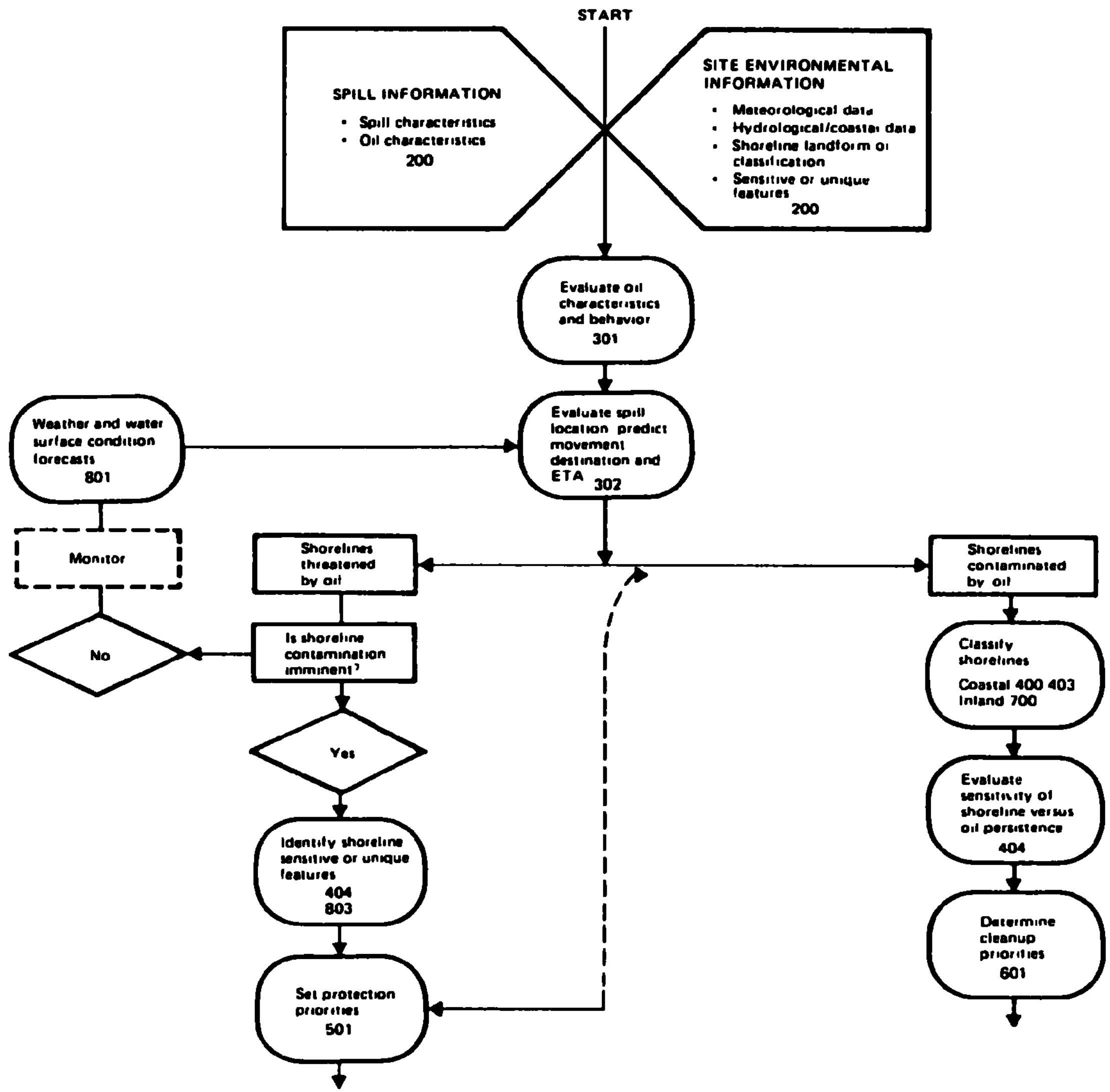
*A discrete section of shoreline is a continuous shoreline area which has a similar substrate along its length.

The appendices (Volume II) provide background information on data sources, oil characteristics, shoreline processes, and unique and sensitive features, and detailed instructions on how to conduct the protection and cleanup techniques identified in Sections 500 and 600.

Scope

This manual of practice describes proven state-of-the-art techniques, using manual or mechanical means, for the protection and cleanup of ocean estuarine and inland shorelines. Techniques which are considered experimental or have not been proven during an oil spill are not considered in this manual. The protection and cleanup of marshes and mangroves is not included in this manual but is the subject of a separate manual of practice published by the Environmental Protection Agency. The use of chemical agents for protection and/or cleanup of a shoreline are not covered in this manual and are also the subject of a separate EPA manual.


START
SPILL INFORMATION
• Spill characteristics
• Oil characteristics
200
SITE ENVIRONMENTAL INFORMATION
• Meteorological data
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• Shoreline landform or classification
• Sensitive or unique features
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Evaluate oil characteristics and behavior
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801
Evaluate spill location predict movement destination and ETA
302
Monitor
Shorelines threatened by oil
Shorelines contaminated by oil
No
Is shoreline contamination imminent?
Yes
Identify shoreline sensitive or unique features
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803
Set protection priorities
501
Classify shorelines
Coastal 400 403
Inland 700
Evaluate sensitivity of shoreline versus oil persistence
404
Determine cleanup priorities
601

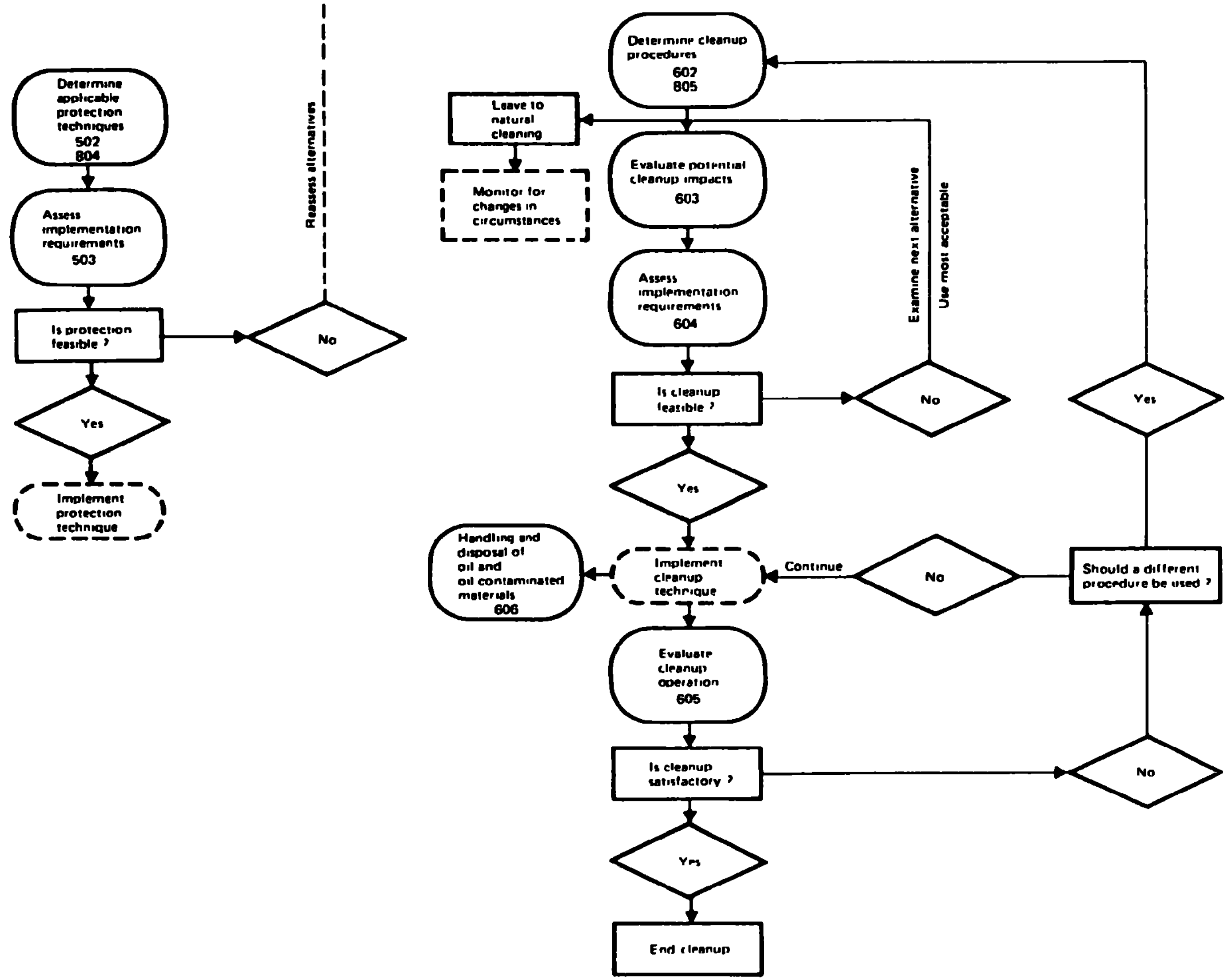


Figure 100-2. Decision flow chart for protection and restoration of shorelines. (Note: The numbers in each box refer to section of the manual.)

SECTION 200

INFORMATION CHECKLIST

Before shoreline protection and cleanup efforts are initiated, information about the spill and the affected or potentially affected area should be collected. Much of this information can be collected before an incident occurs by the preparation of comprehensive local contingency plans. The following checklists (Tables 200-1 and 200-2) call for the information that will assist the user in the selection of protection or cleanup methods and determination of priorities. Those sections in the manual that more fully describe the key words used in the checklists are noted next to the general category headings.

The checklist shown in Table 200-1 calls for general information about the spill itself. Time, location, and volume of the spill and characteristics of the oil will be used in determining the extent of the spill and its shoreline contamination potential. Meteorological and oceanographic data form the basis for predicting movement of the spill and, in turn, implementing effective protection measures and mobilizing cleanup equipment and crews.

The checklist shown in Table 200-2 calls for information on the specific shoreline areas that have been or may be contaminated by the spill. A separate checklist should be filled out for each discrete shoreline area. The list requires information on the general physical character and special or unique features of the shoreline, hydrological character of the nearshore area, extent of contamination, and additional features applicable to protection and/or cleanup decisions.

Most of the information required by the checklists can be obtained from aerial (ideally by helicopter on initial overflight), vessel, and/or land reconnaissance of the spill site and associated shoreline areas. These checklists should be used in conjunction with maps and overlays. Sources for information not obtained by reconnaissance are given in Section 801.

TABLE 200-1. GENERAL DATA CHECKLIST

SPILL DATA

Apparent Source: ______________________________

Time and Date: ______________________________

Location: ______________________________ (plot on chart or overlay)

Is spill continuing? Yes ___ No ___

Volume of Discharge Known ______________ (barrels/or gal)

(rate if continuing): Estimated ______________ (barrels/or gal/day)

Maximum Spill Potential: ______________ (barrels/or gal)

Size and Location of Slick(s): (Plot on Chart or Overlay)

Direction of Slick Movement: ____________

Oil Type: A___ B___ C___ D___ (Section 301)

METEOROLOGICAL DATA (Section 302)

Air Temperature: ____________ °C (or °F)

Wind: Speed ________ Direction ________

Precipitation: None ______ Rain ______ Snow ______

Visibility: Good ______ Fair ______ Poor ______

Forecast: ______________________________

____

____

OCEANOGRAPHIC DATA (Section 302)

Water Temperature: ____________ °C (or °F)

Water Current: Speed________ Direction ________

Sea State: 1___ 2___ 3___ 4___ 5___

ADDITIONAL INFORMATION

____

____

____

____

____

TABLE 200-2. SHORELINE INFORMATION CHECKLIST

Beach Name____________________ Location____________________

<u>GENERAL DESCRIPTION</u> (Section 401)

Length and Width:
Intertidal: __________Long (m or ft),__________Wide (m or ft)
Backshore: __________Long (m or ft),__________Wide (m or ft)

Substrate:	(1)	(2)	(3)
Type:	________	________	________
Depth:	________	________	________

Shoreline Exposure: Exposed______ Sheltered ______

Energy Level: High________ Low________

Type of Access: (Plot on Map Overlay)
Land: Heavy Equip. _____ Vehicular _____ Foot _______
Water: Barge or LCM _____ Small Craft _____ Swim _______

Sensitive or Unique Features (Plot on Map Overlay)

Biological:____

____

Physical:____

Cultural:____

Recreational Use: Type________________ Extent________________

<u>HYDROLOGICAL CHARACTERISTICS</u> (Section 803)

Wave Height: ________m (or ft)

Currents:
Tidal (Ebb): Speed________ Direction______ Duration_______
Tidal (Flood): Speed________ Direction______ Duration_______
Longshore: Speed________ Direction______

Tidal Range: __________m (or ft) rising ____falling___(moon phase)

Water Depth (nearshore): ________m (or ft)

Sediment Cycle:
Seasonal: Erosion________ Deposition______
Tidal: Erosion________ Deposition______

TABLE 200-2 (Continued). SHORELINE INFORMATION CHECKLIST

OIL CONTAMINATION (Section 302) (Plot on Map Overlay)

Degree of Contamination: High______ Low______
Migration Potential: High______ Low______
Depth of Penetration: __________ cm (or in)

FEATURES/CONFIGURATION FOR PROTECTION (Section 502) (Indicate on Map Overlay)

OTHER FEATURES (Section 803) (Plot on Map Overlay)

Trafficability: Good_____ Fair_____ Poor_____ Cone Index __________
Debris: Type________________________ Location______________________
Man-made Structures: Type ______________________________
Location ______________________________
Vegetation: Type ______________________________
Location ______________________________
Ice: Amount ______________________________
Location ______________________________

ADDITIONAL INFORMATION

SECTION 300

SPILL CHARACTERISTICS AND MOVEMENT

301 OIL CHARACTERISTICS AND BEHAVIOR

General

In defining an acceptable response to an oil spill incident, it is necessary to know certain physical and chemical characteristics of the oil involved. Typically, analytical data will not be available during an emergency, nor will it be relevant after a short time. It is therefore necessary and desirable to field-categorize oils as they react and change in the environment. Although they vary widely in properties, oils have common basic features that permit their grouping for predictive evaluation of environmental effects and determination of control actions.

Oil Classification

The following classification has been developed specifically for use in oil spill response. It considers general toxicity, physical state, and changes with time and weathering.

Class A: Light, volatile oils
Class B: Non-sticky oils
Class C: Heavy, sticky oils
Class D: Nonfluid oils

It is essential to recognize the dynamic nature of this classification. Some oils can rapidly undergo extensive modification of properties, whereas others may remain relatively unaffected over longer periods of time. For this reason, an oil can and often will, change characteristics sufficiently to be ranked in more than one of the above oil classes over time. In addition, types of oil can change with the time of day, becoming fluid during exposure to sunlight and solidifying during night and morning hours.

Representative oils, diagnostic properties, and physical chemical properties for each of these classes are summarized in Table 301-1.

Class A: Light, Volatile Oils. This class typically includes diesel oils and many light crude oils. These materials are generally flammable when fresh. Class A oils can be identified by high fluidity, clarity, rapid spreading rate, strong odor, and high evaporation rate. They do not tend

TABLE 301-1. SPILL RESPONSE OIL CLASSIFICATION

Field-Determined Oil Type	Designation	Representative Oils	Diagnostic Properties	Physical/Chemical Properties
A	Light volatile oils	Distillate fuel and most light crude oils	Highly fluid, usually transparent but can be opaque, strong odor, rapid spreading, can be rinsed from plant sample by simple agitation.	May be flammable, high rate of evaporative loss of volatile components, assumed to be highly toxic to marine or aquatic biota when fresh, tend to form unstable emulsions, may penetrate substrates.
B	Non-sticky oils	Medium to heavy paraffin-base refined and crude oils	Moderate to high viscosity, waxy or oily feel, can be rinsed from surfaces by low pressure water flushing.	Generally removable from surfaces, penetration of substrates variable, toxicity variable. Includes water in oil emulsions.
C	Heavy sticky oils	Residual fuel oils; medium to heavy asphaltic and mixed-base crudes	Typically opaque brown or black, sticky or tarry, viscous, cannot be rinsed from plant sample by agitation.	High viscosity, hard to remove from surfaces, tend to form stable emulsions, high specific gravity and potential for sinking after weathering, low substrate penetration low toxicity (biological effects due primarily to smothering). Will interfere with many types of recovery equipment.
D	Nonfluid oils (at ambient temperature)	Residual and heavy crude oils (all types)	Tarry or waxy lumps.	Nonspreading, cannot be recovered from water surfaces using most conventional cleanup equipment, cannot be pumped without pre-heating or slurrying, initially relatively nontoxic, may melt and flow when stranded in sun.

to adhere to surfaces and can be largely removed by flushing. This tendency can be experimentally determined by agitating an oiled sample (i.e., plant material) in water.

The lighter members of this class tend to evaporate entirely and quickly. Heavier Class A oils may partially evaporate, leaving a residue that falls into one of the other response classes. The tendency to penetrate porous surfaces is high, and in the case of contaminated substrate, the oil may be persistent. When fresh, volatile oils can be considered highly toxic. They generally form unstable emulsions.

Class B: Non-Sticky Oils. This class of oils includes medium to heavy paraffin-base oils and is distinguished by a waxy, oily or non-sticky feel. Although they adhere to plant and other surfaces, the oils of this class tend to be moderately removable by flushing. Their tendency to penetrate permeable substrates is variable, and increases as temperatures rise. Their toxicity is variable. When weathered or subjected to low temperatures, they may become solid and fall into the Class D category. Fluid, emulsified oils generally fall into this class.

Class C: Heavy, Sticky Oils. This class typically includes residual fuel oils and heavier asphaltic and mixed-base crude oils in the fluid state. Characteristically viscous, sticky or tarry, and brown or black in color, they cannot be readily removed from test samples of vegetation by agitation. After natural light ends and cutter stock evaporates from an oil, its toxicity tends to be lower. Biological effects are generally the result of smothering. Typically, the ability to penetrate substrates is low. Many Class C oils have a specific gravity near or exceeding that of water and may sink. Class C oils will weather to a tar- or asphalt-like consistency and then may be considered as Class D oils. Emulsions formed tend to be stable. Water in oil emulsions with high water contents may fall into Class C.

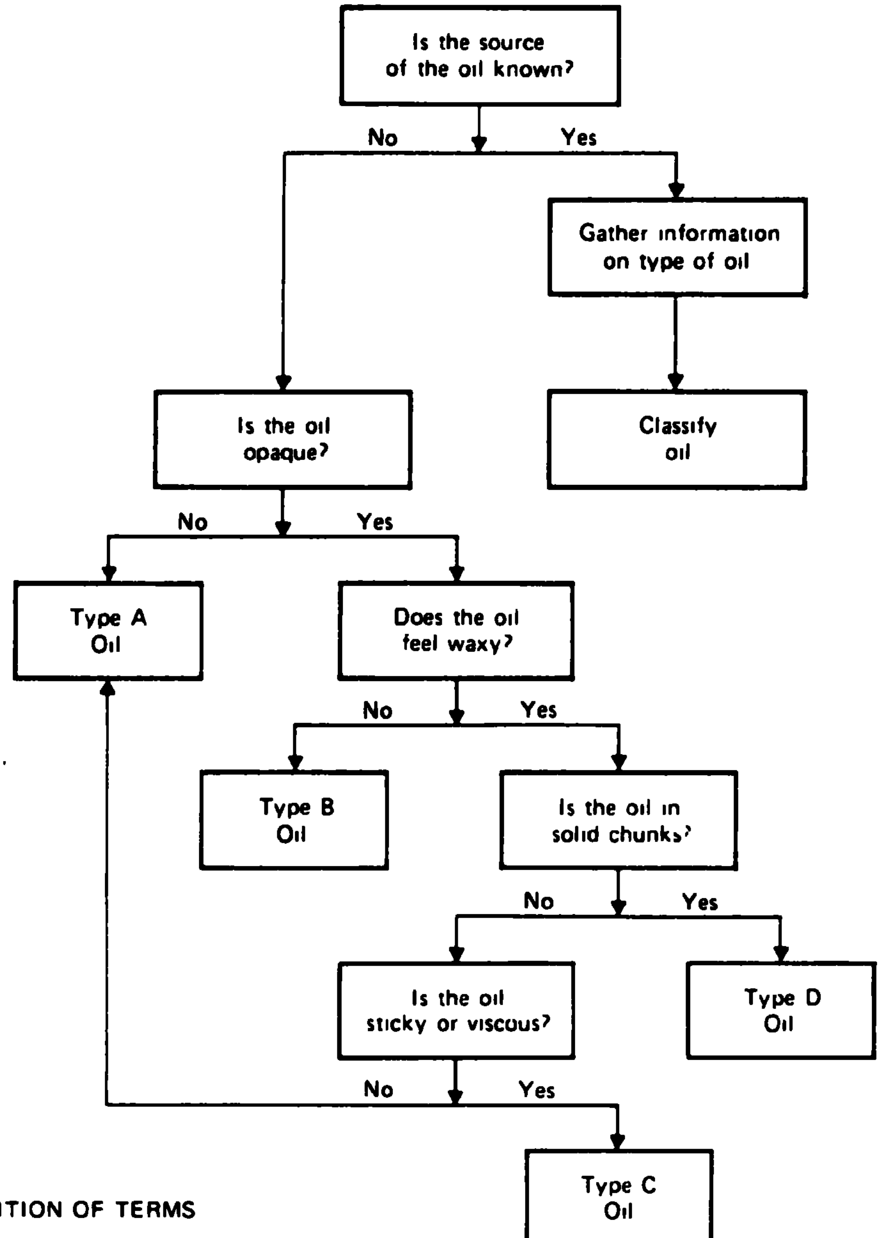
Class D: Nonfluid Oils. This class includes residual oils, heavy crude oils, some high paraffin crude oils, and weathered oils that are solid or nonfluid at spill temperatures. In the solid form, they are essentially nontoxic. When heated, many melt and contaminate adjacent areas. Some water in oil emulsions may become nonfluid.

Oil Identification

The criteria for field categorization of oil type are shown graphically in Figure 301-1. The key diagnostic factors are described on the lower left portion of the figure.

Estimation of Oil Contamination

Estimation of the degree to which a shoreline is contaminated by oil is subjective and can be difficult, depending primarily on the type of oil and beach substrate and the existing tidal and wave conditions. Oil tends to wash ashore in patches and streaks; only in cases of extremely heavy contamination does oil completely cover a shoreline. If the contamination



DEFINITION OF TERMS

OPAQUE	Cannot see through coating of oil
WAXY	Feels slick but is not sticky can be easily wiped off fingers or hand with a cloth, can be viscous
SOLID CHUNKS	Does not flow, can have solid consistency or be soft like putty
STICKY OR VISCOUS	Oil is very sticky and has a thick consistency, is not easily removed from hands or fingers without using detergents or cloth

Figure 301-1 Field identification of oil types.

is light, oil tends to be deposited in a narrow windrow along the high tide line, with occasional streaks or blotches occurring in the mid-tide zone.

Wave and tidal action also affect shoreline contamination, since they are the primary vehicles of oil deposition. During periods of high wave activity or large tidal ranges, oil is often deposited over a large area. The length of time oil has been on a beach is an important factor. Oil initially contaminating a beach will often remain on the surface; however, oil that has been on a beach for several days or longer will have time to penetrate the beach or be buried by sediments. Oil type is also important; Class A oils will usually quickly penetrate most sediment beaches, whereas Class B, C, and D oils will normally remain on the surface of sand on mud beaches when they first come ashore.

Appearance alone cannot be used to determine the amount of oil on a shoreline accurately. A sand or gravel beach might give the appearance of being slightly contaminated when the majority of oil has penetrated the substrate or has been buried by tidal and wave action. Therefore, when estimating the percent of a shoreline surface covered by oil, holes should be dug into a beach or cores taken to determine the amount and depth of oil penetration. Estimation of shoreline oil contamination is then done by combining estimates of the extent of surface oil contamination with an estimate of the depth of oil penetration as shown in Table 301-2. For example, 20 percent of the upper intertidal beach surface maybe oil-contaminated with oil penetration varying from 1 to 3 cm and a clean mid-intertidal area. Figures 301-2 to 301-7 show beaches with various amounts of oil contamination.

TABLE 301-2. WORKSHEET FOR ESTIMATING OIL CONTAMINATION OF SHORELINES

Beach Name	Amount of Oil Contamination			
	Location of Oil		Depth of Oil Penetration	
	Upper Intertidal % covered	Mid-Intertidal % covered	Upper Intertidal cm	Mid-Intertidal cm

Figure 301-2. Light oil contamination on a cobble bank.

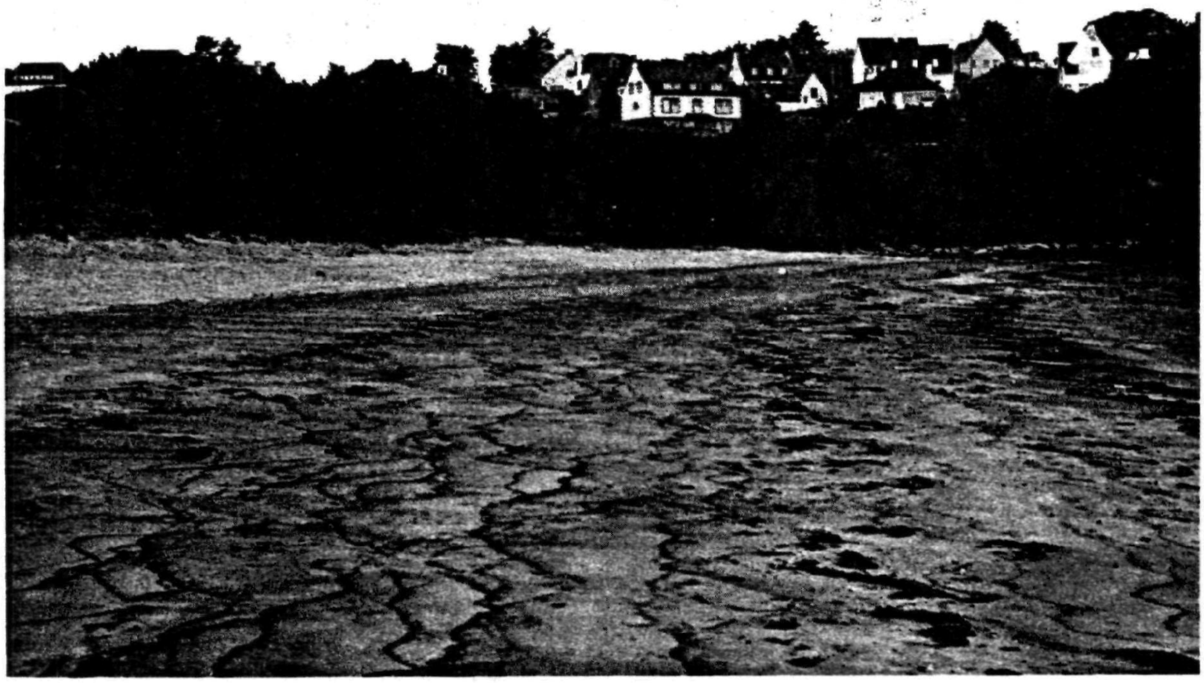


Figure 301-3. Light oil contamination on a sand beach.

Figure 301-4. Medium oil contamination on a boulder beach.

Figure 301-5. Light to medium oil contamination on a gravel beach.

Figure 301-6. Heavy oil contamination on a gravel beach.

Figure 301-7. Heavy oil contamination on a sand beach.

302 OIL SPILL MOVEMENT

General

The movement of oil spilled on water depends primarily on the effects of wind and the surface currents present near the site of the spill. Less important is the internal spreading of the slick itself.

When current and wind are absent, slick spreading will dictate the probable location of beach contact. However, the movement of a slick will be dictated by even weak wind or surface currents when they exist.

When spills threaten to affect shoreline areas, slick movement predictions can be used to determine the location of potential shoreline contamination and to direct the protection of sensitive areas. Data that are helpful for predicting oil spill movement (listed in order of importance) are: 1) surface current speed and direction, 2) wind speed and direction, and 3) oil spreading characteristics.

Another important aspect for the planning of oil spill response actions is the determination of the volume of oil involved. An accurate assessment of spill volume is needed for determining cleanup equipment requirements.

Prediction of Spill Movement

The National Oceanographic and Atmospheric Administration (NOAA) under the National Contingency Plan is assigned the responsibility for providing marine environmental data to the OSC. These data include current and predicted meteorological, hydrological, and oceanographic conditions for an area.

Prediction of oil slick movements by on-scene personnel can be accomplished by vector addition of the two main motive forces that apply: surface currents and winds. Surface currents will dominate spill movement unless the winds are extremely strong. Observations from actual spill situations have shown that the wind will cause an oil slick to move at about 3 percent of the wind speed, and in the same general direction. Figure 302-1 gives an example of the vector addition method of oil slick movement prediction; the general methodology of this technique is as follows:

1. Draw ocean current and wind component vectors in their relative directions and lengths (length of vector represents velocity: 10 mm = 0.1 km/hr).

2. Draw a line parallel to the wind vector starting from the tip of the current vector and measuring the exact length of the wind vector.

3. Draw a line from the point of origin (present oil slick position) to the tip of the parallel wind vector line drawn in Diagram 2 of Figure 302-1. This final line is the resultant vector that gives

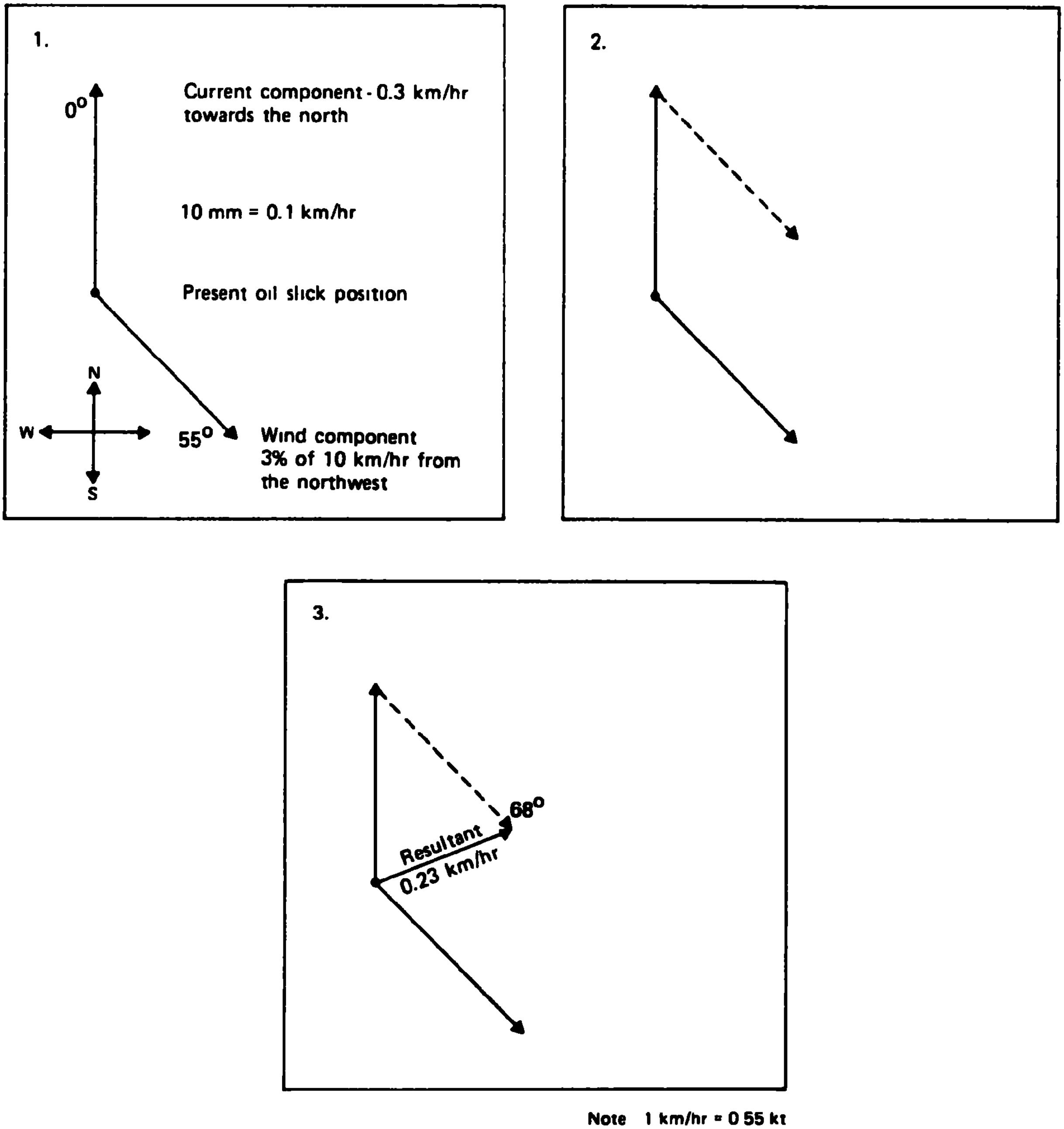


Figure 302 - 1. Vector addition for 10 km/hr NW wind and 0.3 km/hr north current.

the direction and speed of the oil slick movement. The direction can be measured by using the cardinal points of a compass. The speed is determined by the length of the resultant vector relative to the scale used in drawing the component vectors.

Aerial reconnaissance is a useful tool for predicting the time(s) and location(s) of spill contact. Separate observations can be compared to quantify the direction and amount of slick movement. The distance noted can be divided by the time between observations to obtain the speed and direction of slick movement.

Estimation of Spill Volume

A rough estimate of the total volume of the spill is desirable. Early in the response, total spill volume determines, in part, the equipment and manpower needed, and the requirements of the disposal site.

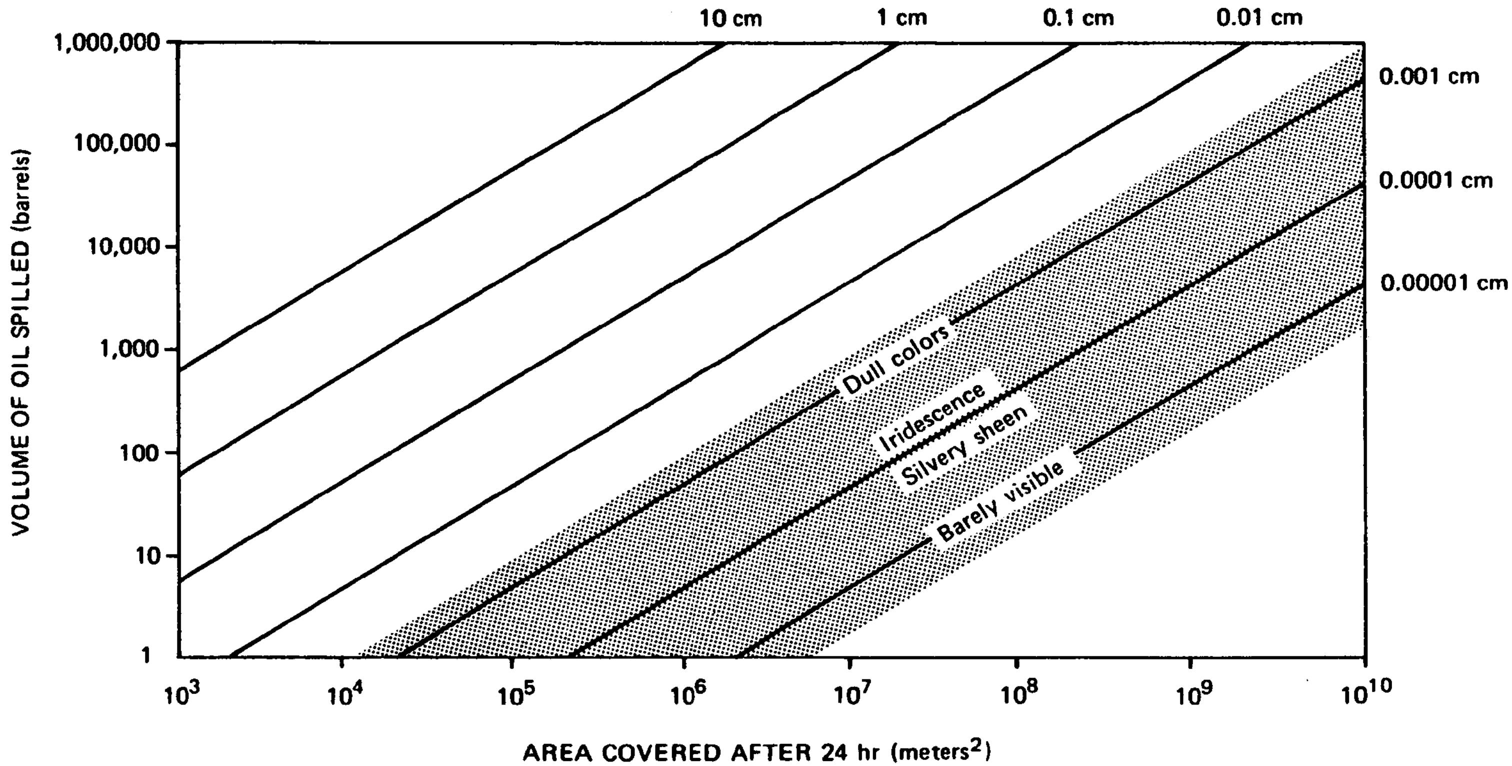
Because early estimates of spill size are often either unavailable or of questionable accuracy, onsite estimations are generally necessary. Several quick methods can be used to provide working approximations.

When a tanker or an oil barge suffers serious damage, e.g. owing to a collision or grounding, spill volumes can be estimated if the cargo capacity and extent of hull damage are known. Typically no more than two compartments will be breached during the first hours following an accident. A reasonable estimate of maximum probable spill size would be the volume of these tanks. For a barge, this would mean about one-fourth of its cargo and for a tanker approximately one-eighth. If the vessel cannot be off loaded and continues to breakup then its total cargo and on-board fuel can be considered the maximum spill volume.

If a spill occurs during oil transfer, the total spill volume can be estimated if the pumping rate and the elapsed time between leak commencement and transfer shutdown are known. The maximum transfer rate from a vessel to receiving facility multiplied by the length of time the pumping continued until shutdown may be assumed to be the spill volume for a complete transfer hose rupture or manifold failure. Spills resulting from improper flange makeup or from hose leaks would be likely to occur at significantly lower rates. Estimates of likely spill volumes from ruptured hoses are:

Large crude oil tanker	300 barrels
Product tanker	200 barrels
Barge	50 barrels

A rough estimate of spill volume can be attempted by considering slick size and thickness. Figure 302-2 relates the appearance of oil on water to its thickness. Slick thicknesses greater than 0.25 mm cannot be differentiated by appearance. A direct measurement of slick thickness would be preferable.



Shaded area indicates the range of oil slick observations for which thickness and area covered can be determined by appearance. Any value below the shaded area would not be visible, and any value above would be a dark brown or black.

Figure 302-2. Oil-spill volume, film thickness, appearance, and area covered.

Oil spills eventually cease to increase in area if the spill source is stopped. Figure 302-3 shows the radius to which an oil spill is expected to spread and the time it takes for the spill to attain these proportions for four spill volumes.

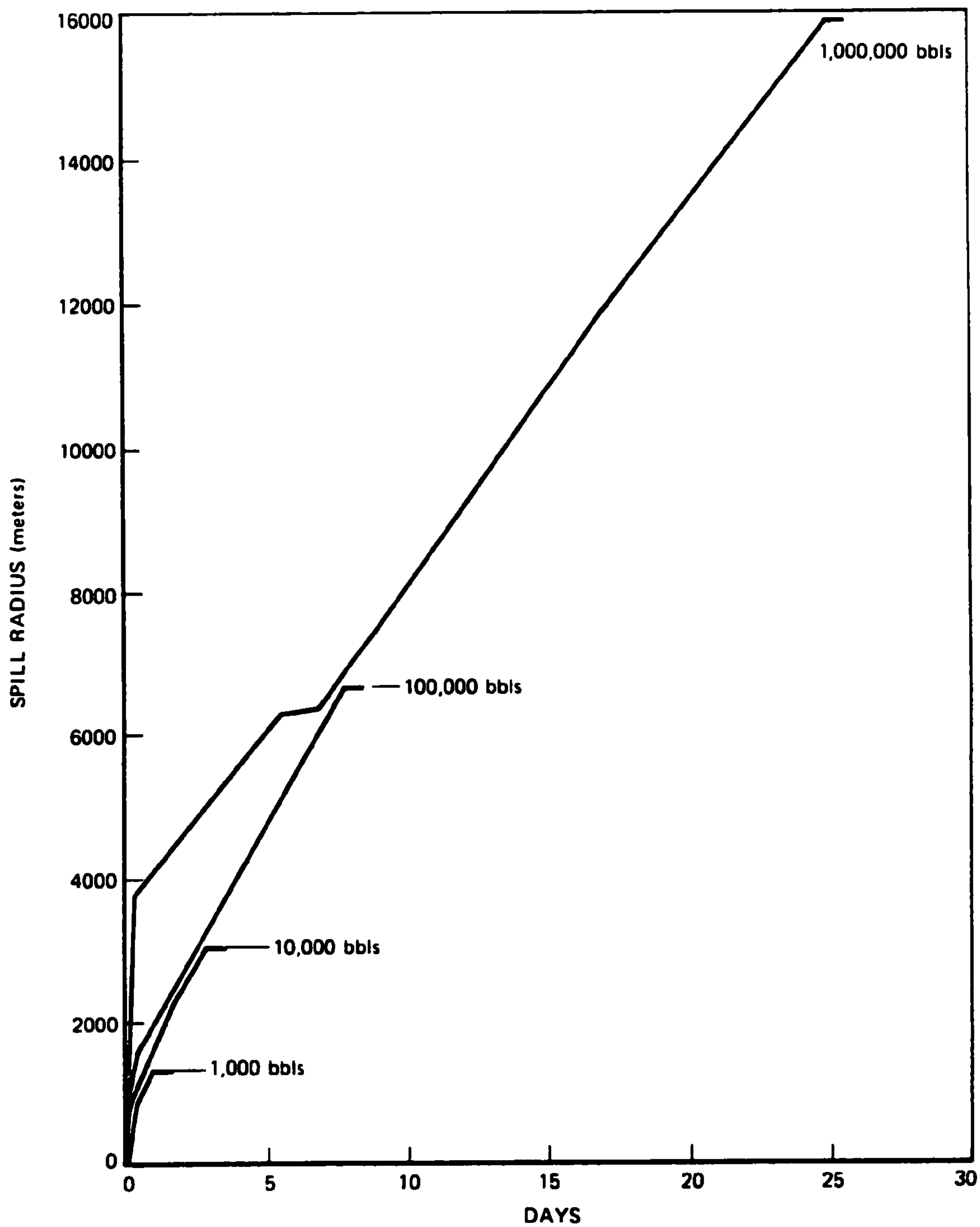


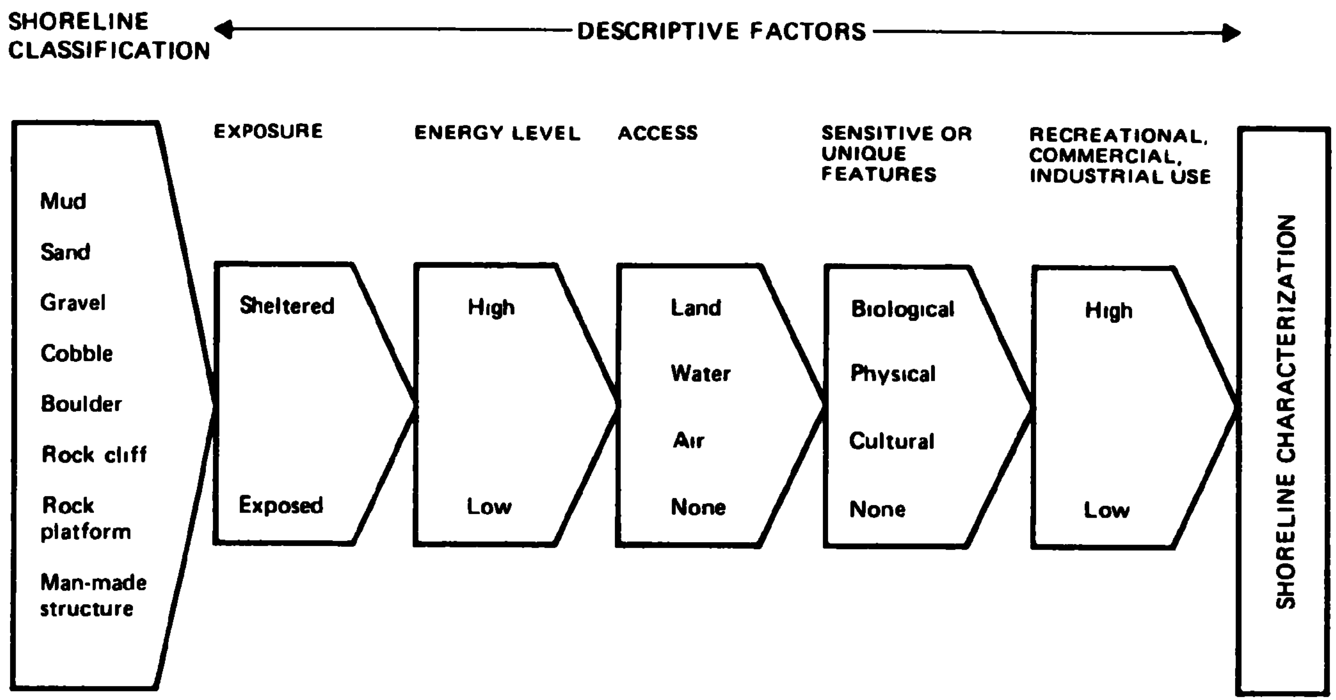
Figure 302-3. Maximum oil spill radius versus time (Fay-Hoult model).

SECTION 400

SHORELINE CHARACTERIZATION

401 INTRODUCTION

The type of shoreline, its uses and the environmental conditions at the time of an oil spill will affect the spills impact on the shoreline and the response which is required. Factors involved include substrate type, exposure, energy, and access. On occasion, sensitive and unique features and the recreational value of the shoreline must also be considered. When evaluating a shoreline, each of these components is identified separately and then related to provide the information needed to determine how and to what extent protection and cleanup operations should be conducted. Figure 401-1 identifies the important shoreline characteristics and illustrates how they are categorized.



Note Marsh lands are not included in this manual

Figure 401-1. Shoreline characterization.

402 SHORELINE CLASSIFICATION

Selection of cleanup alternatives (e.g., removal of the oiled substrate or removal of the oil from the substrate) and the expected persistence and impact of the oil on shore are dictated largely by substrate type. For use in oil spill response planning, shorelines may be classified by the following substrate catagories: mud, sand, gravel, cobble, boulder, rock, marine terrace, and man-made structures (marshlands are the subject of another manual and excluded from this discussion). If more than one substrate type is present, the most predominant substrate is listed first, the second most predominant next, and so on. For example, a beach area composed primarily of cobbles with some gravel zones would be classified as a cobble/gravel beach. Table 402-1 can be used as a guide to classify shoreline types. In addition to substrate classification, several descriptive factors are shown in Table 402-1 which are used to characterize shorelines.

TABLE 402-1. SHORELINE CLASSIFICATION

Substrate Type	Grain Size (mm)	General Descriptive Features
Mud	≤ 0.06	• ≤ 1° beach slope • Develop in areas where there is a source of fine material • Incised by a complex network of creeks and channels despite the generally flat surface • Saturated with water; even at low tide, the mud deposits are usually covered with a thin film of water that cannot drain through the closely packed sediments • Low bearing capacities frequently incapable of supporting the weight of a person
Sand	0.06-2.0	• 1°-40° beach slope • Subjected to seasonal erosion and deposition cycles as a consequence of the varying levels of incoming wave energy and to a lesser extent, ebb and flood tidal action • Closely packed substrate with a low water infiltration rate
Gravel	2.0-50	• Narrower and steeper beach slope than sand beaches • Storm ridges[a] often present to the landward side of the berm[a]
Cobble	50-256	• Narrower and steeper beach-face than gravel beaches • Rock fragments are somewhat rounded or modified by abrasion • Storm ridge usually present to the landward side of the berm
Boulder	≥ 256	• Detached rock masses that are somewhat rounded or otherwise distinctively shaped by abrasion in the course of transport • Typically located near the base of cliffs or rocky outcrops; often found on pocket beaches[a]
Rock cliffs	N.A.[b]	• Typically associated with emergent coastlines • Occur as a result of high relief in the coastal zone or because the unresistant rocks or unconsolidated material are rapidly eroded by littoral processes • Often little or no sediment accumulation at the cliff base allowing erosional processes to act directly on the cliffs
platforms	N.A.	• Typically occur in shallow waters at the base of rock cliffs • Sediment cover, if it occurs, does not provide a protective cover; wave- and tide-induced processes act directly on the rock surfaces
Man-Made Structures	N.A.	• Any structure found on a shoreline constructed or fabricated by man • Examples include piers, boat ramps, seawalls, groins, rock jetties, oil handling facilities, houses, etc.

[a]For definitions of storm ridges, berms, and pocket beaches, refer to Section 803.
[b]N.A. = not applicable.

403 DESCRIPTIVE FACTORS

Shoreline Exposure

Shoreline exposure will partially determine the potential for booming and the expected persistence of the oil. A shoreline can generally be classified as exposed or sheltered, depending on whether or not it is exposed to wind and waves and on the protection that may be provided by nearby land forms. The degree to which a beach is exposed varies among localities, so that there is a transition rather than a distinct difference between exposed and sheltered beaches.

Exposed shorelines are subjected to swell and storm waves or high currents with little or no protection from adjacent land forms. A shoreline along a straight, open coastline that receives the full force of wind and waves would be classified as exposed. Beaches located on exposed shorelines typically have a well-defined sequence - low tide terrace, beach slope, and berm - that results from the sorting of sediment grain sizes.

Sheltered shorelines are usually protected by land forms such as spits, sand bars, reefs, or peninsulas and usually have limited fetches, as shown in Figure 403-1. A shoreline that is located on the leeward side of a peninsula or sand bar, for example, would be classified as sheltered. Section 803 gives more detailed information on these shoreline processes.

Energy Level

The energy level of a shoreline will influence the extent and persistence of the oil, contamination, recontamination potential, and the effectiveness of booming. Energy level refers to the relative amount of energy being transmitted from wave, current, and tidal action to a shoreline.

In a high energy environment moderate or high amounts of energy are transmitted to the littoral zone throughout the year. These shorelines are usually open and exposed to swell and storm waves or to currents that can remove large amounts of sediment in a short time.

In a low-energy environment there is normally little or no wave, current, and tidal activity, although occasionally there may be intense storm-waves. These shorelines are usually protected or sheltered and have limited fetches.

In the marine environment, there are four types of water currents that could impart energy to a coastal area: wind-induced, oceanic, long-shore, and tidal. Wind-induced and oceanic currents are major factors in the movement of an oil spill on the open sea. Longshore currents, formed by waves approaching a shoreline at an angle, are the transporting force in sediment movement, beach erosion, and replenishment and oil migration from a contaminated shoreline. Tidal currents are not as significant in open water as they are in coastal inlets, intertidal channels, and estuaries. Where the water moves through constricted areas, current velocities during the ebb and flood

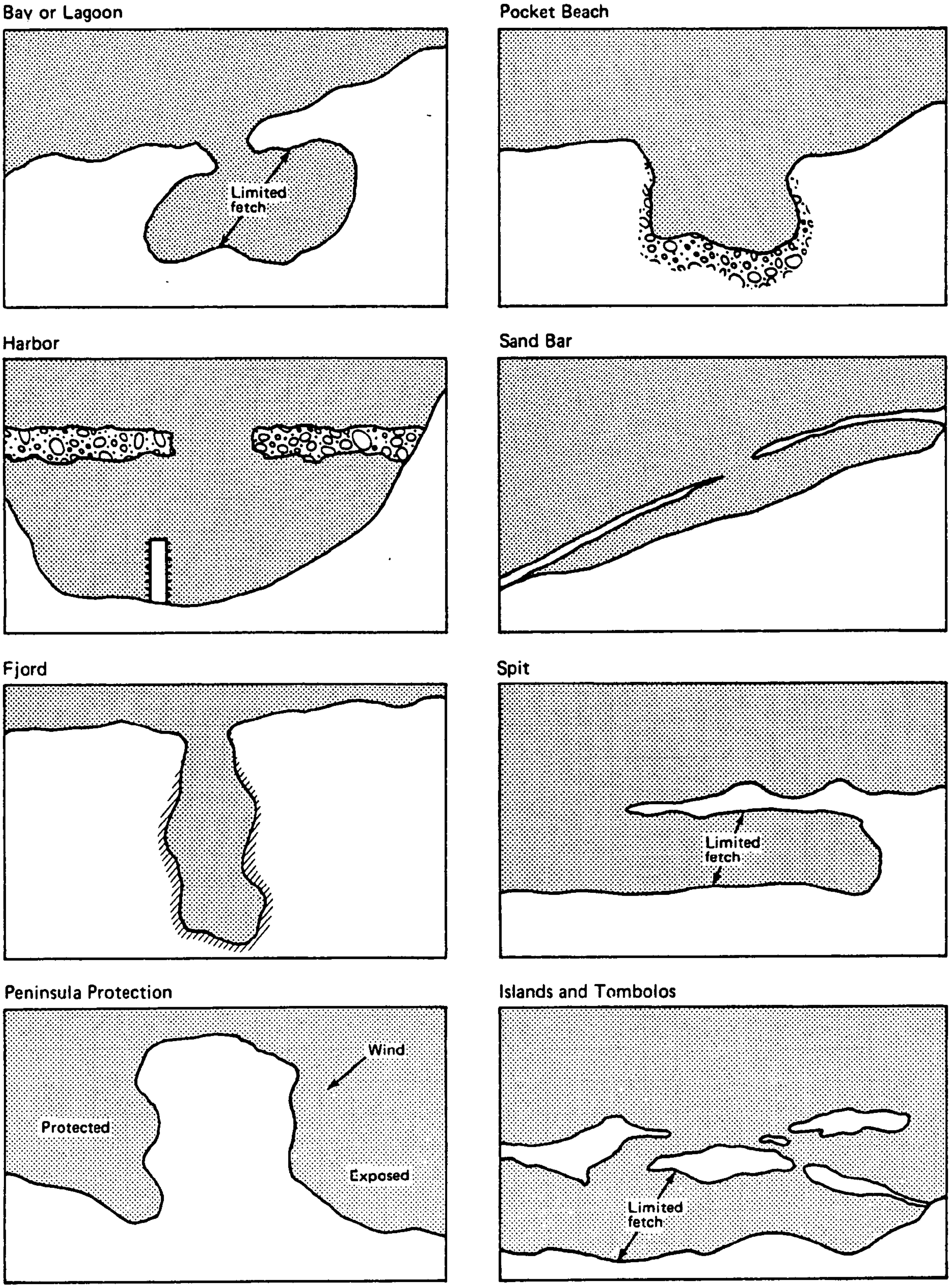


Figure 403-1. Typical shoreline landforms.

periods can be greatly increased. In general, high water currents can be expected in areas where water bodies narrow down, where deep water to shallow water transitions occur, and at stream entrances into larger bodies of water. Low water currents can be expected in large, calm bodies of water; in channel openings at right angles to the main current flow; and where there are small tidal ranges in shallow backwater areas. Figure 403-2 illustrates the effect of landform configuration on high and low current areas.

The shape of the shoreline sediments can often be used as an indicator of wave-energy levels. In sheltered or low-energy environments, the sediments tend to be angular or have few rounded edges. As levels of wave energy increase, abrasion of sediment particles against each other results in rounded material with no edges or flat faces.

Another indicator of the energy level on a beach is the degree of sorting (i.e., the degree to which different sizes of sediment are preferentially transported and deposited). On low-energy coasts, sediments are usually a poorly-sorted mixture of sands, pebbles, cobbles, and boulders. As energy levels increase, sorting of the material also increases, and the beach is composed of only one size of sediment or the sediments have a distinct zonation across the beach.

Shoreline Access

Any protection and cleanup actions must consider access. Shoreline access should be evaluated in terms of type, seasonality, and whether access can be improved by construction.

The three major types of access to a shoreline are land, water, and air. These can be further subdivided as follows:

Land access:

1. Heavy equipment access - paved, gravel, or dirt roads, sufficiently wide to allow passage for earthmoving equipment directly to the beach

2. Light vehicular access - narrow roads or trails that will allow passage of small trucks or four-wheel-drive vehicles to a beach

3. Foot access - narrow trails or paths down cliffs, through marshes or ravines, or across high relief topography that will allow personnel on foot access to a beach

4. No land access - no discernible trails, paths, or roads lead to the shoreline

Water access:

1. Barge or landing craft access - shoreline free from submerged obstacles with sufficient water depth to allow a landing craft or barge to ground on beach

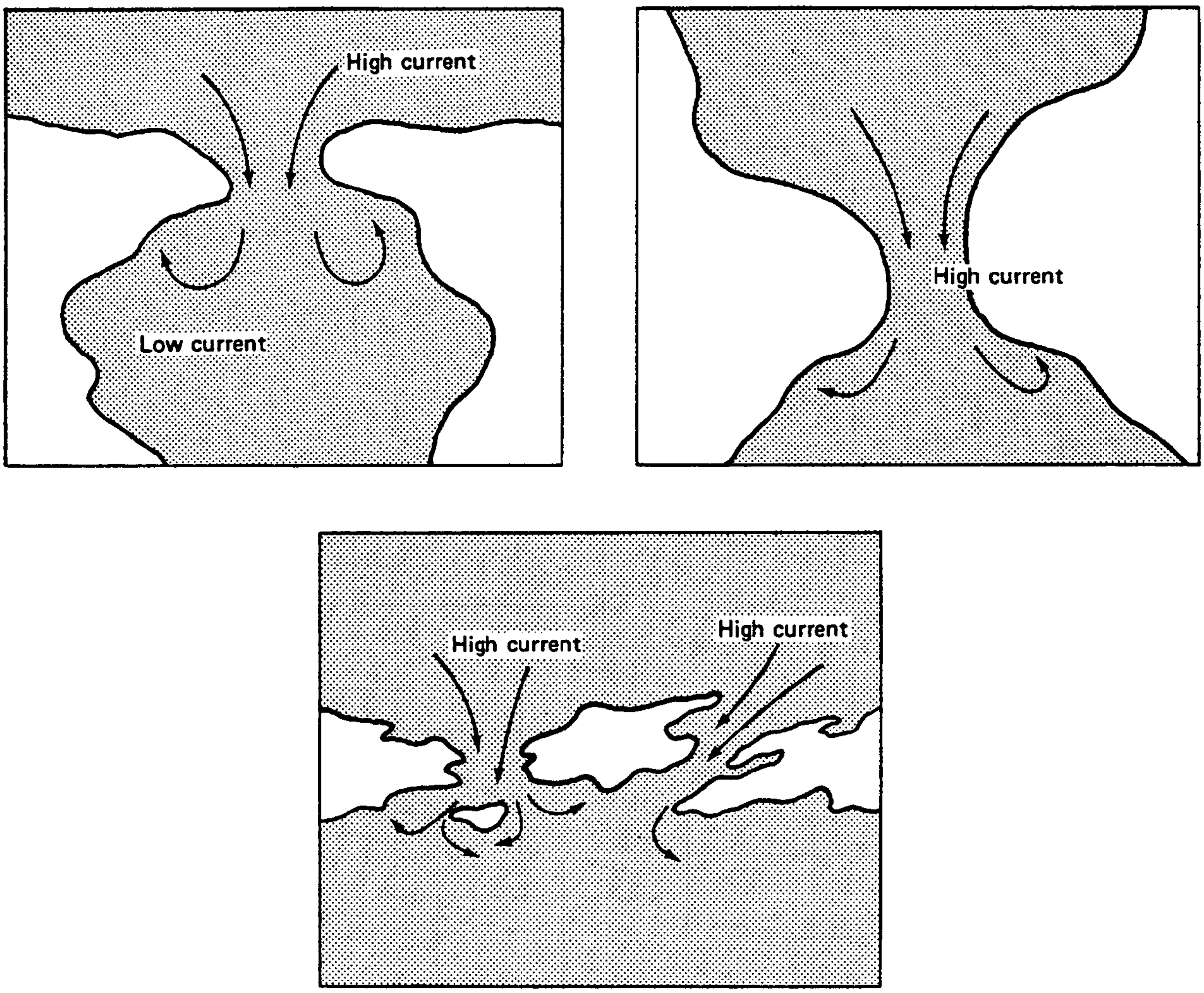


Figure 403-2. Landform configurations affecting current flows.

2. Shallow draft access - nearshore area is shallow and will only permit passage of small boats

3. No water access - submerged rocks, high currents, or waves

Air access:

1. Helicopter access - area sufficiently flat and open to allow helicopter to land or operate

2. No air access - no flat shoreline area, or shoreline too narrow to allow helicopter landing

It may be possible to improve access to a shoreline. If the terrain permits, trails can be widened or unpaved roads quickly cut to allow passage of heavy equipment. Trail widening or road construction should be limited to that which is absolutely necessary.

Sensitive or Unique Features

Sensitive or unique features are those characteristics of a shoreline that are of special biological, physical, or cultural importance. These features may strongly influence the setting of protection and cleanup priorities and the form and extent of cleanup activities.

Shorelines can be classified as biologically sensitive if one or more of the following features are present:

1. Rare, threatened, endangered, or protected species
2. Reserves, preserves, and other legally protected area
3. Waterfowl rookeries or concentration areas
4. Mammal rookeries, calving grounds, and concentration areas
5. Species of commercial importance
6. Species of recreational importance
7. Ecologically productive areas
8. Areas of beach stabilizing vegetation

Examples of these features are given in Section 803.

Shorelines can be classified as physically sensitive if special or unique geological features are present on the shoreline. Examples of such areas are:

1. High erosion potential areas if disturbed
2. Specially designated geological study areas
3. Fossiliferous formations
4. Mineral-bearing sediment deposits

Shorelines classified as culturally sensitive or unique areas would be those that have historical, tribal, or archaeological significance and could include:

1. Archaeological study areas
2. Tribal fishing areas
3. Historical monuments

Recreational, Commercial, and Industrial Use

The extent to which a shoreline is used recreationally is of major importance in setting cleanup priorities. As a rule, marinas and popular beaches will receive a high priority whereas beaches that are seldom or never used by the public will be cleaned later or left to natural recovery. Typically, extensive sand or gravel beaches located near metropolitan areas have heavy recreational use whereas boulder beaches or cliff areas have limited recreational value. Examples of high recreational use shoreline areas are:

1. Marinas and boat harbors
2. State parks and beaches
3. Sunbathing, surfing, and swimming beaches
4. Beaches with shore-front homes
5. Beaches with shore-front hotels and restaurants
6. Beaches adjacent to roads and highways

Shorelines with high commercial and industrial use generally warrant high protection and cleanup priority because of the public pressure and economic loss associated with temporary shut-down of a service or business. Examples of high commercial and industrial use are:

1. Cooling water intakes
2. Process water intakes
3. Domestic and agricultural water supply (applicable to freshwater systems)

404 SHORELINE SENSITIVITY

A shoreline's sensitivity to oil spill damage may affect the setting of protection and cleanup priorities. Differences in sensitivity between shorelines reflect differences in the biological value of the area and the physical processes governing the persistence of the oil.

Biological Value

Biological effects will vary with the type and amount of oil spilled, season, life stages of the affected organisms, and persistence of the oil. In general, however, the most biologically valuable shoreline areas will be: 1) highly productive habitats, usually sources for repopulation of surrounding areas (e.g., estuaries), or 2) ecologically significant habitats, usually areas of particular food chain importance (e.g., mudflats).

Persistence

The persistence of an oil on a shoreline is generally influenced by a combination of physical processes controlling oil deposition, penetration, and removal. More specifically, oil and substrate type, wave energy, and air and water temperature are the principal forces that set the length of time that oil will remain on a shoreline. Figure 404-1 indicates the relation of physical variables which affect the persistence of an oil type on a variety of shorelines. Because of the variability in the physical characteristics of shorelines and the way in which the different shoreline processes interact, Figure 404-1 should be used only as an indicator of the relative persistence of an oil type on a variety of shorelines and not as an estimate of the length of time the oil will remain there. In general, the physical variables of a shoreline will affect persistence in the following manner:

1. The deeper the oil penetrates and/or is buried, the more likely the oil will persist. Penetration and burial insulate the oil from surface radiation and mechanical energy. The lighter oils (Class A) will tend to penetrate more than the heavier oils. Oil will penetrate the larger grain size beaches most readily; oil will be buried most readily in areas characterized by high sedimentation rates (e.g., longshore sand transport, freshwater sediment loading).

2. The lower the shoreline energy level, the more likely the oil will persist. Mechanical energy is related to the action of waves, tides, and winds that change the physical character of the oil directly and expose greater surface areas to other weather and aging processes as well (photo oxidation, biodegradation, dissolution, evaporation, emulsification).

3. The colder the air and water temperatures, the more likely the oil will persist. Rates of physical and biological (microbial) degradation decrease as temperatures decrease.

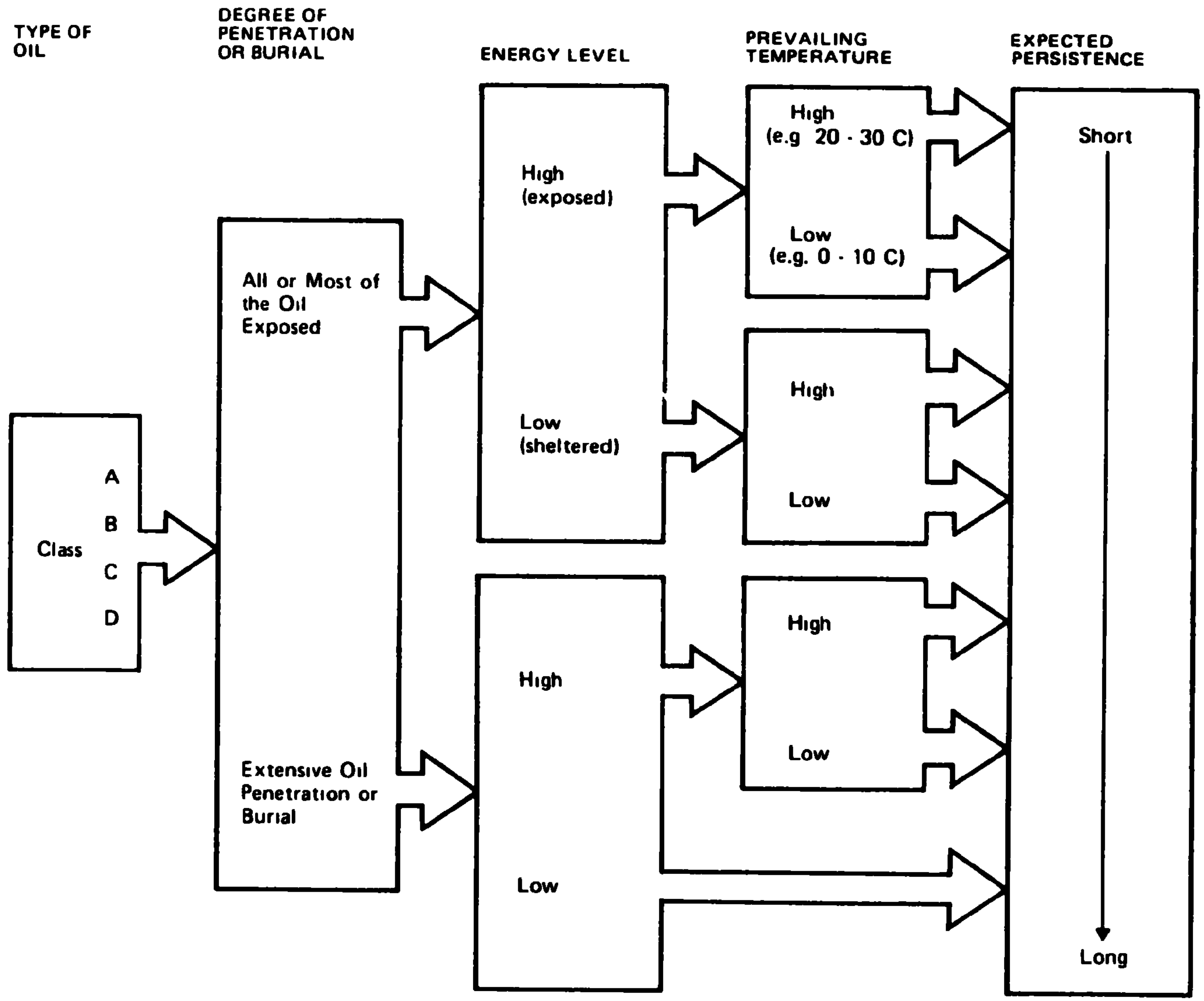


Figure 404-1. The potential for persistence of oil.

Relative Sensitivity

Taking into account relative biological value and persistence, a classification of shoreline types has been developed to reflect potential shoreline sensitivities to oil spill damage (Table 404-1). Because persistence will vary with different oils, Table 404-1 separately lists the relative sensitivity rankings for Class A, B, C, and D oils.

Table 404-1 is best used in a potential spill area as a guide for comparing the sensitivities of shoreline types not characterized by special and unique features or uses. For example, consider a coastal area composed of sheltered tidal flats, exposed tidal flats, gravel beaches, boulder beaches, and exposed wave-cut platforms subjected to a Class A spill. Table 404-1 shows the relative sensitivities in order of decreasing sensitivity to be sheltered tidal flats, gravel beaches, exposed tidal flats and wave-cut platforms, and boulder beaches. In several cases, no discernible differences exist between shoreline types (e.g., exposed tidal flats and exposed wave-cut platforms for a Class A spill) and thus are given the same relative rankings. The sensitivity rankings in Table 404-1 will aid the user in identifying those shoreline areas most susceptible to a spill of each oil class; although the relative rankings themselves will be applicable to most spill events, the greater the difference in rank, the less likely are site-specific conditions to change the order of sensitivities.

Although special and unique features have not been used to set the relative shoreline sensitivities, they will strongly influence the ultimate selection of protection and cleanup priorities. Similarly, previous or ongoing pollution (e.g., chronic oil, pesticides, heavy metals) may alter the sensitivity hierarchy developed here.

TABLE 404-1. SHORELINE SENSITIVITY

Shoreline Type	Relative Sensitivity[a] of Oil Class[b] A	B	C	D	General Comments
Sheltered tidal flats	10[c]	10	9	8	Probability of persistence high; high biological value.
Exposed, compacted tidal flats	4-5	3	3	3	Typically consist of fine-grained mud or sand tidal flats exposed to winds, waves, and currents; probability of persistence generally low but varies depending upon oil class; moderate biological value.
Sand beaches	6	1	1	1	Low biological value.
Mixed sand and gravel beaches	8	6	5-6	7	Low to moderate biological value.
Gravel beaches	7	6	5-6	4-5	Low biological value.
Cobble beaches	1	6	4-5	6	Probability of persistence generally high but varies depending upon oil class; low biological value.
Boulder beaches	3	8	8	9	Probability of persistence high; low to moderate biological value depending on the presence of sediment in the spaces between the boulders and the exposure of rock faces.
Sheltered rocky coasts	9	9	10	10	Probability of persistence high; high biological value.
Exposed rocky headlands	2	2	2	2	Probability of persistence low; high biological value.
Exposed wave-cut platforms	4-5	4	4-5	4-5	Typically consist of eroding glacial material or platforms cut directly into crystalline or sedimentary rock; some sediment deposition in holes and crevices; probability of persistence low; high biological value.

[a]Based on persistence and biological sensitivity.

[b]From Section 301.

[c]Scale of 1 to 10, with 10 being the most sensitive.

SECTION 500

PROTECTION OF SHORELINES

501 PROTECTION PRIORITIES

One of the realities of responding to a major oil spill is that protection of large areas of coastline is seldom possible. Limitations of time, manpower, and equipment make the setting of priorities an essential part of a rapid and effective response.

The need to protect a shoreline area is directly related to the potential for contamination; the presence of sensitive and unique features and/or recreational, commercial, and industrial uses; and the relative sensitivity of that particular shoreline. In addition, the feasibility of successfully implementing protection techniques must be considered. Figure 501-1 illustrates how these variables can be combined into a general decision guide for selecting protection priorities. The relative sensitivities of different shoreline types are listed in Table 404-1 and can be applied to the priority setting process as soon as the coastline has been characterized and the spilled oil classified. The potential for contamination, presence of special features and uses, and feasibility of protection must be determined with additional site-specific information developed by the OSC staff and, when possible, local and regional experts.

Because several shoreline areas might be given the same priority based on Figure 501-1, a more detailed guide (Table 501-1) has been developed using the same key components. The matrix should be used in the following manner:

1. List the different shoreline types, and locations, in the area of potential impact.

2. For the type of oil spilled, assign the shoreline sensitivities according to Table 404-1. This assures that in those cases where no special features exist, the most sensitive shorelines will receive the highest priorities.

3. Assign a rating of 10 to 20 for those shorelines with sensitive or unique features and/or high recreational, commercial, or industrial use. The evaluation of the special features and uses should reflect their value relative to the other features and uses in the potentially impacted area. The use of a rating scale between 10 and

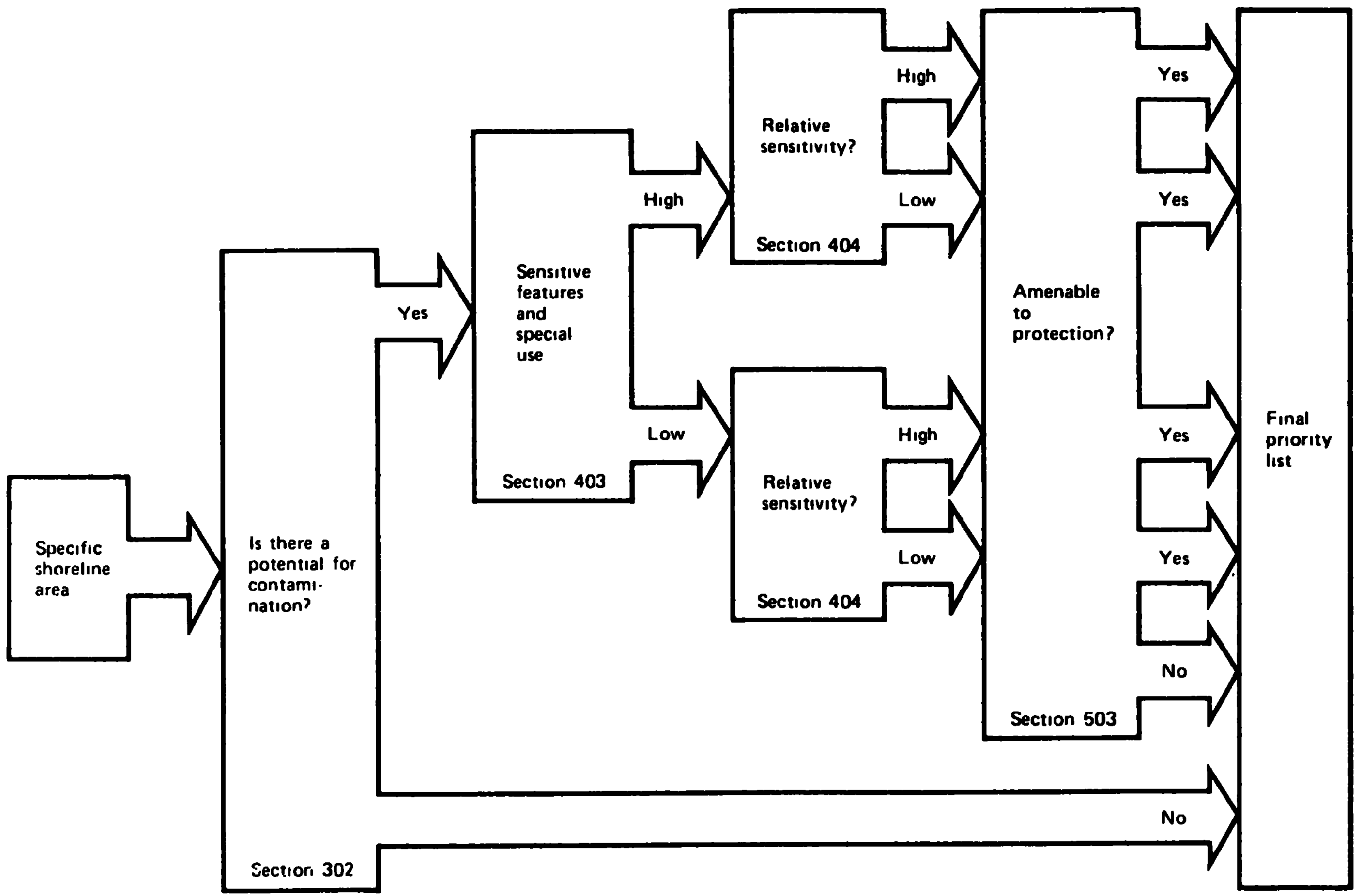


Figure 501-1. Decision guide for protection priorities.

TABLE 501-1. RESPONSE GUIDE WORK SHEET - ESTABLISHING PROTECTION PRIORITIES

Shoreline Type and Location	Sensitivity	Special Features and Uses	High Potential for Contamination	Feasibility of Protection	Total

20 ensures that special features and uses of a shoreline will dominate the selection of priorities (i.e., a low sensitivity beach with a special feature will receive a higher priority rating than a high sensitivity shoreline without a special feature). There are no predetermined values for any of the special features, nor are there specific rules for setting these values; thus it becomes advantageous for the OSC and staff to consult local regional experts capable of assigning values that reflect the time- and site-specific characteristics of the spill area.

4. Check off those shoreline areas with a high probability of contamination.

5. Check off those shoreline areas where protection implementation is feasible.

6. Total the sensitivity and special feature use values only for those shoreline areas with both contamination and protection checkmarks.

7. Plot the total values on an overlay or map along with the present location and direction of the slick.

8. Protect those areas on the map that 1) have the highest total values and 2) are most likely to be contaminated next. If time, equipment, and/or manpower are limiting, protect the area with the highest total value first, the next highest total second, and so on. If time, equipment, and manpower are or will be sufficient to cover all sensitive areas, protect the area closest to the slick first, the next closest second, and so on.

The use of the protection priority work sheet can be demonstrated with the help of a hypothetical spill event. For example, assume a Class C oil spill occurs off the coastal area shown in Figure 501-2. Several shoreline types and sensitive or unique features characterize this area. The different shoreline types are first listed in Table 501-2 (from north to south) and sensitivity values for a Class C spill are given to each type (from Table 404-1). The OSC, with the assistance of local and/or regional biologists/ ecologists, then assigns values between 10 and 20 to those coastline areas with special features and/or uses. In this example, the sheltered tidal flat is given the highest value (in this case, 20) because of the presence of both a rare and endangered species and a waterfowl concentration area. The waterfowl rookery along the sheltered rocky coast is given the next highest value (in this case, 15), the state preserve and commercial shellfishing areas each a value of 12, and the recreational beach a value of 10. Actual values assigned to the special features and uses along a coast after a real spill event will vary according to the season, species involved, impact to the population as a whole, etc. A waterfowl concentration area, for example, might be given a higher value than a recreational beach during a winter spill when large populations of birds are present, but given a lower value during the summer when the bird populations are smaller and recreational use of the beach is at its peak.

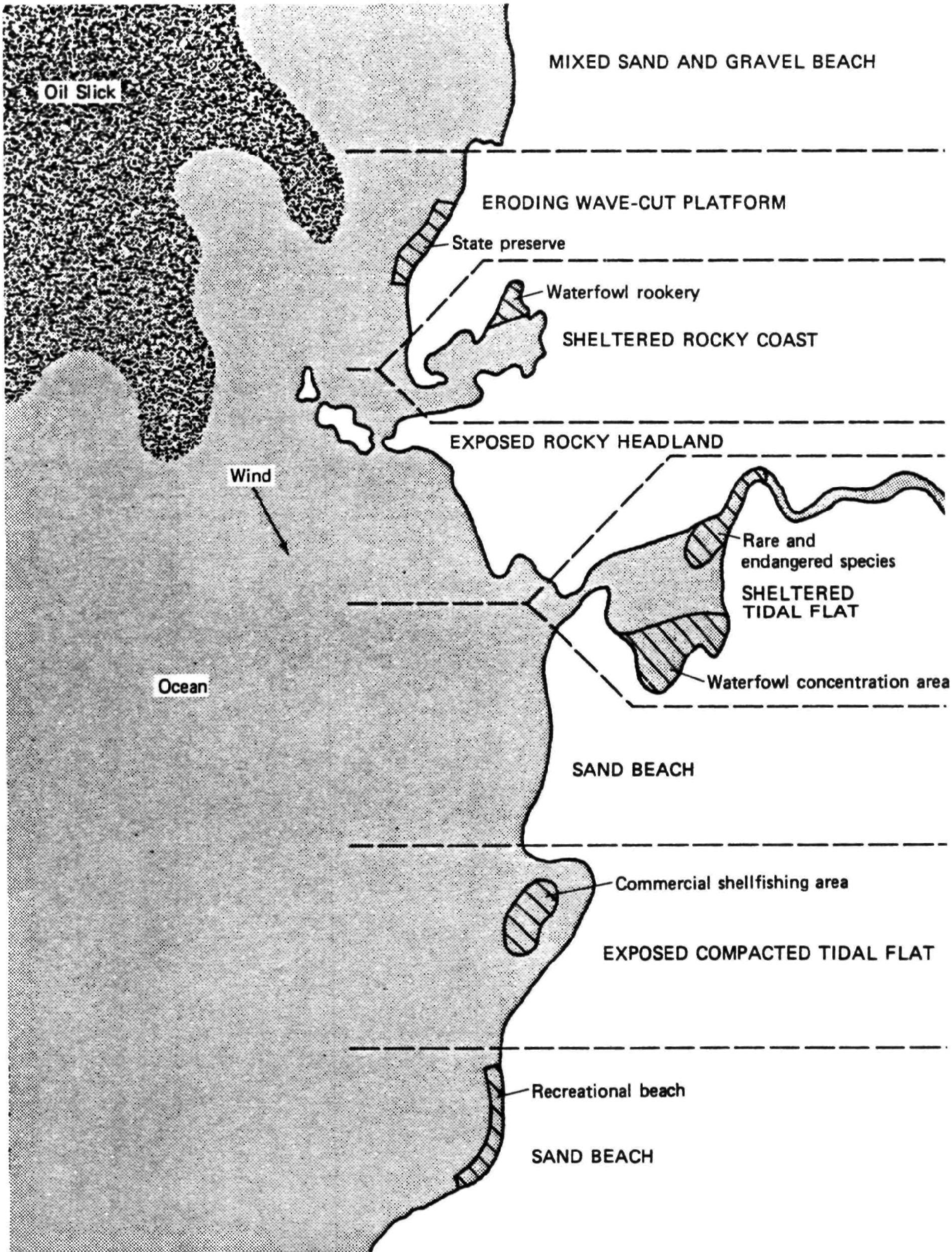


Figure 501-2. Hypothetical spill and coastline.

TABLE 501-2. RESPONSE GUIDE WORK SHEET - ESTABLISHING PROTECTION PRIORITIES FOR A HYPOTHETICAL SPILL EVENT[a]

Shoreline Type and Location	Sensitivity[b]	Special Features	High Potential for Contamination	Feasibility of Protection	Response Guide Total
Mixed sand and gravel	6.5	0			
Eroding wave-cut platform	4.5	12	X		
Sheltered rocky coast	10	15	X	X	25
Exposed rocky headland	2	0	X		
Sheltered tidal flat	9	20	X	X	29
Sand beach	1	0	X		
Exposed compacted tidal flat	3	12	X	X	15
Sand beach	1	10	X	X	11

[a]Class C oil.
[b]From Table 404-1.

Once the special feature and use values are assigned, shoreline areas with a high potential for contamination are designated. This judgment is best made by the OSC with information given to him by his staff. In the example, those areas south of the eroding mixed sand and gravel beach are likely sites of contamination; X's are therefore placed in the boxes associated with potentially impacted sites.

Given the areas of high sensitivity, special features and uses, and likely oil contamination, the OSC and his staff must then evaluate the feasibility of protecting these sites. Again, X's are placed in those boxes where protective measures can be implemented. In this case, the exposed rocky headland and northernmost sand beach cannot be protected; but various combinations of diversion, exclusion, and/or containment booming might protect the sheltered rocky coast, sheltered tidal flat, exposed compacted tidal flat, and southernmost sand beach from heavy contamination.

The sensitivity and special feature and use values are then added only for those shoreline types with both X's (i.e., the sheltered rocky coast, sheltered tidal flat, exposed compacted tidal flat, and southernmost sand beach). These values are then plotted on another map or overlay (Figure 501-3) and protection priorities are set. If there is only enough time and boom to protect one area, the sheltered tidal flat would receive first priority in this case because it has the highest value. If adequate time and boom are available for at least two areas, then the sheltered rocky coast should be protected first because it is closer to the oil slick and the first to be impacted and then the sheltered tidal flat should be protected. The OSC should also consider the probable success of protection measures in setting the final priorities.

The OSC now directs the protection efforts in accordance with the priorities and pursues these efforts until the lack of equipment or manpower prevents him from doing so, or until new information (e.g., on movement prediction or special features) surfaces to change the order of priorities. Such changes can be quickly incorporated into the work sheet: For example, if the area of potential contamination along the hypothetical shoreline shifts to the north, the OSC merely has to evaluate the feasibility of protecting the eroding wave-cut platform to reorder the priorities.

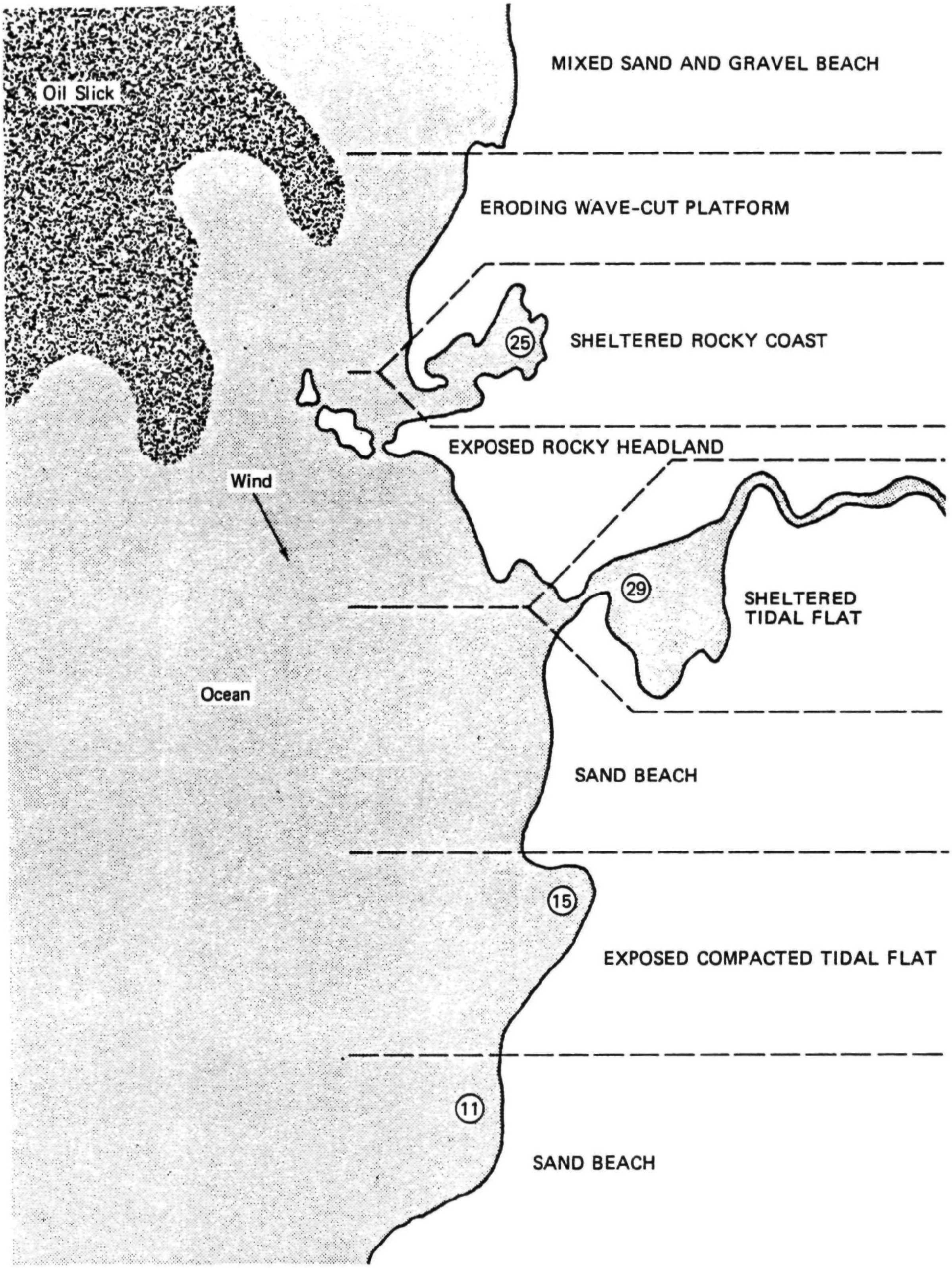


Figure 501-3. Hypothetical spill response guide totals.

502 SELECTION OF PROTECTION TECHNIQUES

Selection of an appropriate protection technique for a shoreline or water area depends on the following factors:

- type of water body (e.g., inland waters - lakes, rivers etc; coastal waters - bays, tidal channels, open water)
- velocity of water currents
- land form and water body configurations, (e.g. straight coastline, harbor or bay entrance, etc.)
- depth of the water
- presence of breaking waves
- amount of oil contamination

Table 502-1 lists seven protection techniques that are applicable for controlling or containing floating oil slicks. Figures 502-1 and 502-2 are decision guides that will help the user evaluate the factors affecting the use of a protection technique(s) and select the appropriate technique(s) for the particular spill conditions.

Decision Guide Use

The decision guides are divided into two categories: Figure 502-1 for protection of inland waters and Figure 502-2 for protection of coastal waters. They are used as follows:

- For inland waters (Figure 502-1), enter the figure at the type of water body where protection is needed and select the appropriate booming technique depending on the amount of oil contamination and the water current speed (except for shallow waters). If a large lake is involved where water currents and waves are present, use the decision guide for coastal waters (Figure 502-2).

- For coastal waters (Figure 502-2) enter the figure at the configuration of the area to be protected and select the appropriate booming technique depending on the presence of breaking waves and the velocity of water currents.

In any location (inland and coastal waters) where currents exceed 3 knots or breaking waves are greater than 25 cm, it is best to move the proposed boom location away from turbulent waters and into a more quiescent area along the water body.

Once a protection technique has been selected, the implementation requirements should be checked (Section 503). Instructions on how each technique is used are given in Section 804.

The use of the decision guide in selecting a protection technique can be demonstrated using the hypothetical spill solution described in Section 501. For example: Assume the entrance to the sheltered tidal flat had water currents of approximately 1.5 knots at flood tide with no breaking waves;

TABLE 502-1. PROTECTION TECHNIQUES

Protection Technique	Description of Technique	Primary Use of Protection Technique	Environmental Effect of Use
1. Exclusion Booming	Boom is deployed across or around sensitive areas and anchored in place. Approaching oil is deflected or contained by boom.	Used across small bays, harbor entrances, inlets, river or creek mouths where currents are less than 1 kt and breaking waves are less than 25 cm in height.	Minor disturbance to substrate at shoreline anchor points.
2. Diversion Booming	Boom is deployed at an angle to the approaching slick. Oil is diverted away from the sensitive area or to a less sensitive area for recovery.	Used on inland streams where currents are greater than 1 kt; across small bays, harbor entrances, inlets, river or creek mouths where currents exceed 1 kt and breaking waves are less than 25 cm, and on straight coastline areas to protect specific sites, where breaking waves are less than 25 cm.	Minor disturbances to substrate at shoreline anchor points, cause heavy shoreline oil contamination on downstream side.
3. Containment Booming	Boom is deployed in a "U" shape in front of the oncoming slick. The ends of the boom are anchored by drogues or work boats. The oil is contained within the "U" and prevented from reaching the shore.	Used on open water to surround an approaching oil slick to protect shoreline areas where surf is present and oil slick does not cover a large area; also on inland waters where currents are less than 1 kt.	No effect on open water; minor disturbance to substrate on inland anchor point.
4. Sorbent Booming	Boom is anchored along a shoreline or used in one of the manners described above to protect sensitive areas and absorb oil.	Used on quiet waters with minor oil contamination.	Minor disturbance to shoreline at anchor points.
5. Sorbent Barriers	Barriers are constructed across a waterway and constructed of wire mesh and stakes which contain loose sorbents. The barrier allows water to flow but retains and absorbs oil on the surface.	Used in small, low velocity streams, tidal inlets or channels, or any narrow waterway with low current velocities.	Minor disturbance to stream or channel substrate.

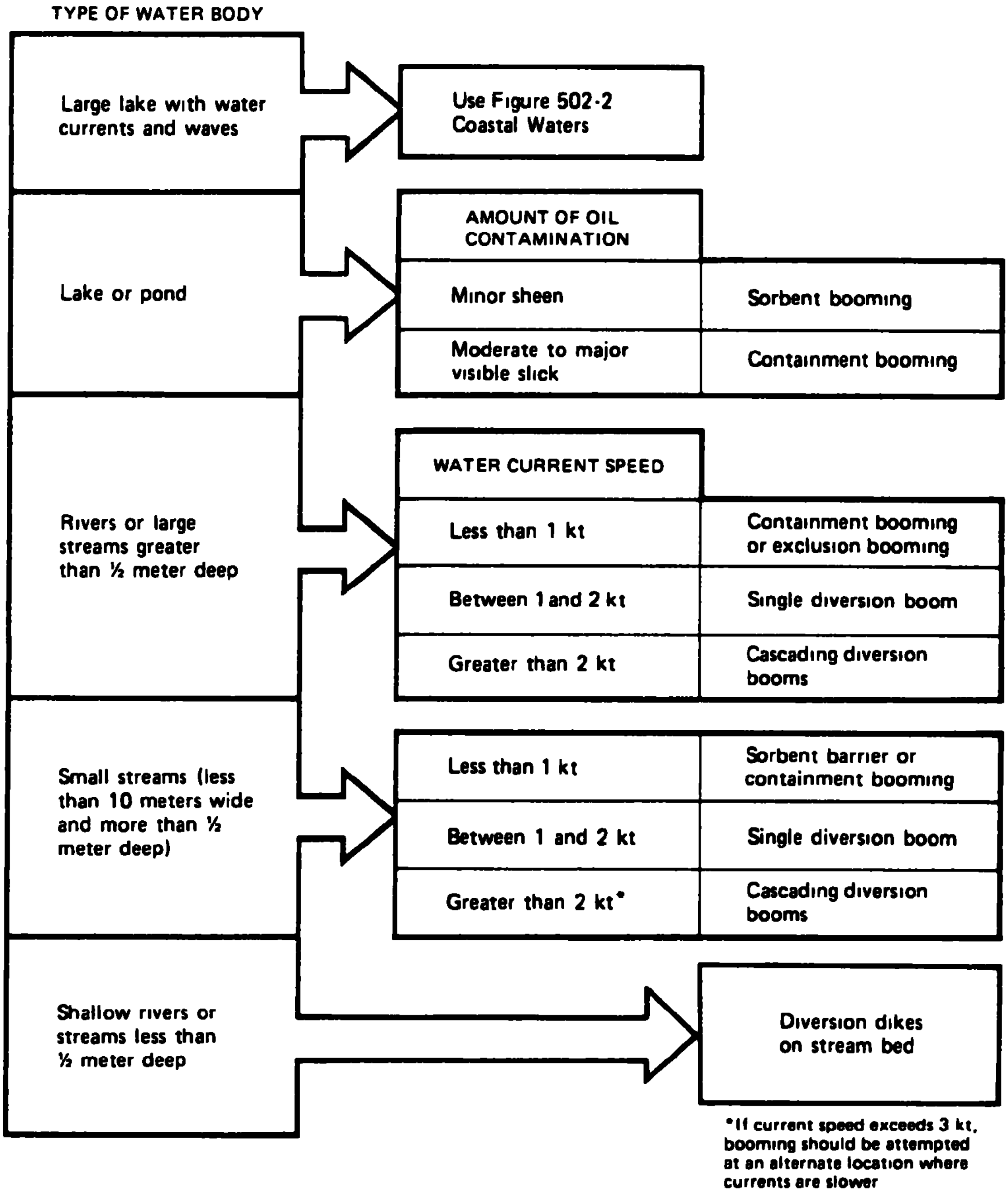


Figure 502-1. Decision guide for inland waters.

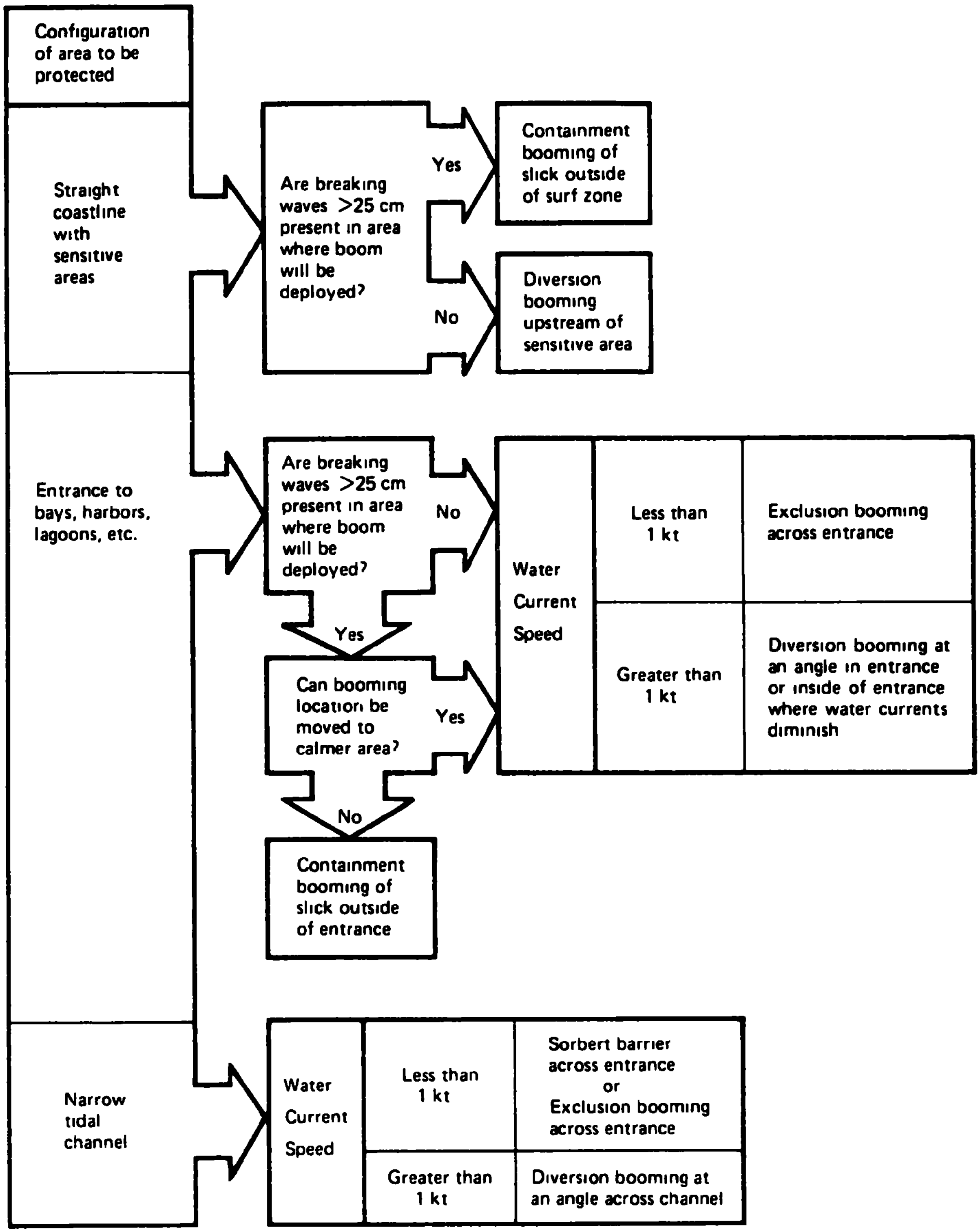


Figure 502-2. Protection decision guide for coastal waters.

according to Figure 502-2 under "Entrance to Bays, Harbors, Lagoons, Etc." the most appropriate protection technique would be diversion booming in the entrance to the tidal flat as shown in Figure 502-3. In a similar manner, the selection of protection techniques for the three other priority areas under the conditions given would be as described in Table 502-2 and shown in Figure 502-3.

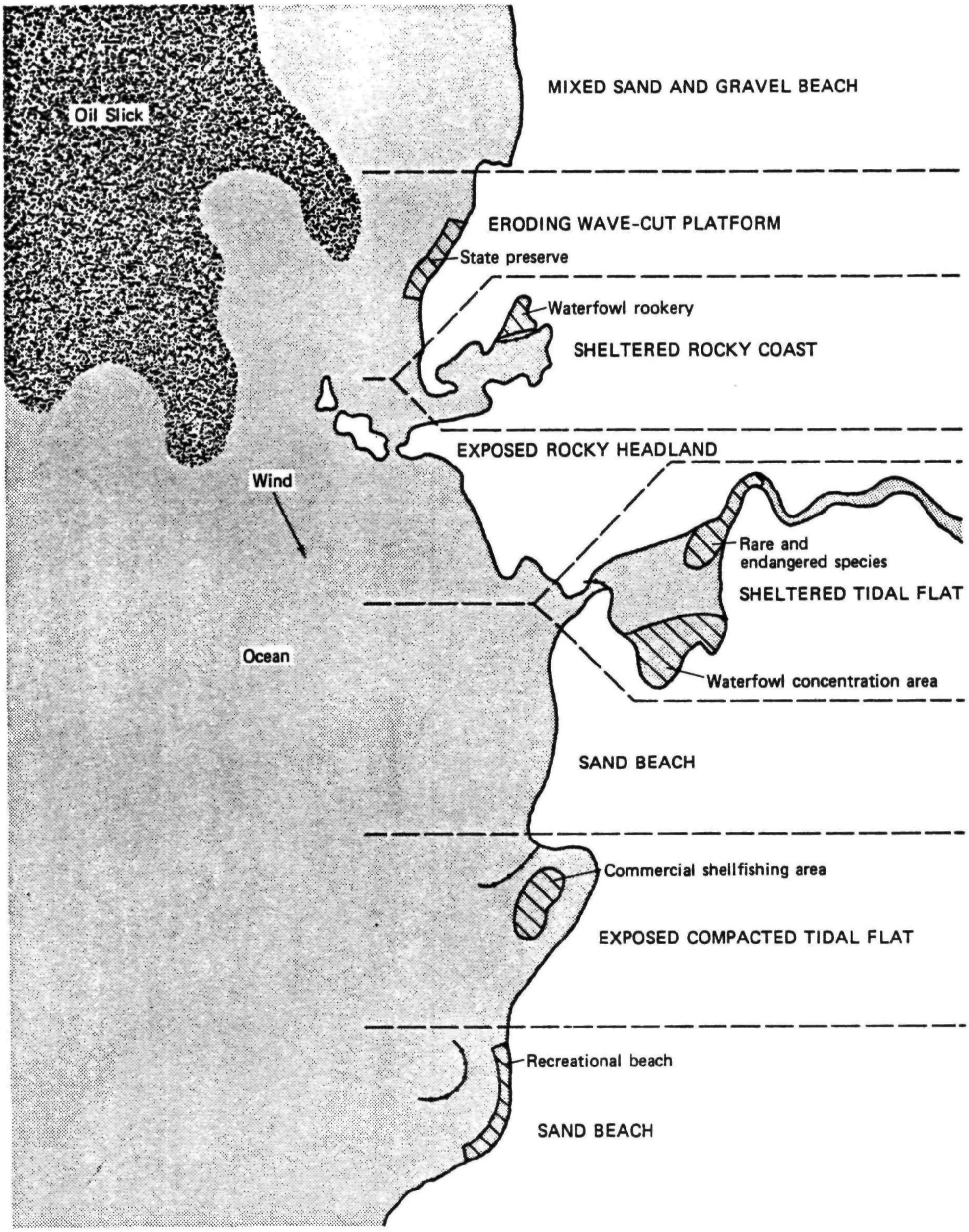


Figure 502-3. Protection techniques for hypothetical spill.

TABLE 502-2. PROTECTION TECHNIQUES FOR A HYPOTHETICAL SPILL

Shoreline Type	Conditions	Booming Technique
Sheltered rocky coast	Breaking waves in entrance, water currents less than 1 knot	Exclusion booming across front of waterfowl rookery
Exposed compacted tidal flat	No surf, protected by headland to north	Diversion booming
Recreational sand beach	Surf along whole length of beach	Containment booming of slicks outside of surf zone

503 PROTECTION IMPLEMENTATION REQUIREMENTS

Before the initiation of shoreline protection measures, various requirements must be satisfied to ensure effective and efficient implementation. This section will help the user identify those requirements by providing procedures and decision guides for determining the feasibility of effectively implementing shoreline protection techniques.

The following is a list of requirements that must be evaluated before determining the feasibility of using a protection technique.

- type and length of boom
- anchoring method
- available manpower and support equipment
- availability of protection equipment and materials
- time required to deploy or initiate technique
- estimated arrival time of oil

The type of boom required is determined mainly by the conditions under which it is to be used. Table 503-1 gives suggested boom types for different conditions of use.

TABLE 503-1. BOOM SELECTION

	Conditions of Boom Use	Type of boom
1.	Shallow water (less than 0.5 to 1 m)	Curtain boom
2.	Across intertidal zone	Curtain boom
3.	Water depth over 1 meter in:	
	a) calm water (wave height <25 cm)	Curtain or fence boom
	b) rough water (wave height >25 cm)	Heavy duty curtain boom or fence boom
4.	Water currents above 1 kt	Curtain boom with tension cables at top and bottom

The length of boom needed is dependent on the width of the inlet or area to be protected. Extensive testing under actual spill conditions indicates that the best performance of a boom (with regard to stability and oil retention) occurs when it takes a parabolic shape. It has been found that the optimum boom length is about 1.5 times the straight-line distance between the points where the boom is to be anchored. This added length gives the boom stability and will reduce its tendency to roll. A boom tends to become unstable when its length is less than 1.25 times the straight-line distance between the anchor points.

Anchoring Requirements

Anchoring requirements will vary with the boom and technique used, and the shoreline topography. When a boom is anchored to a shoreline, it can be attached to large boulders or trees by a cable sling and shackles. If there are no natural structures available, an anchoring system will have to be constructed. Ideally, the onshore anchoring device should be some type of deadman buried at right angles to the direction of maximum force (pull, in this case). If it is possible to dig a hole, a log .3 m in diameter and about 2 m long can be buried 1.2 m deep. A cable sling is attached to the log and, in turn, the boom to the sling. If there is no timber available, a Danforth anchor can be buried in a similar fashion. If digging a hole is not feasible, a deadman that can be handled by one man should be taken ashore. The deadman will plow itself into the ground when it is pulled by a winch or another source of power, as shown in Figure 503-1.

Boom deployment using shoreline anchoring can be achieved with the use of a winch-boat and smaller power craft. The small craft can pull a leader line from the winch-boat to the point on shore where the boom is to be secured. The line is passed through a sheave block and returned to the winch-boat where the boom is attached to it and winched ashore. Boom should be positioned so that the boom ends are above the high tide line. This will enable the boom to act as a barrier throughout the entire tide cycle.

Booms can be anchored in the water by using conventional ship's anchors, sea anchors (drogues), or a vessel, depending on the situation. Sea anchors or drogues* are used for containment booming when the boom drifts with the contained oil slick. Conventional anchors or a vessel are used to anchor boom in the water for shallow water containment or diversion booming. When an anchor is used, a line approximately three to four times as long as the water depth is attached to the anchor. The other end is fixed to a buoy float which is then attached to the boom with a short piece of line. The buoy float prevents the boom from being affected by the pull of the anchor.

Support Requirements

Equipment support requirements must also be evaluated along with their availability. Once the specific protection technique has been selected, the major support equipment and materials can be determined from the summary given in Table 503-2.

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*Drogues or sea anchors holding booms need to be tended by a vessel.

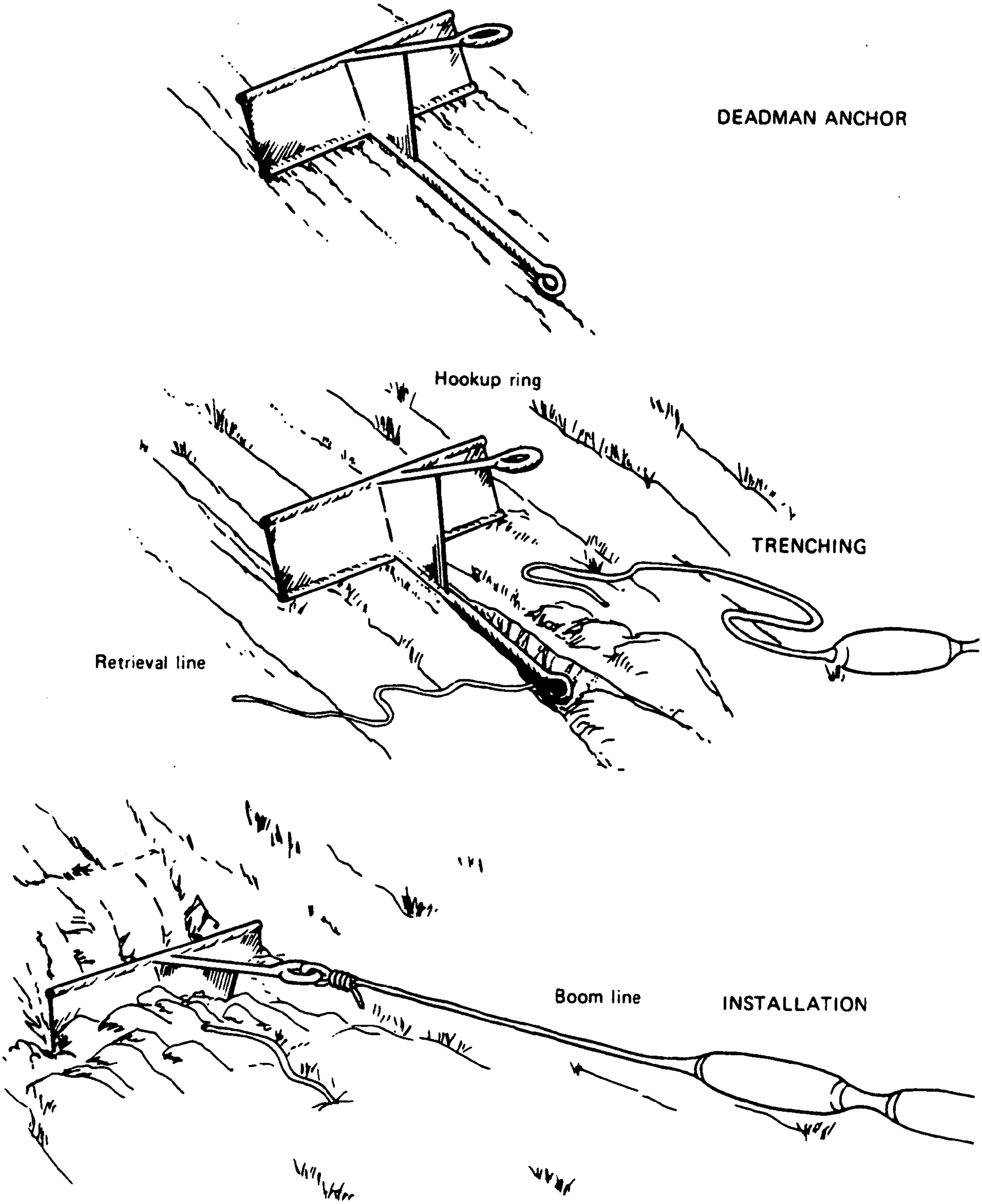


Figure 503-1. Deadman boom anchor.

TABLE 503-2. SUPPORT EQUIPMENT AND MATERIALS

Protection Technique	Controlling Variable	Support Equipment and Materials
Exclusion Booming	Calm weather, light boom	1 - workboat plus crew 6 - anchors plus anchor line and buoys
	Rough weather, heavy boom	1 - workboat plus crew 12 - anchors plus anchor line and buoys
Diversion Booming	Single boom	1 - anchor and anchor line 1 - workboat plus crew 1 - recovery unit
	Cascading boom	6-9 - anchors plus anchor line and buoys 1 - workboat plus crew 1-2 - recovery units
Containment Booming	150 m diameter slick	1 - workboat plus crew 2 - drogues 1 - skimmer, pump, storage tank
	250 m diameter slick	1-2 - workboats plus crews 2 - drogues 1-2 - skimmer, pump, storage tank
Sorbent Booming	Booms	1 - small motor boat 2 - anchors plus anchorline and buoys 1-2 - disposal barrels or containers
	Barriers	Cyclone, chicken wire, or suitable fencing. Iron pipe or wooden supports. Disposal container.
Beach Berms	Good trafficability	1 - motor grader
	Poor trafficability	1-2 - bulldozers
Berms and Dams	Diversion berm or overflow dam	1 - front-end loader or bulldozer 3-6 - short or 1 long section of boom 1 - skimmer, pump, and tank
	Water bypass dam	1 - front-end loader or bulldozer 1 - discharge tube w/ or w/o valve 1 - skimmer, pump, and tank

The vessels used for boom deployment should have sufficient towing capabilities to overcome the drag created by the boom being towed through the water.* Figures 503-2 and 503-3 give the approximate towing forces and equivalent inboard and outboard horsepower requirements** for straightline towing of various boom types at 2 and 6 knots respectively. If booms are to be towed in other than a straight line or if they are towed against or across a current or in breaking waves, then additional towing force would be required. If water conditions in which a boom is to be towed are unknown, a vessel with at least twice the required horsepower needed should be used for straightline towing of a boom.

Protection Feasibility

The critical factor for determining feasibility is the relationship between the total deployment time of the technique and the estimated time of arrival (ETA) of the oil at the protection site. The procedure and formulas for calculating the ETA of an oil slick are given in Section 302.

When estimating the total deployment time, several variables must be considered. Table 503-3 gives an example of a form that might be used to estimate the total deployment time. The form lists the primary variables that must be quantified with respect to the time required to complete each task.

TABLE 503-3. DATA FORM FOR DETERMINING DEPLOYMENT TIME

Description of Task	Time Required	
Procure boom, support materials, and personnel at deployment site	___ hr	___ min
[a]Unpackage and assemble boom	___ hr	___ min
[a]Deploy boom initially into water	___ hr	___ min
Tow boom to site and anchor in position	___ hr	___ min
Total Deployment	___ hr	___ min

[a]Refer to Table 503-4.

---

*If booms are towed at speeds of 1 knot or less, the towing vessel will need controllable pitch propellers, Kort nozzles or bow thrusters, in order to control the vessel at such a low speed.

**The towing capabilities of a vessel are determined by its horsepower rating. Horsepower is multiplied by a factor of 13 for outboard motors and 20 for inboards (workboats) to yield the available towing force in kgs. The available force must exceed that required by the boom to ensure effective implementation.

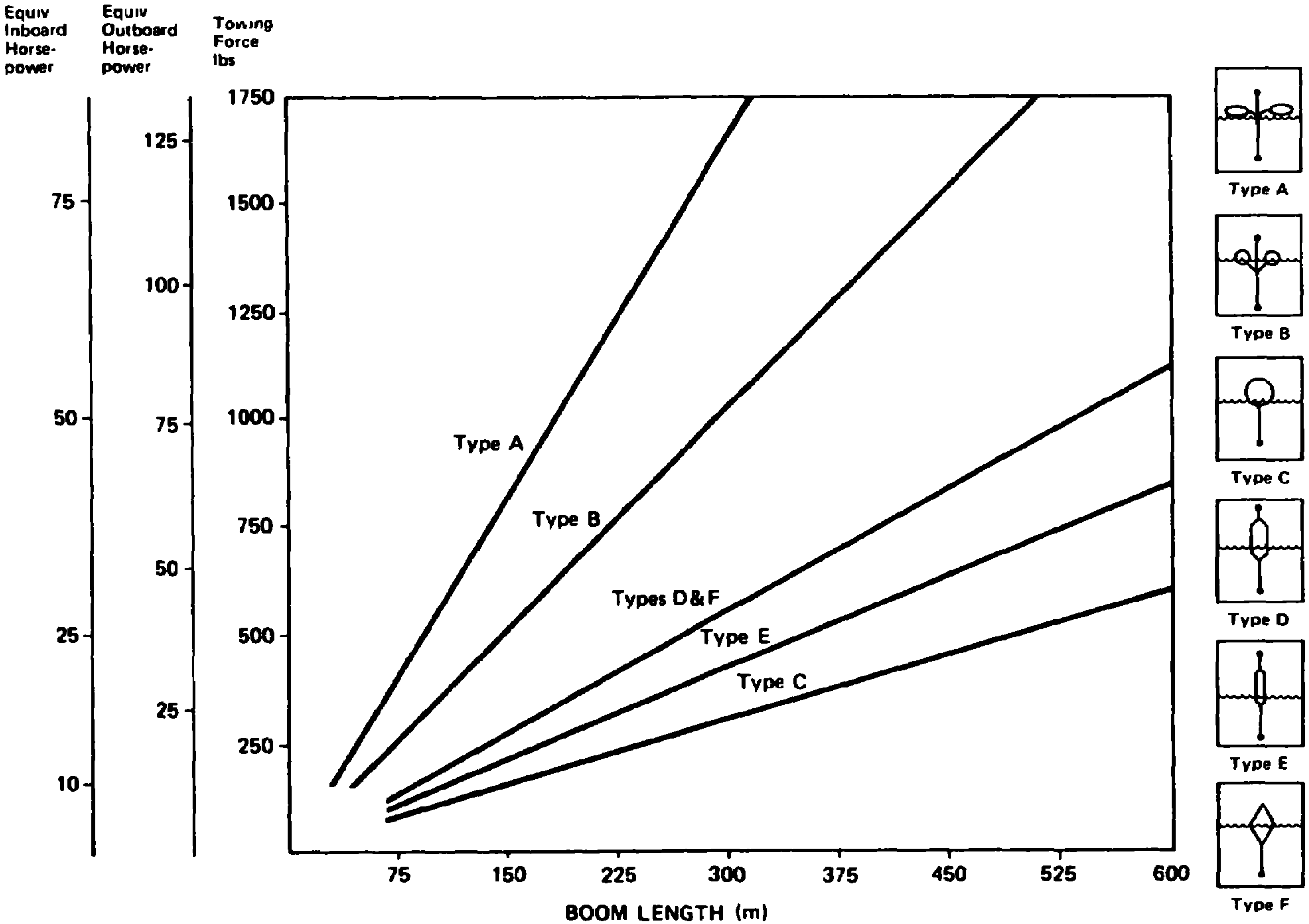


Figure 503-2. Straight line towing force versus boom length at 2 knots.

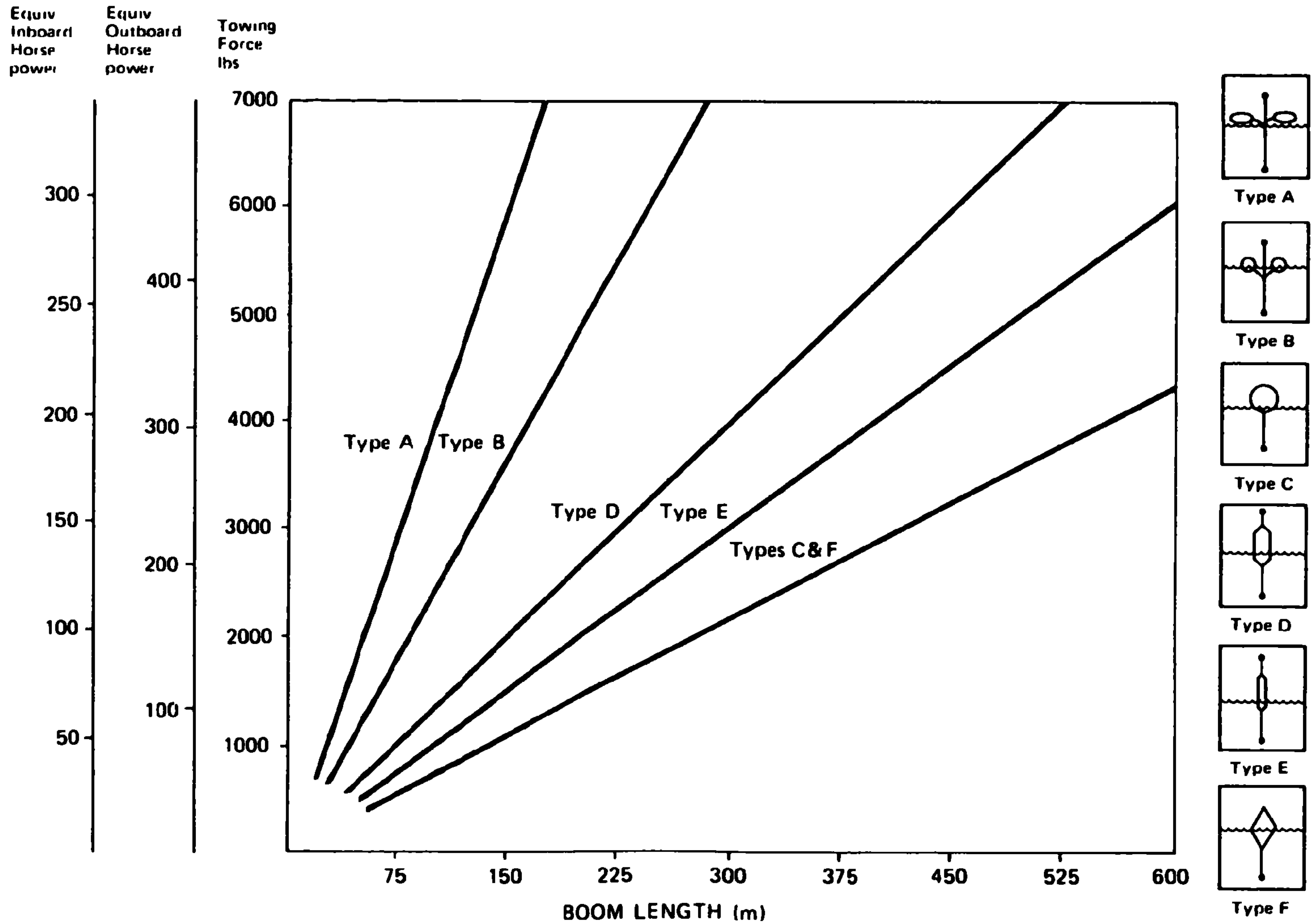


Figure 503-3. Straight line towing force versus boom length at 6 knots.

In the case of berms or dams used as protection measures, the variables would be aquisition of materials, equipment, and personnel, travel time to site, and construction of the berm or dam. Table 503-4 lists the time, equipment, and manpower required to deploy six different types of boom. The times listed encompass assembly and launch time and do not include towing to the site and positioning the boom. Towing, positioning, and anchoring the boom are site-specific factors and have to be evaluated for each specific booming location.

Once all the requirements have been satisfied, the total deployment time must be compared to the ETA of the oil to determine if it is feasible to implement the protection procedure effectively before oil contact with the shoreline. The checklist shown in Table 503-5 indicates the procedure for determining the feasibility of protection. If all the requirements cannot be met, or if the ETA is less than the implementation time, other techniques should be examined.

TABLE 503-4 BOOM HANDLING REQUIREMENTS

	Transportation		Prelaunch			Launch		Retrieval	
Boom	Equipment to Load/Unload and Transport	Manpower to Load/Unload and Transport	Approximate Time to Unpackage and Assemble	Workers Required	Tools Required	Approximate Time to Complete Launch	Men Required	Time to Complete Retrieval	Men Required
Type A	Small forklift 16-ft flatbed truck	1 - Driver 1 - Forklift operator 1 - Laborer	1/2 hr	2	None	1/2 hr	5	1/2 hr	3
Type B	Small forklift 1/2-ton flatbed truck	1 - Driver 1 - Forklift operator 1 - Laborer	1/2 hr	3	None	10 min	3	1 hr	2
Type C	Medium size forklift 16-ft flatbed truck	1 - Driver 1 - Forklift operator	1/2 hr	3	Handtools	10 min	4	20 min	3
Type D	Medium size forklift Small flatbed truck	1 - Driver 1 - Forklift operator	1/4 hr	2	None	1/2 hr	4	1 hr	2 Full-time 1 Part-time
Type E	Small forklift 16-ft flatbed truck	1 - Driver 1 - Forklift operator	1/2 hr	3	Handtools	10 min	4	1/2 hr	3
Type F	Small forklift 1/2-ton pickup truck	2 - Laborers	1/4 hr	3	None	1/4 hr	3	2 3/4 hr	4

NOTE: All booms were 91 m in length.

TABLE 503-5. CHECKLIST FOR IMPLEMENTING PROTECTION PROCEDURES

1. DETERMINE:	A. Length of boom required or length of dams or berms required	________
	B. Number of personnel required	________
	C. Type and number of vehicles and vessels required	________

THEN:

Are sufficient boom personnel and support equipment available to implement protective procedure?	Yes	No
If not, can another technique be used which requires less boom, personnel or support equipment?	Yes	No
If boom is not available, can booms be constructed on shoreline?	Yes	No

2. DETERMINE:	A. Estimated arrival time of oil slick	________
	B. Time required to implement protection technique	________

THEN:

Can protection technique be deployed before arrival of oil?	Yes	No
If not, can another technique be used which requires less time to implement?	Yes	No

SECTION 600

CLEANUP OF SHORELINES

601 CLEANUP PRIORITIES

In most instances, oil spill cleanup efforts are not subject to the same time constraints imposed upon protection efforts, such as reliance on availability of equipment and manpower. As a result, cleanup planning may be conducted with greater attention to detail, including damage assessment, selection of techniques, and cost effectiveness. Shoreline cleanup, however, should be implemented as rapidly as possible to reduce the effects of oil migrating to adjacent clean shorelines.

For any spill situation, it is probable that a variety of shoreline types will have to be considered. Spill impacts on different shoreline types can range from severe cases, requiring immediate and thorough attention, to cases where leaving the oil alone may be acceptable. Thus, as a first step in cleanup planning, it is necessary to relate impacted shorelines in order of cleanup need (or priority). To assist in the setting or identification of cleanup priorities, a decision guide has been developed (Figure 601-1). In essence, the position of a particular shoreline area in the resulting cleanup priority list will depend on the answers to the following questions:

1. Is the biological, physical, or cultural value of the shoreline high or low?

2. Is the degree of oil contamination high or low?

3. Is it likely that oil will migrate from the contaminated shoreline to a clean shoreline?

4. What is the spacial distribution of the shorelines relative to each other?

Shoreline areas can be ordered in priority of consideration by entering the discrete areas contaminated by a spill into the decision guide and answering the above questions. A brief description of the components of Figure 601-1 is presented below. It is recommended that characteristics under consideration be plotted on a chart or overlay.

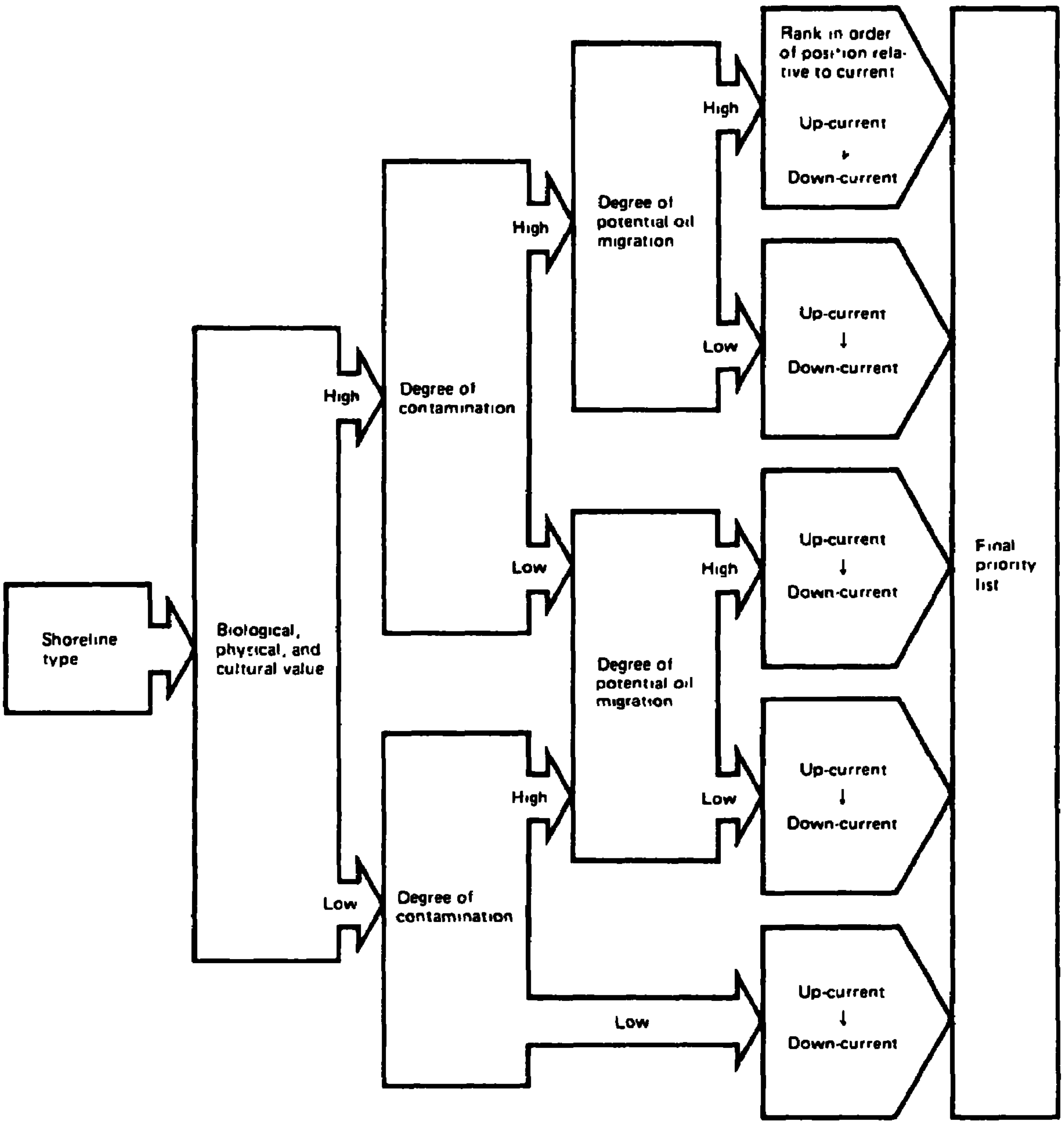


Figure 601-1. Decision guide for cleanup priorities.

Biological, Physical, and Cultural Value

The features of a shoreline that make it valuable are discussed in Sections 403 and 803 (sensitive and unique features). Whether the presence of one of the these features on a particular shoreline warrants a "high" or "low" value rating will depend on the onsite evaluation of the OSC and his staff in consultation with local experts familiar with the amenities of the entire shoreline area contaminated by the spill. In most cases, however, the presence of a sensitive or unique feature alone will justify a "high" value.

Degree of Contamination

The extent of oil contamination on a shoreline (Section 301) will depend on the type of oil; type of substrate; and currents, tides, and wave energy. Because the degree of contamination may vary within a specific shoreline area itself, the "high" and "low" determination should reflect the average oil coverage on the shoreline. As a rule, an oil thickness or penetration of > 1 cm can be considered as a "high" degree of contamination.

Oil Migration

Even when the oil on a specific shoreline area does not threaten any sensitive features or recreational use, it may be a threat to other, more valuable shoreline areas if the oil can move off the beach and be carried elsewhere. Oil migration will be a function of the winds, currents, and wave energy characterizing the contaminated shoreline. In general, the potential for oil migration is "high" when strong longshore currents, an offshore wind, and/or high tidal fluctuations are present.

Spatial Distribution

Because more than one shoreline area can emerge from Figure 601-1 with the same priority, the position of the shoreline relative to water current direction has been added to the decision guide. Within the same priority level, areas up-current should be given a higher priority.

The OSC can use the final priority rankings as a guide in selecting where and when he should implement cleanup measures. As conditions change or new information becomes available, the OSC can use the decision guide again to reorder the cleanup priorities as required.

602 SELECTION OF CLEANUP PROCEDURE

Twenty-three shoreline cleanup techniques have been identified as being in general use. Selection of the proper technique to clean an oil-contaminated shoreline depends on the following factors:

1. Type of substrate
2. Amount of oil contamination
3. Depth of oil contamination in sediments
4. Type of oil (class A, B, C, or D)
5. Type of oil contamination (i.e. tar balls, pooled oil, viscous-coating, etc.)
6. Trafficability of equipment on shoreline
7. Environmental sensitivity of contaminated shoreline

A series of decision guides have been prepared that will allow the user to evaluate these factors for a given shoreline and to select the preferred cleanup technique. Figure 602-1 presents a key to these decision guides (Figures 602-2 through 602-4). Table 602-1 lists the shoreline cleanup techniques and gives a brief description of how and where they are used.

Decision Guide

The procedure for using the decision guide is as follows:

1. Use Figure 602-1 (Key to Decision Guides) to determine which of the other three decision guides is applicable for the cleanup of each shoreline in question. Enter with the type of substrate that is contaminated and follow the guide, answering the questions where appropriate.

2. Enter the decision guide selected (Figure 602-2, 602-3, or 602-4) and answer the questions for each shoreline section that requires cleanup. The guide will lead the user to one or more cleanup techniques applicable to his situation, with the most preferable technique listed first. If the first technique cannot be used because of the lack of equipment or access to shoreline, then the next technique should be chosen.

3. Instructions on how to use each cleanup technique are given in Section 805.

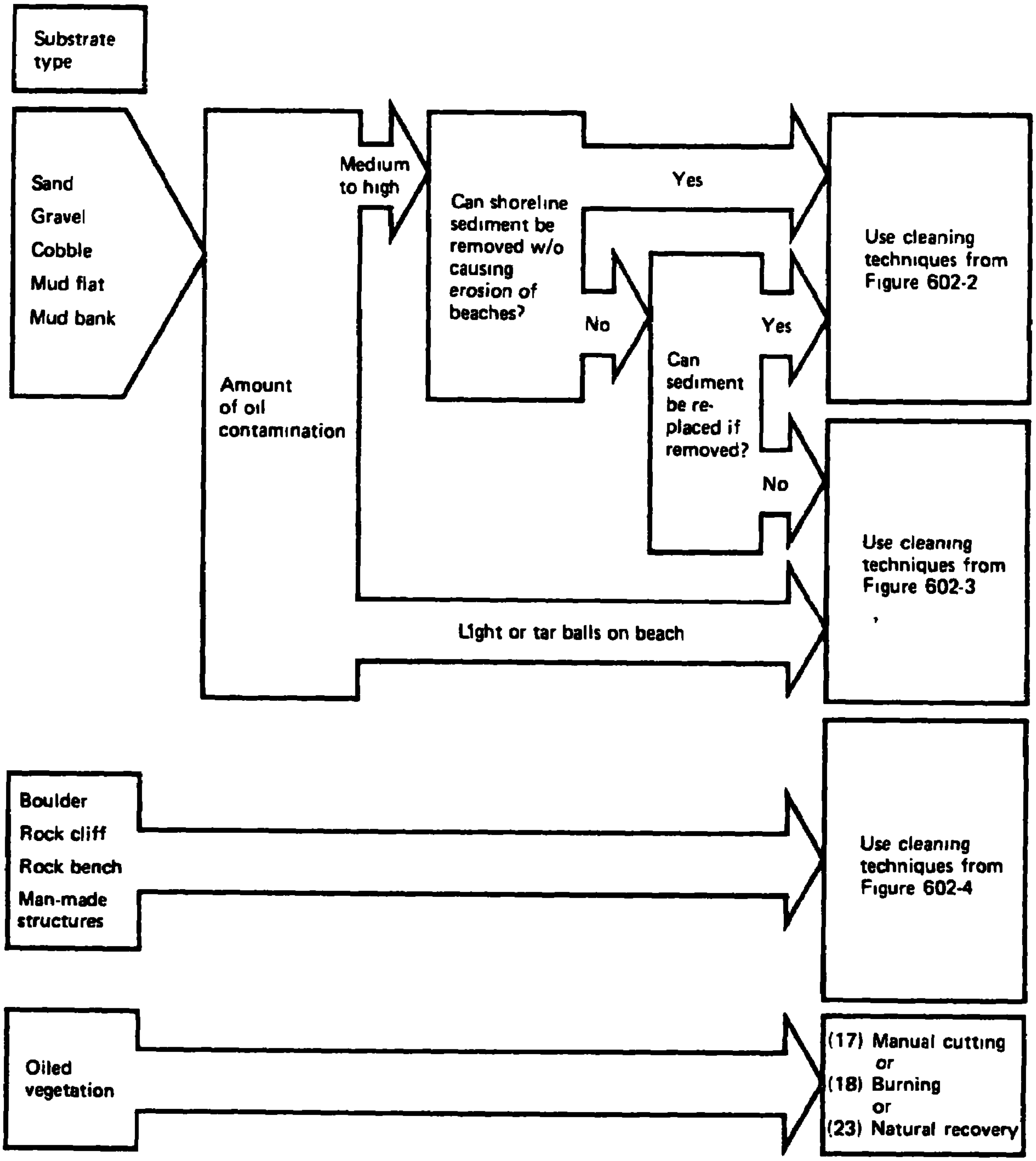


Figure 602-1. Key to decision guides.

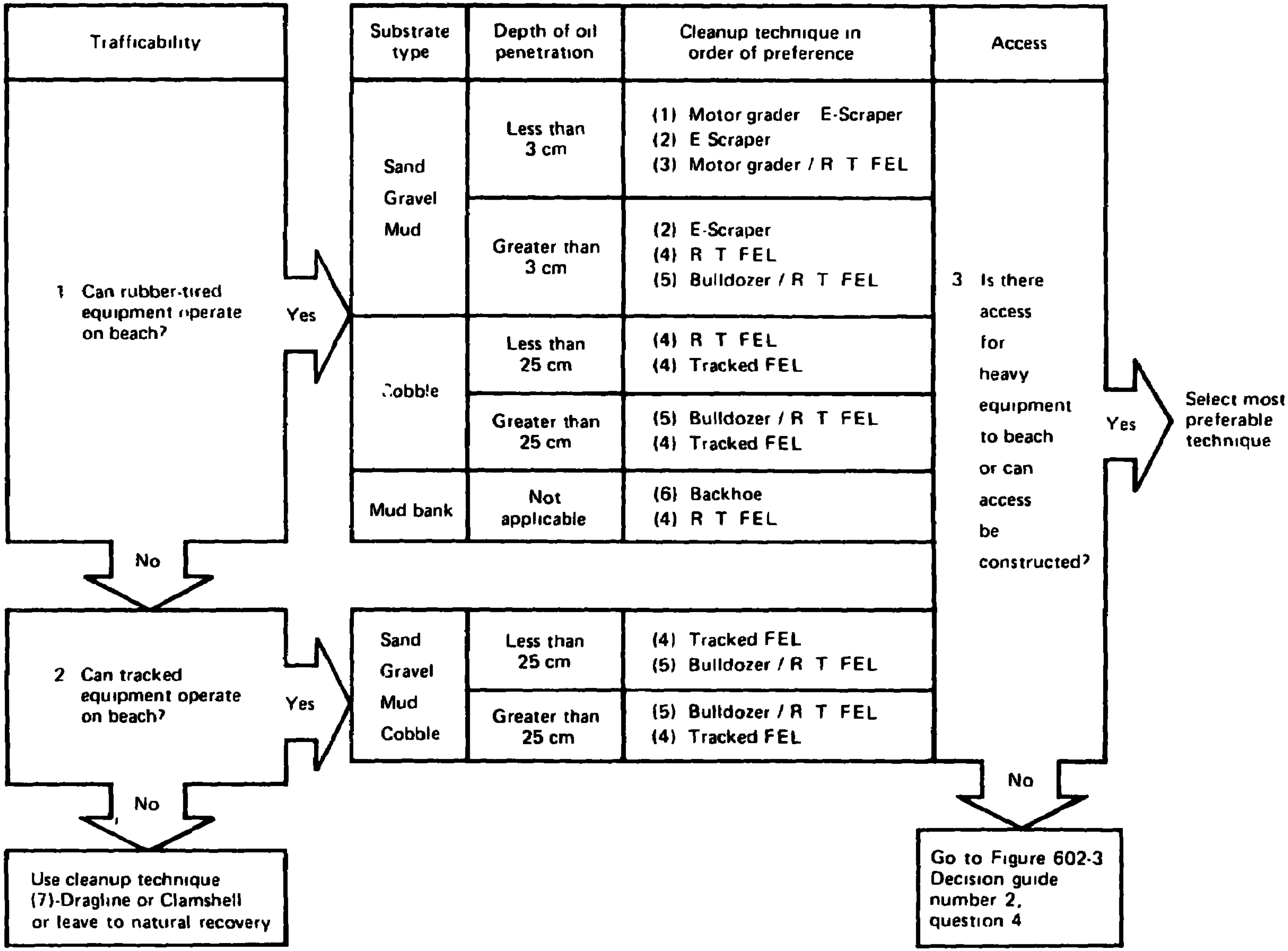


Figure 602-2. Cleanup decision guide number 1.

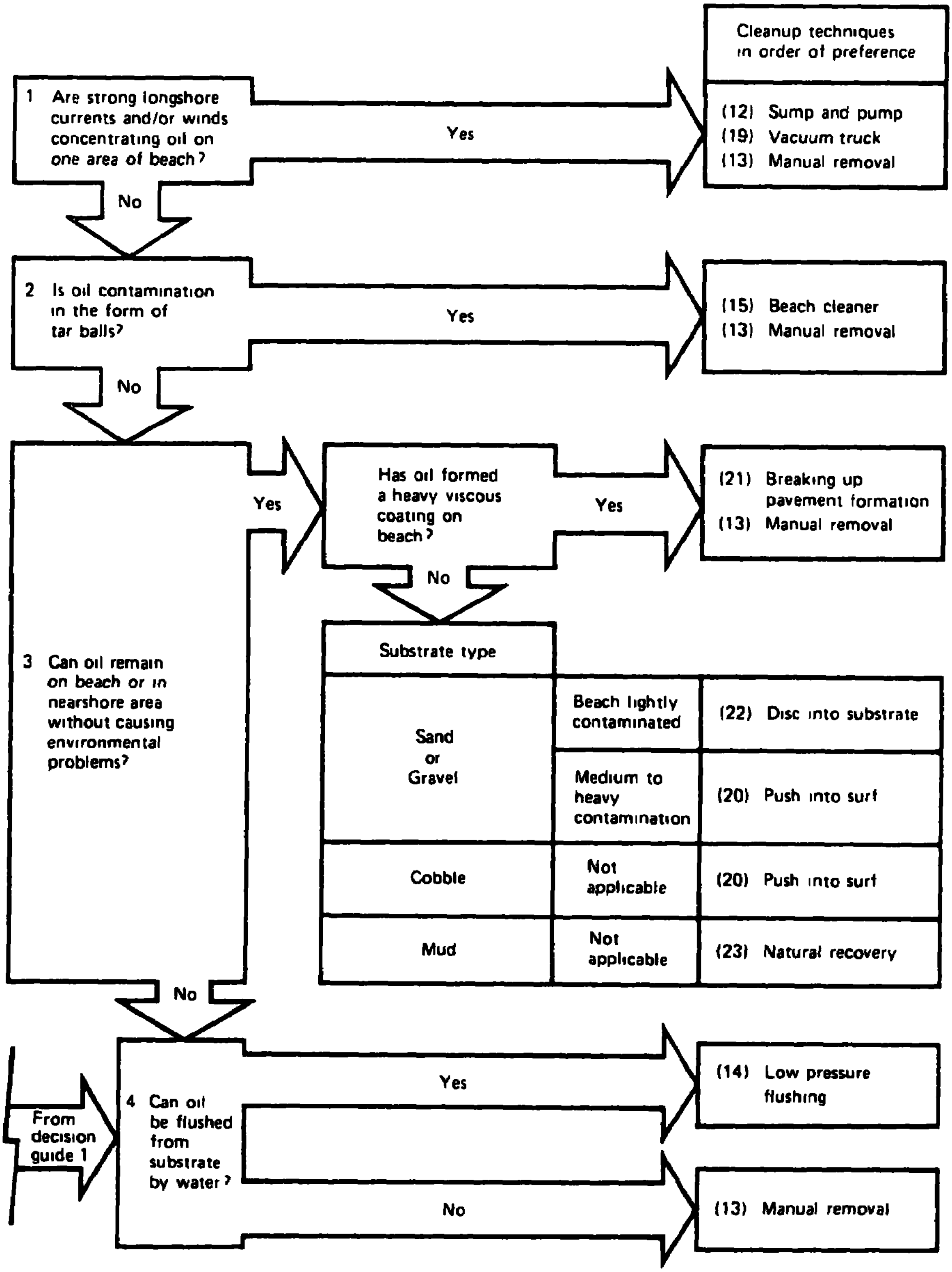


Figure 602-3. Cleanup decision guide number 2.

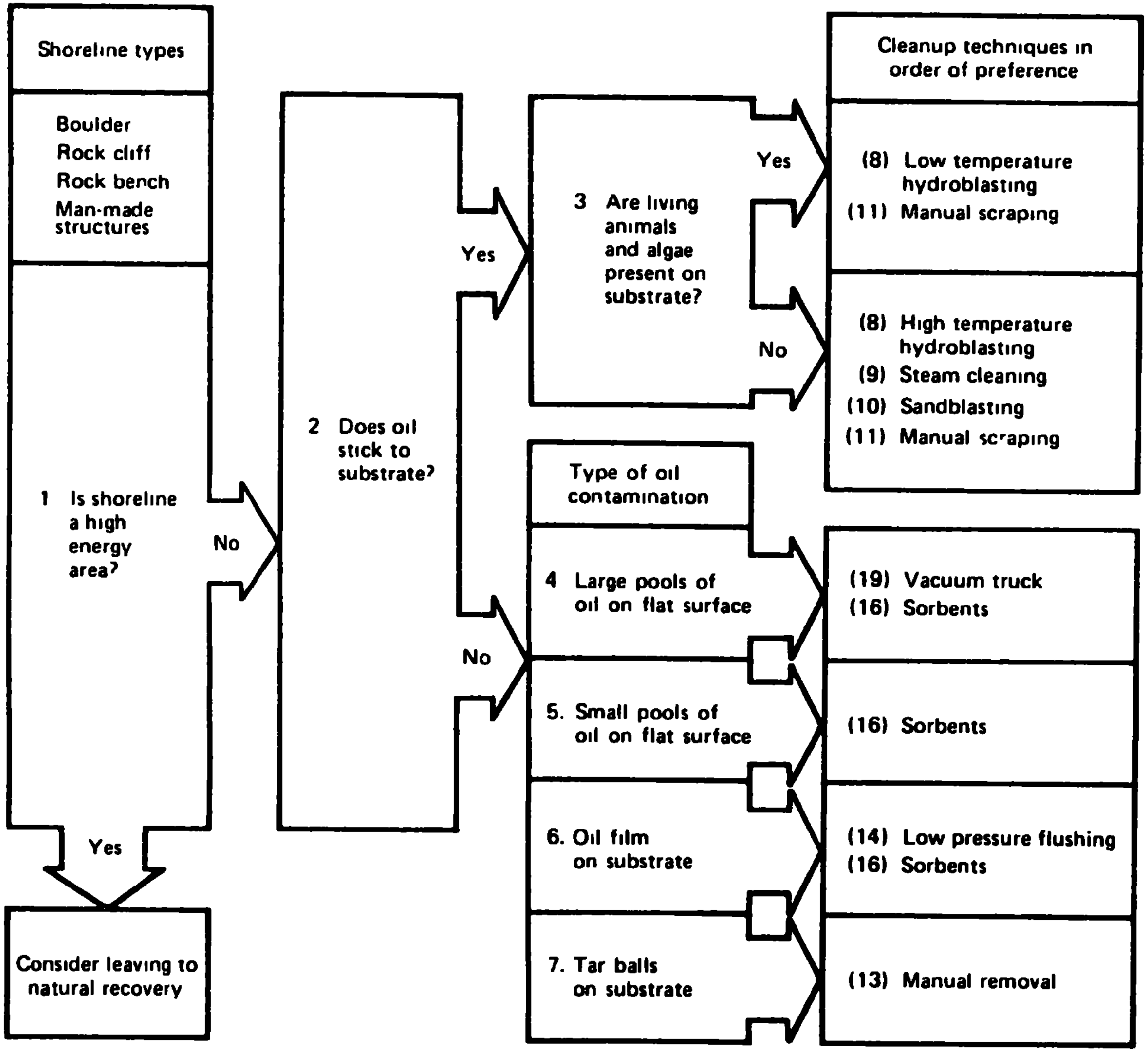


Figure 602-4. Cleanup decision guide number 3.

TABLE 602-1. CLEANUP TECHNIQUES

Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
1. Motor grader/ elevating scraper	Motor grader forms windrows for pickup by elevating scraper.	Used primarily on sand and gravel beaches where oil penetration is 0 to 3 cm, and trafficability of beach is good. Can also be used on mudflats.	Good trafficability. Heavy equipment access.
2. Elevating scraper	Elevating scraper picks up contaminated material directly off beach.	Used on sand and gravel beaches where oil penetration is 0 to 3 cm. Can also be used on mudflats. Also used to remove tar balls or flat patties from the surface of a beach.	Fair to good trafficability. Heavy equipment access.
3. Motor grader/ front-end loader	Motor grader forms windrows for pickup by front-end loader.	Used on gravel and sand beaches where oil penetration is less than 2 to 3 cm. This method is slower than using a motor grader and elevating scraper but can be used when elevating scrapers are not available. Can also be used on mudflats.	Good trafficability. Heavy equipment access.
4. Front-end loader - rubber-tired or tracked	Front-end loader picks up material directly off beach and hauls it to unloading area.	Used on mud, sand, or gravel beaches when oil penetration is moderate and oil contamination is light to moderate. Rubber-tired front end loaders are preferred because they are faster and minimize the disturbance of the surface. Front-end loaders are the preferred choice for removing cobble sediments. If rubber-tired loader cannot operate, tracked loaders are the next choice. Can also be used to remove extensively oil-contaminated vegetation.	Fair to good trafficability for rubber-tired loader. Heavy equipment access.
5. Bulldozer/ rubber-tired front-end loader	Bulldozer pushes contaminated substrate into piles for pickup by front-end loader.	Used on coarse sand, gravel, or cobble beaches where oil penetration is deep, oil contamination extensive, and trafficability of the beach poor. Can also be used to remove heavily oil-contaminated vegetation.	Heavy equipment access. Fair to good trafficability for front-end loader.
6. Backhoe	Operates from top of a bank or beach to remove contaminated sediments and loads into trucks.	Used to remove oil contaminated sediment (primarily mud or silt) on steep banks.	Heavy equipment access. Stable substrate at top of bank.
7. Dragline or clamshell	Operates from top of contaminated area to remove oiled sediments.	Used on sand, gravel, or cobble beaches where trafficability is very poor (i.e., tracked equipment cannot operate) and oil contamination is extensive.	Heavy equipment access to operating area. Equipment reach covers contaminated area.
8. High pressure flushing (hydroblasting)	High pressure water streams remove oil from substrate where it is channeled to recovery area.	Used to remove oil coatings from boulders, rock, and man-made structures; preferred method of removing oil from these surfaces.	Light vehicular access. Recovery equipment.

TABLE 602-1 (Continued). CLEANUP TECHNIQUES

Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
9. Steam cleaning	Steam removes oil from substrate where it is channeled to recovery area.	Used to remove oil coatings from boulders, rock, and man-made structures.	Light vehicular access. Recovery equipment. Fresh water supply.
10. Sandblasting	Sand moving at high velocity removes oil from substrate.	Used to remove thin accumulations of oil residue from man-made structures.	Light vehicular access. Oil must be semi-solid. Supply of clean sand.
11. Manual scraping	Oil is scraped from substrate manually using hand tools.	Used to remove oil from lightly contaminated boulders, rocks, and man-made structures or heavy oil accumulation when other techniques are not allowed.	Foot access. Scraping tools and disposal containers.
12. Sump and pump/ vacuum	Oil collects in sump as it moves down the beach and is removed by pump or vacuum truck.	Used on firm sand or mud beaches in the event of continuing oil contamination where sufficient longshore currents exist, and on streams and rivers in conjuction with diversion booming.	Heavy equipment access. A longshore current present.
13. Manual removal of oiled materials	Oiled sediments and debris are removed by hand, shovels, rakes, wheelbarrows, etc.	Used on mud, sand, gravel, and cobble beaches when oil contamination is light or sporadic and oil penetration is slight, or on beaches where access for heavy equipment is not available.	Foot or light-vehicular access.
14. Low-pressure flushing	Low pressure water spray flushes oil from substrate where it is channeled to recovery points.	Used to flush light oils that are not sticky from lightly contaminated mud substrates, cobbles, boulders, rocks, man-made structures, and vegetation.	Light vehicular access. Recovery equipment.
15. Beach cleaner	Pulled by tractor or self-propelled across beach, picking up tar balls or patties.	Used on sand or gravel beaches, lightly contaminated with oil in the form of hard patties or tar balls.	Moderate to heavy vehicular access. Good trafficability.
16. Manual sorbent application	Sorbents are applied manually to contaminated areas to soak up oil.	Used to remove pools of light, nonsticky oil from mud, boulders, rock, and man-made structures.	Foot or boat access. Disposal containers for sorbents.
17. Manual cutting	Oiled vegetation is cut by hand, collected, and stuffed into bags or containers for disposal.	Used on oil contaminated vegetation.	Foot or boat access. Cutting tools.

TABLE 602-1 (Continued). CLEANUP TECHNIQUES

Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
18. Burning	Upwind end of contaminated area is ignited and allowed to burn to downwind end.	Used on any substrate or vegetation where sufficient oil has collected to sustain ignition; if oil is a type that will support ignition, and air pollution regulations so allow.	Light vehicular or boat access. Fire control equipment.
19. Vacuum trucks	Truck is backed up to oil pool or recovery site where oil is picked up via the vacuum hose.	Used to pick up oil on shorelines where pools of oil have formed in natural depressions, or in the absence of skimming equipment to recover floating oil from the water surface.	Heavy equipment access. Large enough pools on land or thick enough oil on water for technique to be effective.
20. Push contaminated substrate into surf	Bulldozer pushes contaminated substrate into surf zone to accelerate natural cleaning.	Used on contaminated cobble and lightly contaminated gravel beaches where removal of sediments may cause erosion of the beach or backshore area.	Heavy equipment access. High energy shoreline.
21. Breaking up pavement	Tractor fitted with a ripper is operated up and down beach.	Used on low amenity cobble, gravel, or sand beaches or beaches where substrate removal will cause erosion where thick layers of oil have created a pavement on the beach surface.	Heavy equipment access. High energy shoreline.
22. Disc into substrate	Tractor pulls discing equipment along contaminated area.	Used on nonrecreational sand or gravel beaches that are lightly contaminated.	Heavy equipment access. Fair to good trafficability. High energy environment.
23. Natural recovery	No action taken. Oil left to degrade naturally.	Used for oil contamination on high energy beaches (primarily cobble, boulder, and rock) where wave action will remove most oil contamination in a short period of time.	Exposed high energy environment.

Shoreline Cleanup Factors

Most of the questions asked in the decision guides can be answered after simple field observations have been made for each shoreline section requiring cleaning.

The completed shoreline checklists given in Section 200 (Tables 200-1 and 200-2) should provide most of the information needed for each shoreline area. Two questions, however, may require special local expertise:

Figure 602-1 - Can shoreline sediment be removed without causing erosion of beaches? A local shoreline processes geologist should be consulted to determine if sediment removed from beaches may cause increased erosion of the beach.

Figure 602-3 - Can oil remain on beach or in nearshore areas without causing environmental problems? The OSC and his staff, generally in consultation with local and regional biologists/ecologists, should determine the impacts of leaving oil on or near a shoreline.

Once a cleanup technique has been selected for a particular shoreline area, the impacts of that cleanup technique (Section 603) and the implementation requirements should be assessed (Section 604). If the impacts of the technique are unacceptable or the technique cannot be implemented, then the next preferable technique listed should be chosen or consideration should be given to leaving the shoreline area to natural recovery.

Natural Recovery

Under certain circumstances, it may be preferable to leave an oil-contaminated shoreline to recover naturally rather than to attempt to clean it through physical means. These circumstances depend on the amount, location, type, and persistence of the oil on the shoreline, the nature and uses of the shoreline, and the impacts of various cleanup techniques on the shoreline and its biota. A checklist given in Table 602-2 presents a series of questions that should be considered in determining if a shoreline should be left to natural recovery.

TABLE 602-2. CHECKLIST FOR DETERMINING THE NATURAL RECOVERY POTENTIAL OF A SHORELINE

Factors Influencing Natural Recovery	Yes	No
1. Will cleanup activities on the shoreline cause more damage to the shoreline than leaving the oil to natural recovery?	____	____
2. Will cleanup activities cause severe disruption to shoreline bird or mammal colonies?	____	____
3. Does the oil have a relatively low toxicity?	____	____
4. Will storm activity or seasonal erosion cycles remove the oil from the shoreline?	____	____
5. Is the degradation rate of the oil rapid?	____	____
6. Is the presence of the oil on the shoreline acceptable in terms of the shoreline's use?	____	____
7. Is the shoreline lightly oil-contaminated?	____	____
8. Does the shoreline have a high energy level?	____	____
9. Is the oil present on the surface of the substrate and likely to remain there (as opposed to being incorporated in sediments or buried by seasonal cycles)?	____	____
10. Is rapid (chronic) release of oil likely to occur?	____	____
11. Is oil migration to adjacent shorelines or nearshore areas unlikely?	____	____

NOTE: If most or all of the above questions are answered in the affirmative, then the shoreline is a good candidate for natural recovery. However, in most cases, some of the answers will be negative and it will be up to the OSC and his staff to weigh the relative importance of each factor, depending on the local situation. Natural recovery may be preferred even if there are several negative answers to the above questions.

603 IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Any oil that comes in contact with a shoreline has the potential for adversely affecting biological and physical processes. For this reason, various cleanup techniques have been developed to mitigate the environmental damages that follow a spill event. In some cases, however, the cleanup techniques result in adverse impacts of their own and, particularly if carelessly implemented, can result in greater ecological, aesthetic, recreational, and/or economic damage to the shoreline than the oil contamination itself. The types of physical and biological effects that can occur with different cleanup alternatives are generally described below. Specific impacts associated with each cleanup technique are listed in Table 603-1. These impacts should be considered when selecting cleanup techniques from among those recommended in the previous section, and when deciding to terminate cleanup efforts.

Physical Effects

The major physical impacts associated with shoreline cleanup usually result from sediment removal. A direct relationship between the quantity of sediment removed relative to total sediment budget and rate of replenishment and the severity of impact can be expected. Other physical impacts, such as generation of suspended sediments, are related to *in situ* cleaning techniques and additional specialized methods.

The removal of large quantities of sediment may upset the littoral (or nearshore) sediment balance. A large depletion of sediments from from a beach can shift this balance, resulting in erosion on adjacent beaches and depletion of offshore sediment deposits as natural shoreline processes work to replace the extracted sediments. If there is a large sediment budget, as with most sand and gravel high energy beaches, sediment adjustments can occur fairly rapidly; if the budget is small, however, replacement will be slow or may not occur at all.

Some shoreline types such as poorly resistant or unconsolidated cliffs and pocket, cobble, or mixed sediment beaches are highly susceptible to the adverse effects associated with removal of sediments. Beaches fronting unresistant cliffs often serve to protect them by absorbing the incoming wave energy. Removal of beach substrate allows waves to work directly on cliffs, potentially initiating severe erosion and cliff retreat. Pocket, cobble, and mixed sediment beaches react in much the same way. Because pocket beaches typically have limited sources of sediment supply, replacement is slow and backshore areas may be eroded. If sediment is removed from cobble or mixed sediment beaches, the backshore areas can become inundated during the first storm, especially if the storm ridge or berm is removed. Substantial erosion and beach retreat is also likely to occur. Rocky cliffs and long stretches of sand and gravel beaches are generally more resistant to the effects of sediment removal.

Artificial replacement of removed sediments will, in most cases, prevent substantial disturbance of the beach equilibrium. If sediment removal is

TABLE 603-1. IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

	Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
1.	Motor grader/ elevating scraper	Motor grader forms windrows for pickup by elevating scraper.	Removes only upper 3 cm of beach.	Removes shallow burrowing polychaetes, bivalves, and amphipods. Recolonization likely to rapidly follow natural replenishment of the substrate.
2.	Elevating scraper	Elevating scraper picks up contaminated material directly off beach.	Removes upper 3 to 10 cm of beach. Minor reduction of beach stability. Erosion and beach retreat.	Removes shallow and deeper burrowing polychaetes, bivalves, and amphipods. Restabilization of substrate probably slow; recolonization likely to follow natural replenishment of substrate; reestablishment of long-lived indigenous fauna may take several years.
3.	Motor grader/ front-end loader	Motor grader forms windrows for pickup by front-end loader.	Removes only upper 3 cm of beach.	Removes shallow burrowing polychaetes, bivalves, and amphipods. Recolinization likely to rapidly follow natural replenishment of the substrate.
4.	Front-end loader - rubber-tired or tracked	Front-end loader picks up material directly off beach and hauls it to unloading area.	Removes 10 to 25 cm of beach. Reduction of beach stability. Erosion and beach retreat.	Removes almost all shallow and deep burrowing organisms. Restabilization of the physical environment slow; new faunal community could develop.
5.	Bulldozer/ rubber-tired front-end loader	Bulldozer pushes contaminated substrate into piles for pickup by front-end loader.	Removes 15 to 50 cm of beach. Loss of beach stability. Severe erosion and cliff or beach retreat. Inundation of backshores.	Removes all organisms. Restabilization of substrate and repopulation of indigenous fauna is extremely slow; new faunal community could develop in the interim.
6.	Backhoe	Operates from top of a bank or beach to remove contaminated sediments and loads into trucks.	Removes 25 to 50 cm of beach or bank. Severe reduction of beach stability and beach retreat.	Removes all organisms. Restabilization of substrate and repopulation of organisms is extremely slow; new faunal community could develop in the interim.

TABLE 603-1 (Continued). IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Clean up Technique	Description	Physical Effect of Use	Biological Effect of Use
7. Dragline or clamshell	Operates from top of contaminated area to remove oiled sediments.	Removes 25 to 50 cm of beach. Severe reduction of beach stability. Erosion and beach retreat.	Removes all organisms. Restabilization of substrate and repopulation of indigenous fauna is extremely slow; new faunal community could develop in the interim.
8. High-pressure flushing (hydroblasting)	High pressure water streams remove oil from substrate; oil is channeled to recovery area.	Can disturb surface of substrate.	Removes some organisms and shells from the substrate, damage to remaining organisms variable. Oil not recovered can be toxic to organisms downslope of cleanup activities.
9. Steam cleaning	Steam removes oil from substrate where it is channeled to recovery area.	Adds heat (> 100°C) to surface.	Removes some organisms from substrate but mortality due to the heat is more likely. Empty shells remaining may enhance repopulation. Oil not recovered can be toxic to organisms downslope of cleanup activities.
10. Sandblasting	Sand moving at high velocity removes oil from substrate.	Adds material to the environment. Potential recontamination, erosion, and deeper penetration into substrate.	Removes all organisms and shells from the substrate. Oil not recovered can be toxic to organisms downslope of cleanup activities.
11. Manual scraping	Oil is scraped from substrate manually using hand tools.	Selective removal of material. Labor-intensive activity can disturb sediments.	Removes some organisms from the substrate, crushes others. Oil not removed or recovered can be toxic to organisms repopulating the rocky substrate or inhabiting sediment downslope of cleanup activities.
12. Sump and pump/ vacuum	Oil collects in sump as it moves down the beach and is removed by pump or vacuum truck.	Requires excavation of a sump 60 to 120 cm deep on shoreline. Some oil will probably remain on beach.	Removes organisms at sump location. Potentially toxic effects from oil left on the shoreline. Recovery depends on persistence of oil at the sump.

TABLE 603-1 (Continued). IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
13. Manual removal of oiled materials	Oiled sediments and debris are removed by hand, shovels, rakes, wheelbarrows, etc.	Removes 3 cm or less of beach. Selective. Sediment disturbance and erosion potential.	Removes and disturbs shallow burrowing organisms. Rapid recovery.
14. Low-pressure flushing	Low-pressure water spray flushes oil from substrate and is channeled to recovery points.	Does not disturb surface to any great extent. Potential for recontamination.	Leaves most organisms alive and in place. Oil not recovered can be toxic to organisms down slope of cleanup.
15. Beach cleaner	Pulled by tractor or self-propelled across beach picking up tar balls or patties.	Disturbs upper 5 to 10 cm of beach.	Disturbs shallow burrowing organisms.
16. Manual sorbent application	Sorbents are applied manually to contaminated areas to soak up oil.	Selective removal of material. Labor intensive activity can disturb sediments.	Foot traffic may crush organisms. Possible ingestion of sorbents by birds and small mammals.
17. Manual cutting	Oiled vegetation is cut by hand, collected, and stuffed into bags or containers for disposal.	Disturbs sediments because of extensive use of labor; can cause erosion.	Removes and crushes some organisms. Rapid recovery. Heavy foot traffic can cause root damage and subsequent slow recovery.
18. Burning	Upwind end of contaminated area is ignited and allowed to burn to downwind.	Causes heavy air pollution; adds heat to substrate, can cause erosion if root systems due damaged.	Kills surface organisms caught in burn area. Residual matter may be somewhat toxic (heavy metals).
19. Vacuum trucks	Truck is backed up to oil pool or recovery site where oil is picked up via vacuum hose.	Some oil may be left on shoreline or in water.	Removes some organisms. Potential for longer-term toxic effects associated with oil left on the shoreline. Recovery depends on persistence of oil left in the pools.

TABLE 603-1 (Continued). IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

	Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
20.	Push contaminated substrate into surf	Bulldozer pushes contaminated substrate into surf zone to accelerate natural cleaning.	Disruption of top layer of substrate; leaves some oil in intertidal area. Potential recontamination.	Kills most of the organisms inhabiting the uncontaminated substrate. Recovery of organisms usually more rapid than with removing substrate.
21.	Break up pavement	Tractor fitted with a ripper is operated up and down beach.	Disruption of sediments. Leaves oil on beach.	Disturbs shallow and deep burrowing organisms.
22.	Disc into substrate	Tractor pulls discing equipment along contaminated area.	Leaves oil buried in sand. Disrupts surface layer of substrate.	Disturbs shallow burrowing organisms. Possible toxicity effects from buried oil.
23.	Natural recovery	No action taken. Oil left to degrade naturally.	Some oil may remain on beach and could contaminate clean areas.	Potential toxicity effects and smothering by the oil. Potential incorporation of oil into the food web. Potential elimination of habitat if organisms will not settle on residual oil.

required and replacement is not practical, contaminated material can be pushed into the surf zone. This serves to accelerate the natural cleaning process but without significantly reducing beach stability.

In situ cleaning of oil-contaminated sediments usually does not cause severe physical impacts upon a shoreline. The primary problems associated with high and low pressure flushing, steam cleaning, sand blasting, and manual scraping and sorbent application are 1) recontamination by oil that is removed but not effectively recovered and 2) substrate disturbance caused by extensive manual labor or the physical effects of the cleanup technique itself. Large numbers of workers operating in an area can make recovery difficult by trampling oil into the substrate. If manual labor is required on a hillside or steep bluff, workers can induce severe erosion problems.

Biological Impact

Five general types of biological impacts resulting from cleanup techniques exist: 1) removal of biota with the substrate or as a consequence of the cleanup efforts; 2) extension of toxic effects because of cleanup-induced recontamination; 3) habitat disruption by equipment, techniques, or cleanup crews; 4) crushing of organisms with manual methods or heavy machinery; and 5) disturbance of organisms due to the noise and commotion associated with heavy equipment and/or large numbers of people.

The biological effects of sediment removal are heavily dependent on the depth and, to a lesser degree, area of substrate being removed regardless of the cleanup technique used or sediment type. In general, the number and diversity of affected organisms and habitats increases as the depth of removed substrate increases. Similarly, recovery time increases with the extent of substrate removal. As is the case with all cleanup effects, the severity of impact depends on the biological value of the particular shoreline, the presence of similar and unaffected habitats nearby, and whether the affected organisms spawn and produce sufficient offspring for recruitment.

With removal of the upper 3 to 10 cm of the beach, the shallow burrowing polychaetes, bivalves, amphipods, and other infaunal organisms are likely to be affected. Because these organisms have generally adapted to disturbed beach environments, however, the regional population is not likely to be affected. Repopulation is usually rapid owing to recruitment from the shallow subtidal area or from other, unaffected areas of the same or adjacent beaches.

The removal of 10 to 25 cm of substrate would probably remove the majority of organisms inhabiting the beach. The short-term impact could be severe, but the longer-term impact would be somewhat mitigated by recruitment from offshore and longshore areas. If substrate replenishment is slow and the interim habitat is not acceptable for repopulation by the same organisms, colonization of an entirely new fauna is possible. And if the removed substrate is artificially replaced, it could take several seasonal cycles for the beach to become stabilized and repopulated because of the low nutrient content of the new material.

The removal of 25 to 50 cm of sediment would deplete the beach of almost all its organisms. Recruitment would be slow and both long- and short-term impacts could be significant.

The biological implication of cleanup techniques using *in situ* cleaning vary considerably. Low- and high-pressure flushing, steam cleaning, sandblasting, and manual scraping will, to different extents, remove organisms from substrates along with the oil. Low pressure flushing will disturb the fewest organisms. Although steam cleaning leaves most of the organisms in place, the intense heat involved will frequently kill them. In some cases, however, empty shells left attached to rocky environments have provided habitat and aided natural recovery to pre-spill conditions (e.g., barnacles and mussel tend to settle on or close to their own species).

High-pressure flushing, sandblasting, and manual scraping remove almost everything from the substrate resulting in dramatic short-term impacts. High-pressure flushing and sandblasting normally leave a clean surface that, compared with an oiled surface, offers an attractive habitat for new recruits. Because it more selectively removes oiled flora and fauna, manual scraping usually has the least short-term impact.

By transporting oil off the rocks, into the sediments, and around and under rocks, *in situ* cleanup techniques can indirectly affect organisms outside the area of initial contamination if appropriate recovery measures are not implemented. Similarly, equipment and people traffic can extend the area and duration of impact by pushing oil deeper into the sediments.

Natural cleaning can have the least overall biological impact of the cleanup options. The actual impacts that result from reliance on natural cleaning are extremely time dependent and site-specific and cannot be easily predicted.

604 CLEANUP IMPLEMENTATION REQUIREMENTS

Before implementing a cleanup operation, there are several factors that must be considered to ensure that implementation of the proposed cleanup operation is feasible. These factors are:

- access requirements
- logistical requirements
- personnel requirements
- equipment availability

The section also aids the user in estimating the total cleanup effort involved and approximating the amount of time required to effect cleanup.

Once a cleanup technique is chosen for a section of shoreline, the equipment and personnel requirements can be evaluated using Table 604-1. Access to the contaminated areas must be evaluated to determine if the existing access is compatible with that required by the cleanup equipment or if access can be modified to satisfy cleanup requirements. Land access is preferable and should be evaluated first; if limited or nonexistent, however, accessibility by air or water should also be considered. If existing access is compatible with the requirements of the equipment, the selected cleanup technique can be implemented providing other logistical requirements are met. If available access is nonexistent or not sufficient the possibility of improving or providing access should be determined. Improvements can include widening, grading, decreasing the slope, or increasing trafficability of an existing road, trail, or path. If terrain permits, roads can be quickly cut where no access previously existed.

Before any improvements are made, consideration must be given to the environmental effects of constructing or modifying access routes in addition to obtaining permission from the landowner and permits from government agencies. Common effects of such surface disturbing activities are erosion and increased runoff, disruption of wildlife habitats, aesthetic degradation, and destruction of vegetation. Another consideration is that increasing access for equipment may also increase it for public use. This may be in conflict with the general shoreline plan or the ability of the shoreline to withstand increased human activity.

Once the cleanup technique and associated logistical requirements for each shoreline area are established, they can be combined to estimate the total cleanup effort involved. A summary of the various cleanup techniques and their cleaning rates is given in Table 604-2. The time required to clean each shoreline area can be estimated by dividing the amount of area to be cleaned by the cleaning rate of the particular technique. The time and equipment required to clean each shoreline section can be added together to estimate the total time and equipment required to effectively clean the entire contaminated shoreline.

The final step in determining feasibility of cleanup actions is to compare the equipment and personnel requirements with what is available from

TABLE 604-1. EQUIPMENT AND PERSONNEL REQUIREMENTS

Cleanup Technique	Length of Beach	Amount and Type of Equipment Needed	Amount and Type of Personnel Required	Estimated Time Required to Clean Up Beach (from Table 604-2)

Types of Equipment Needed	Total Number of Each Type	Time Required For Each Piece of Equipment	Total Personnel Required by Type	
			Heavy Equipment Op.	
			Manual Laborers	
			Truck Drivers	
			Cleanup Equipment Operators	

TABLE 604-2 SUMMARY OF CLEANING RATES

Cleanup Technique	Cleaning Rates[a]	
	30-m (100 ft) Haul Distance)	150-m (500 ft) Haul Distance
Combination motor grader/ Elevating scraper	2.5 hr/hectare (1 hr/acre)	7 hr/hectare (2.8 hr/acres)
Elevating scraper	2.4 hr/hectare (0.95 hr/acre)	6.5 hr/hectare (2.6 hr/acre)
Combination motor grader/ front-end loader (rubber-tired)	6 hr/hectare (2.4 hr/acre)	18 hr/hectare (7.2 hr/acre)
(tracked)	8.3 hr/hectare (3.3 hr/acre)	27 hr/hectare (10.8 hr/acre)
Front-end loader (rubber-tired)	16.5 hr/hectare (6.6 hr/acre)	34 hr/hectare (13.6 hr/acre)
(tracked)	22 hr/hectare (8.8 hr/acre)	69 hr/hectare (27.6 hr/acre)
Combination bulldozer/ front-end loader (rubber-tired)	25 hr/hectare (10 hr/acre)	52 hr/hectare (20.8 hr/acre)
Backhoe	17 hr/hectare (6.8 hr/acre	
Dragline or clamshell	Dragline - 28 hr/hectare (11.2 hr/acre) Clamshell - 50 hr/hectare (20 hr/acre)	
Disc into substrate	1 hr/hectare (0.33 hr/acre)	
Beach cleaner	1 hr/hectare (0.5 hr/acre)	
Push contaminated substrate into surf	5 hr/hectare (2 hr/acre)	
Breaking up pavement	1.33 hr/hectare (0.6 hr/acre)	
High-pressure flushing (hydroblasting)	1.5m^2/min (15 ft^2/min)	
Steam cleaning	1 M^2/min (10 ft^2/min)	
Sandblasting	1.25 m^2/min (2.5 ft^2/min)	
Manual cutting	65 m^2/hr (77 $yards^2$/hr)	

[a]Rough estimate only, actual rates may vary depending on the circumstances. Details regarding the basis of these rates are given in the discussion of each individual technique.

contractors. If the supply is sufficient to satisfy the logistical requirements, cleanup can be implemented. Should the supply be inadequate, other cleanup techniques can be evaluated in light of the available resources. In some cases, other types of equipment can be substituted for a specific cleanup technique but are usually less efficient.

A sample form that can be used for gathering data concerning cleanup implementation requirements is given in Table 604-3. A checklist for determining feasibility of different cleanup techniques is given in Table 604-4. Once the cleanup technique and associate equipment and personnel have been established for each shoreline section, the information on the data form can also be used to estimate the total cleanup effort required as described previously.

TABLE 604-3. DATA FORM FOR CLEANUP IMPLEMENTATION REQUIREMENTS

Beach Name and Classification	Cleanup Technique Selected	Type of Available Access	Logistic Requirements of Cleanup Technique (from Section 805)	Is Access Acceptable? (Yes or No)	To What Extent Can Access Be Improved?	Are Required Equipment and Personnel Available?	Can Available Supply Be Supplemented or Improvised?

TABLE 604-4. IMPLEMENTATION OF CLEANUP TECHNIQUES CHECKLIST

Access (Sections 403 and 803)

1. Is there access to the shoreline for the cleanup equipment? Yes No

2. If access is not sufficient, can it be improved by widening the trail or building a road? Yes No

3. Are effects of road building or widening acceptable? Yes No

4. If not acceptable, is other access available (sea or air)? Yes No

5. If other access is not available, select another technique whose access requirements are compatible with the available access.

Equipment and Personnel (Section 805)

1. Are sufficient equipment and supplies available to initiate technique? Yes No

2. Can another item of equipment or supply be substituted for the unavailable item? Yes No

3. If other equipment or supplies are not available, select another technique for which equipment and supplies are available.

4. Are sufficient personnel locally available to implement technique? Yes No

5. If not, can personnel be brought in from outside the local area? Yes No

6. If personnel are not available, select another technique.

605 TERMINATION OF CLEANUP

Determining when specific cleanup actions being conducted on an oil contaminated shoreline should be terminated can be a difficult decision, involving several potentially conflicting factors. These factors are usually the ever-increasing costs of the cleanup actions and the damage to the social and ecological environment caused by the cleanup versus the ecological and economic effects of leaving the remaining oil in place.

The decision to terminate cleanup activities is one which must be made on a case-by-case basis depending on the prevailing local condition. In all cases, two conditions must be met before cleanup actions on a particular shoreline are terminated:

1. Fresh oil contamination of the shoreline is no longer occuring.

2. The oil remaining on the shore can be considered immobilized and is no longer a threat to recontaminate adjacent areas.

Other factors dependent on local conditions that should be considered in terminating cleanup actions are:

1. When environmental damage caused by cleanup efforts is greater than the damages caused to the environment by leaving the remaining oil in place.

2. When local environmental experts or OSC staff deem that the remaining oil is not harmful to local ecology. This is primarily a function of the natural cleaning ability of the shoreline.

3. When cost of cleanup operations increases significantly while the amount of oil being removed decreases significantly.

4. When only occasional spots of oil remain on substrates.

5. When public pressure for continued cleanup terminates.

6. When cleanup operations interfere significantly with the designated use of the shoreline area more than the presence of the remaining oil.

In most cases, only a few of these factors will apply to a given shoreline area. Consequently, the OSC and his staff will have to make subjective judgments in assessing the local conditions and determining at what point a sufficient number of these factors have been achieved so that cleanup activities can be terminated.

Handling recovered oil and oil-contaminated materials can pose both immediate and long-range problems. Oil/water mixtures can be separated in treatment tanks and recovered oil then sent to a refinery.

Disposal of contaminated debris is more difficult. Legal requirements for its disposal are established by most state regulatory bodies. In most cases, contaminated wastes should not be burned. They can, however, be buried safely on land in approved disposal sites if correct procedures are followed. It is often advisable during waste handling, transfer, or storage to prevent contamination by covering the area of operation with plastic sheets.

Disposal can pose several problems. The first of these is temporary onsite storing and then transporting oil and contaminated material to the final disposal sites. In most oil spill situations, recovered material is stored for a short period of time at a local site, while arrangements are made for a final disposal site. Also, recovered liquid wastes can undergo primary separation to reduce the amount of liquid requiring transport.

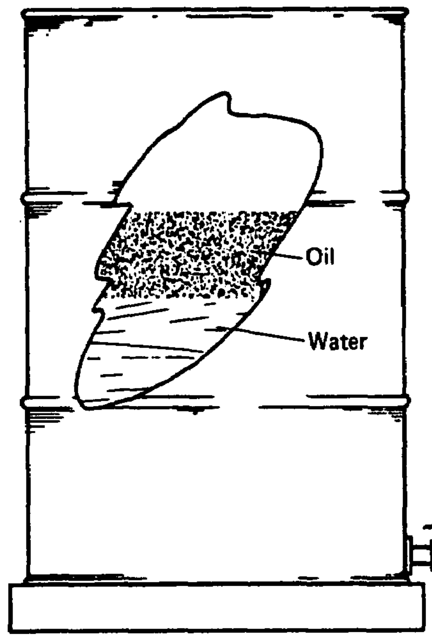
The second problem involves disposal methods, of which several are available. They include oil and water separation, burial, and natural degradation. The specific disposal method selected depends on the nature of the oil-contaminated material and the location of the spill.

Oil and Water Separation

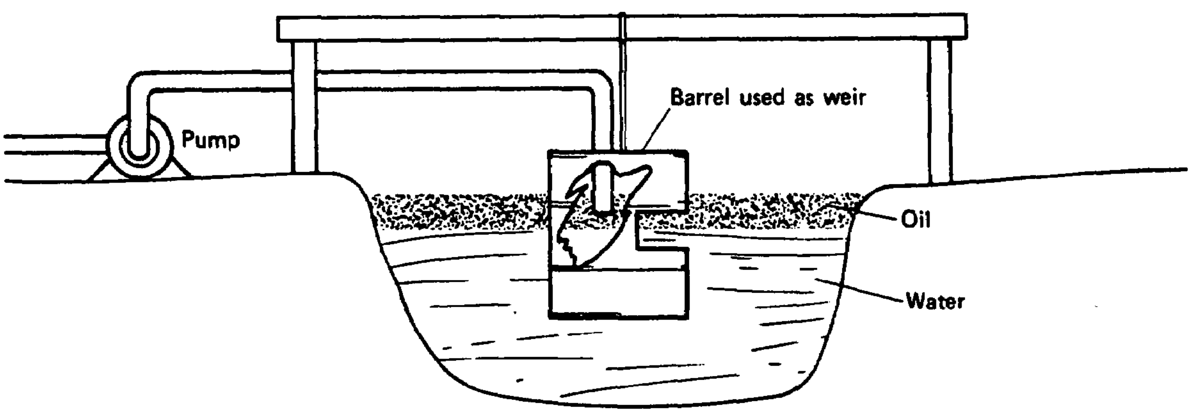
In some areas the majority of the oil and water separation can be performed at existing treatment and separation facilities located at refineries or oil production sites. However, if the spill is minor and/or occurs at a considerable distance from any such facility, the following techniques can be used to provide oil/water separators for field use. These separators might also be utilized locally to remove a portion of the water so as to reduce the bulk of the oil/water mixture before transporting it for final separation.

Effective oil/water separators can be constructed under field conditions to further recover oil from oil/water mixtures. Fifty-five gallon drums or sheet metal welded together into a 4 x 8 x 4-foot transportable container can be used as separators, after being fitted with a bottom draining pipe with valve. The oil/water mixture would enter the container from the top, be allowed to settle, and water then drained off the bottom through the drain pipe. The oil can be pumped from the vat to a storage tank or tank truck (Figure 606-1a).

A second method can be used to remove oil from a natural or excavated sump pit. A 55-gallon drum fitted with a small pump and hose and a 4- x 18-inch slot cut from the top third is suspended upright into the sump pit, positioned such that the bottom of the slot remains just below the surface of the oil layer. Oil flowing into the drum is then pumped into a storage tank or tank truck (Figure 606-1b).



A. 55-gal drum oil/water separator.



B. 55-gal drum and sump oil/water separator.

Figure 606-1. Field oil/water separation.

A tank or any portable tank can also be used to provide oil/water separation. If water in oil emulsions is recovered, chemical de-emulsifiers can be added to the separator tanks to aid in breaking the emulsions and providing more effective water/oil separation.

Temporary Waste Storage Sites

In the event of any shoreline cleanup operation, establishing a temporary oily waste disposal site close to the cleanup operation is very important. The purpose of a temporary storage site is to provide a location to accumulate oily sediment and debris removed during shoreline cleanup operations until a final disposal site can be located, approved, and arrangements made for its use. The temporary storage sites should be located in an area with good access to the shoreline cleanup operation and to nearby streets and highways. Good storage site locations should be flat areas such as parking lots (paved or unpaved) or underdeveloped lots adjacent to the shoreline.

Temporary storage sites should be selected and prepared to minimize contamination of surrounding areas from leaching oil. Therefore, storage sites should not be located on or adjacent to ravines, gullies, streams, or the sides of hills, but on flat areas with a minimum of slope. Once a location is selected, certain site preparation is usually necessary to contain any leaching oil. An earth berm should be constructed (Figure 606-2) around the perimeter of the storage site. If a paved parking lot is used, earth would have to be imported from nearby areas; if an unpaved surface is used, material can be excavated from the site itself and pushed to the perimeter, thereby forming a small basin. Entrance and exit gaps should be left in the berm to allow cleanup equipment access to the site. If the substrate or berm material is permeable, plastic liners should be spread over the berms and across the floor of the storage site in order to contain any possible oil leachate.

A front-end loader should be stationed at each storage site to distribute the dumped oily material evenly and to load trucks removing the material to final disposal.

Transport

Transporting oiled material to a final disposal site is usually done with dump and tank trucks. The material is loaded into the trucks at the point of removal or temporary storage and transported to an approved dump site. The trucks typically have capacities of 10 yd^3 or 20 yd^3. To prevent oil leakage during transport, the truck beds should be lined with plastic sheeting.

The rate at which contaminated material is transported to a disposal site depends on the number and capacity of dump trucks used and the distance to the site. The trucks are loaded by front-end loaders at a date dependent on the bucket size of the loader. The time required to load each truck ranges from 1.5 to 4 minutes for a 10 yd^3 truck and 3 to 8 minutes for a 20 yd^3

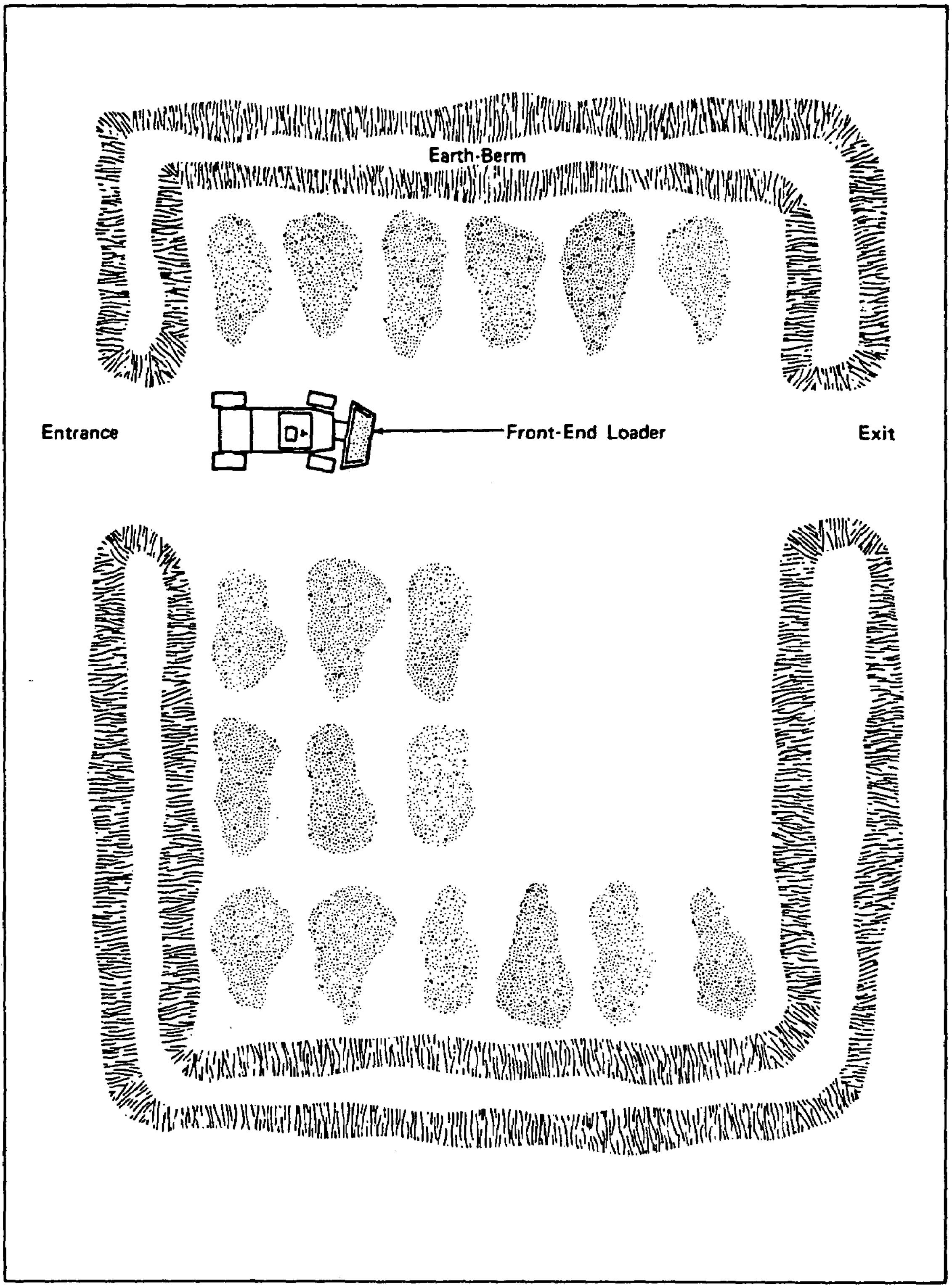


Figure 606-2. Temporary waste storage site.

truck. Table 606-1 lists disposal rates of contaminated material for various haul distances to a disposal site, truck capacities, and number of trucks.

Final Disposal

If an existing, approved disposal site is unavailable or not feasible to use, private burial offers an alternative disposal method. For specific procedures for site selection and burial refer to EPA Disposal Manual #EPA-600/2-77-153a.

TABLE 606-1. RATES OF DISPOSAL FOR OILED MATERIAL

Distance to Approved Disposal Site km	(mi)	No. of 10 yd^3 Cap. Dump Trucks	No. of 20 yd^3 Cap. Dump Trucks	Disposal or Removal Rate[a]
20	(12)	4	2	20 m^3/hr
30	(19)	4	2	12.5 m^3/hr
40	(25)	6	3	14.4 m^3/hr
60	(37)	8	4	13 m^3/hr
80	(50)	10	5	12 m^3/hr

[a]Rates based on an average travel speed of 65 km/hr (40 mph) and a fill time of 2 minutes for 10 yd^3 trucks and 4 minutes for 20 yd^3 trucks.

SECTION 700

INLAND WATERS

The shorelines of inland waterways have many characteristics similar to the shorelines of coastal waters, and much of the information presented in this manual is directly applicable to inland shorelines as well as coastal shorelines. However, some differences do exist that can affect the response actions to a spill. This section supplements the characterization of coastal shorelines with information pertaining primarily to inland waterways and discusses the implication of this information with regard to oil spill response efforts.

701 GENERAL SHORELINE INFORMATION

Hydrological Regime

Oil contamination occurring on lakes, rivers, streams, or other non-tidal environments is affected by a different hydrological regime than that of the ocean. Currents and, to a lesser degree, water level variations are the primary factors controlling oil pollution.

Rivers

Currents. Wind-induced currents and downstream currents are the major movers of an oil spill in a river environment. Wind-induced currents cause the surface water and therefore oil on the surface to move in the direction of the wind. Downstream currents are a function of the channel gradient and the channel width/depth. The currents next to the banks are the least strong; the current is greatest at midstream, except at bends in the river.

Currents tend to be strongest along the outside edge of a bend in a river where the current tends to flow straight into the outside bank before being deflected downstream. Oil contamination is usually heavy in this area because currents drive the oil onto the bank. Other areas of high oil concentrations typically occur in small inlets and back eddy areas along the river bank away from the influence of the main current.

River currents often exceed 1 knot, which is the velocity above which boom failure usually occurs. Therefore, containment booming is relatively ineffective in these high-current environments; however, diversion booming can be used in strong current areas.

In general, high water currents can be expected to occur in the following areas:

- where waterways narrow down
- in shallow water connecting two bodies of deeper water
- at stream entrances into larger streams or water bodies
- in the center sections of streams or rivers

Low water currents can be expected in the following areas:

- in channel openings at right angles to the main current flow
- in shallow backwater areas

Figure 701-1 illustrates typical examples of high and low current areas.

Water Level Variation. In river environments, water level variation is a result of changes in snow melt, natural groundwater inflows, precipitation, evaporation, water releases from dams, and municipal and industrial consumption.

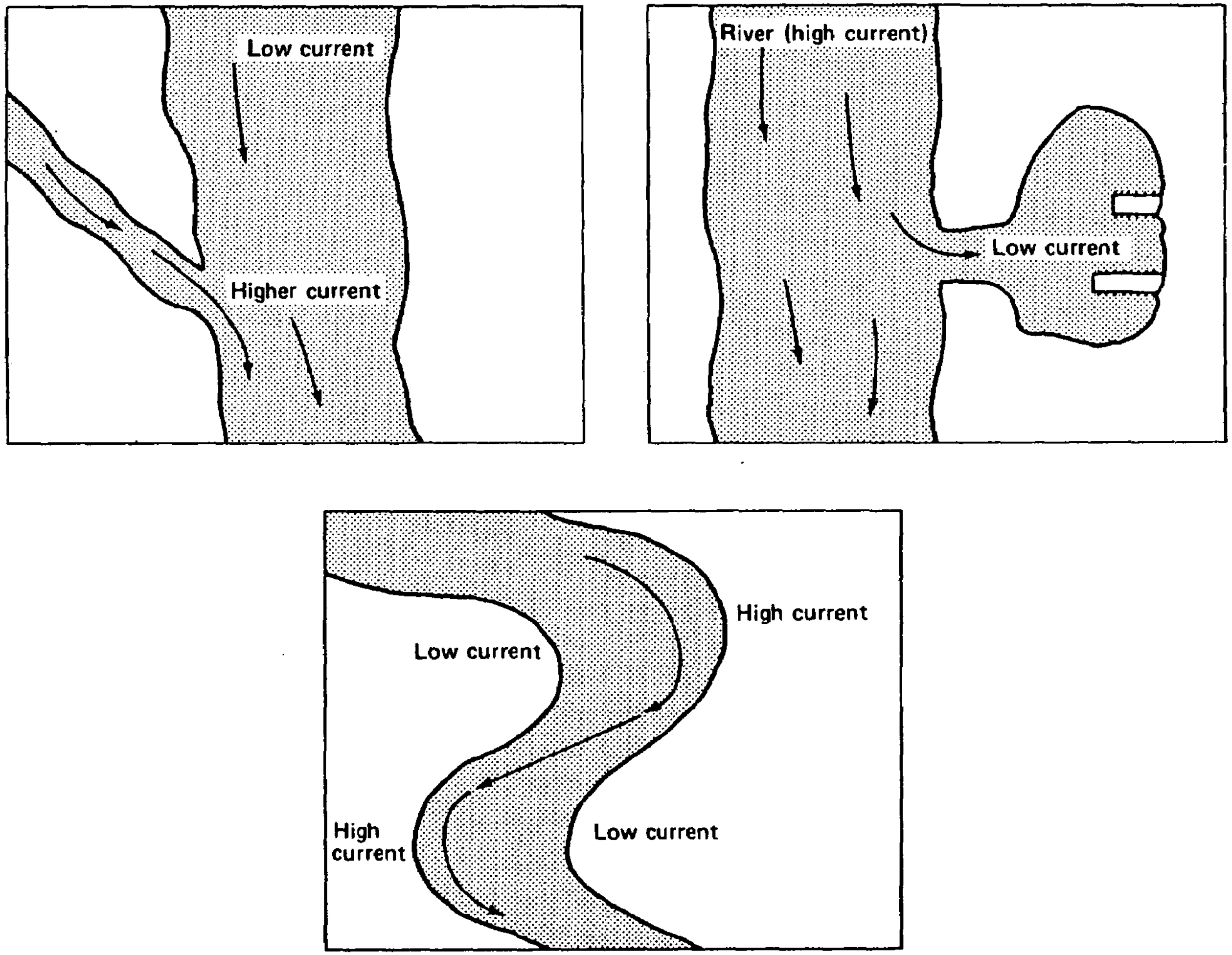


Figure 700-1. High and low current areas.

Oil contamination along a river is essentially linear, i.e., oil contaminates the shoreline in a narrow band at that water level. Storm runoff can raise water levels significantly and, in some cases, cause flooding of surrounding low-lying areas. Oil spilled during these periods can cause extensive contamination. Under normal conditions, though, water level variation is usually small and occurs over a long period of time causing little difficulty for protection and cleanup efforts.

Lakes

Currents. Currents in lakes or other inland water bodies are influenced primarily by the wind, with lesser effects from circulation patterns and river inflows and outflows. Oil movement and contamination is thus controlled mostly by the speed and direction of the wind.

Water Level Variation. In non-tidal environments, long-term water level variations are due to man-induced changes, barometric pressure, wind-generated storm surges, and hydrological factors (water inflow from rivers, lakes, groundwater, and precipitation; water outflow into rivers, lakes, and groundwater; and as evaporation). Short-term water level variations could be induced by barometric pressure, storm surges, and wind set-up (seiche effect).

Oil contamination in a calm, non-tidal environment is also linear except in cases of large water level variations. In these disturbed environments oil contamination is still somewhat linear but in a wider band. Wind seiches and storm surges can deposit oil relatively high on a shoreline where it will remain until subsequent strong seiches and surges act to degrade and wash away some of the oil.

For large bodies of water, such as the Great Lakes, water level variation is an important factor in protection and cleanup. Although they are generally low-energy environments, severe storms, especially those paralleling the long axis of a lake, can create conditions similar to storm surges in a coastal environment. Therefore, oil spills occurring during these periods could cause extensive contamination of backshore areas with the same effects as those described in Section 803.

702 SHORELINE CLASSIFICATION

The classification of inland shorelines basically follows that described for coastal shorelines in Section 400. However, the differences that do exist in sediment type, energy level, sensitivity, and persistence of oil are presented below. The checklists presented in Section 201 can be used to classify inland shorelines and to determine protection and cleanup techniques and implementation requirements.

Sediment Type

Generally, the sediment types of inland shorelines parallel those in coastal areas except for the frequency at which they occur. Lake and river shorelines are frequently composed of mud or dirt banks and may be lined with trees or heavy vegetation. However, sand or gravel beaches are sometimes found on lake shorelines and on river or stream shorelines.

Energy Level

Inland shoreline energy levels are almost always low except during storms or floods. Nonetheless river currents or waves in large lakes can impart some energy on the shore.

Persistence

Although the zone of contamination on inland shorelines is typically small and linear, oil can persist for long periods of time. Since water levels of rivers and lakes tend to decrease during the summer, oil deposited on those shorelines during late spring would likely remain until the following winter when water levels return to their seasonal highs. The same is true of shorelines contaminated during or following storms when water levels are above normal or wind and wave action could deposit oil above normal water levels. The oil would tend to persist until subsequent storms cause water levels to equal or exceed the height of contamination.

703 PROTECTION

The techniques used to protect inland shorelines and their implementation requirements are basically the same as those used for coastal areas as described in Sections 502 and 804. The majority of protection techniques used on inland shorelines are concerned with containment of the spilled oil before the contamination becomes extensive.

704 CRITERIA FOR SELECTING CONTAINMENT SITES

River and Stream Characteristics

When selecting containment sites within rivers and streams, the following stream characteristics must be considered:

- velocity
- discharge and flow characteristics
- channel conformation (width, depth, pool-riffle ratio)
- man-made structures (culverts, spur dikes, bridges, LWC)
- backwater areas
- side channels
- presence of ponds adjacent to stream
- bank vegetation

Availability of access, presence of suitable topography for working conditions, storage areas for oil removed from the rivers, and environmental factors also must be considered.

The selection of containment sites will change somewhat with changes in the flow characteristics of the river. The following discussion considers containment site criteria for periods of low and high flow in rivers and streams. Table 704-1 lists the preferred containment site locations for each period.

Low Flow Period

During low flow, the water level will be below the vegetation along the bank. In the smaller rivers and streams, the flow pattern will probably be a series of pools and riffles. Normally the pools will exist on the outside of a meander where the velocities will be slower. The slower the water velocity, the more effective the containment procedures. Gravel bars and dry, high water channels will probably be present for staging containment operations and obtaining materials for berms and sandbags. Dry depressions in dry highwater channels could be used for temporary storage of removed oil, however the depressions should be lined with polyethylene sheets before being used for oil storage.

High Flow Period

When rainstorms cause high water levels, access and containment procedures are hampered. Velocities of the water will be faster and probably prohibitive to containment booming operations except at specific locations. Increased turbulence will tend to entrain the oil in the water and may tend to form water in oil emulsions. The water level will probably be up to the vegetation line and all highwater channels could contain flowing water, with pool and riffle sequences probably flooded over. Except for the small streams, fording the river by men with equipment will be difficult or impossible.

TABLE 704-1. PREFERRED RIVER AND STREAM CONTAINMENT SITES DURING LOW AND HIGH FLOWS

Low Flow

1. Man-made structures: Bridges, culverts, spur dikes, and low water crossings provide ideal access points where dikes, berms, or diversions can be installed to slow water velocities and facilitate containment procedures.

2. Natural pools: At the outside of meanders or other pools where velocities are slower.

3. Backwater areas: Pools may exist behind log jams or debris jams.

4. Gravel and sand bars: Berming and diking could be facilitated where sufficient gravel materials are available.

High Flow

1. Man-made structures.

2. Side channels: High water channels will probably be flowing water. Those that exist along the side of the river, especially where the oil entered, could be utilized for partial or complete containment. These channels are normally narrower and facilitate berming and diking more easily than the main channel.

3. Backwater areas: Pools with lower water velocities might exist behind log and debris jams, again facilitating containment procedures.

4. Vegetated banks: The water level will probably be up to the vegetation and will probably cause some oil to collect on the vegetation, in small pools and eddys along the bank. Partial containment could be accomplished by utilizing these.

Rivers

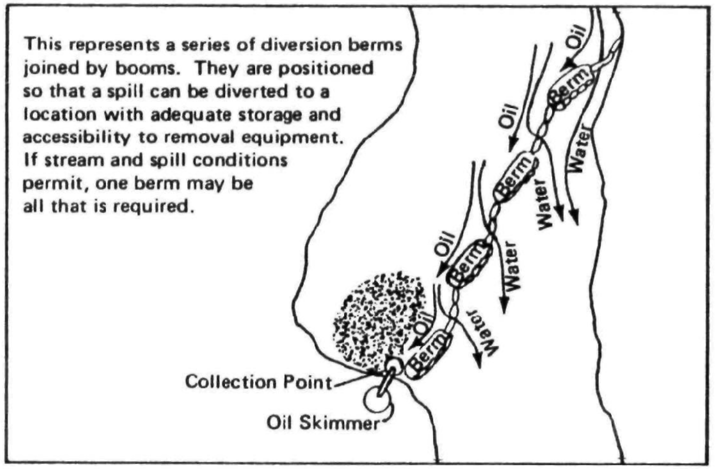
Booms deployed directly across a river or stream will usually contain the flow of oil if current velocity is less than about 1 knot (0.5 m/s). Wind will affect surface water velocity by a factor of approximately 3 percent of the wind speed. This should be taken into consideration when wind is blowing downstream or upstream. When containment booming is used, the oil will have to be removed rapidly from the upstream side of the boom. When current velocities are greater than 1 knot, diversion booming should be used.

If containment booms are deployed across a river or stream, secondary backup or sorbent booms should be positioned slightly behind the primary boom to recover any oil that might escape. Sorbent barriers can also be used in shallow, low-current waterways to contain light oil sheens on the water's surface.

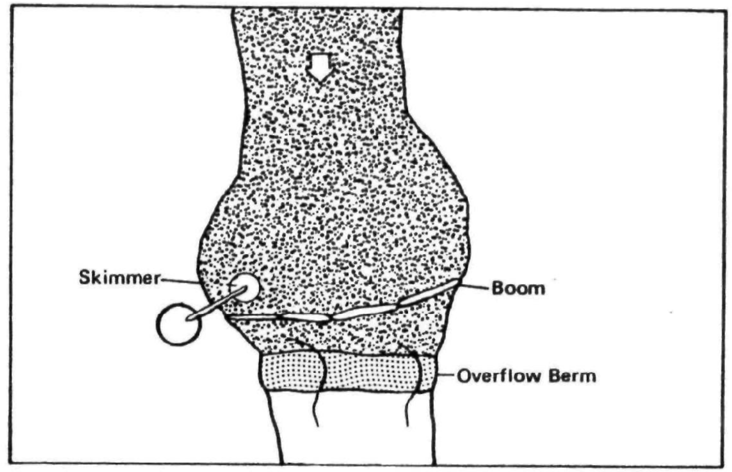
Spills on the main river channel will be difficult to contain and can be treated in several ways. During periods of high stream flow and velocity, a series of diversion berms and booms should be used, diverting the spill to a containment pit or floodplain feature. Digging a pit across the main river channel will create eddies and pools of quieter water. This is practical only on smaller rivers where equipment can be used. This technique is more effective when used with an overflow dam directly downstream. The pit should be located where rapid removal of the oil is possible. Oil should be removed from behind the boom as rapidly as possible to prevent loss of oils.

A spill entering the river can be partially controlled by deploying booms parallel to the river bank downstream from the point of entry. Under some circumstances, side channels could be converted to containment ponds if the following procedures are used: 1) berm or dike the downstream end of the side channel; 2) blast or construct a suitable channel for diversion to a skimmer in conjunction with an overflow berm such that the flowing oil is diverted into the mouth of the side channel, but allows the majority of water to flow down the main channel. Figure 705-1 illustrates the containment techniques described above.

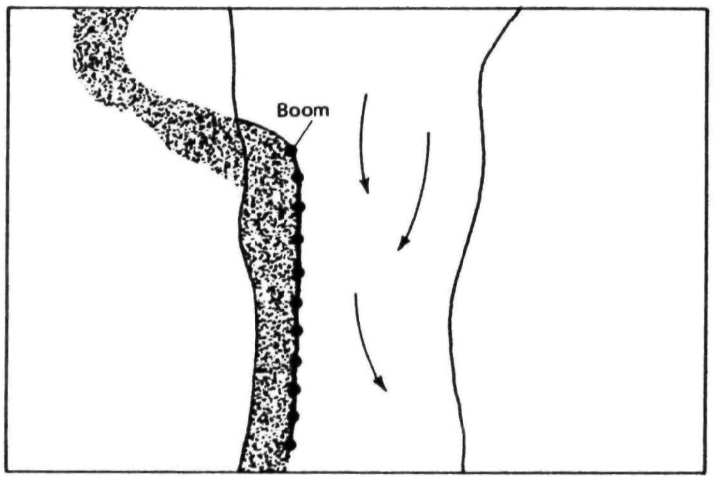
Berms and dams are best suited for shallow rivers, streams, and creeks where booming is ineffective because the draft of the boom exceeds the water depth. Small creeks can be blocked entirely by damming if there is sufficient storage area upstream. However, a means to stop the oil and let the water continue downstream will generally be required, such as an underflow dam, an overflow berm, or a dam in conjunction with a pump or siphon. Side views of these techniques are shown in Figure 705-2. These barriers should be located so that a pond will form upstream from the barrier, allowing the use of sorbents, booms, and skimmers for cleanup. In addition, pools may exist behind log jams or debris jams where containment could be achieved. Where trees exist along the banks, they could be cut and used for booming across the stream in an emergency situation. On fast-flowing creeks, a



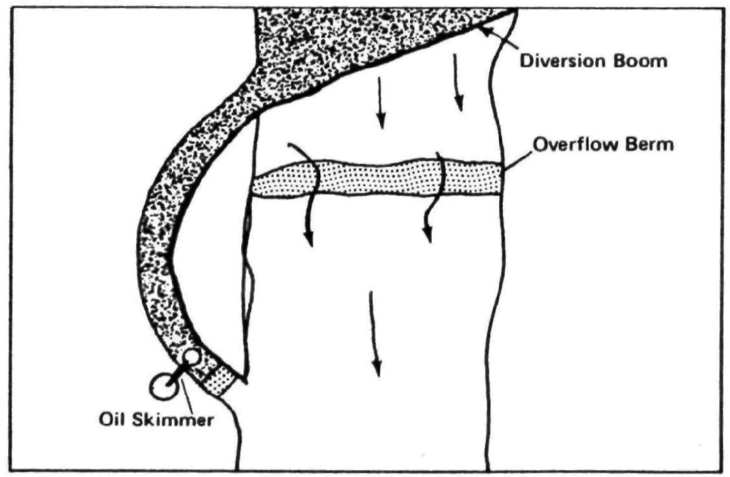
A. Diversion berms and booms



B. Overflow berm and boom



C. Booming parallel to shoreline



D. Diversion boom/side channel containment

Figure 705-1. Oil containment on rivers.

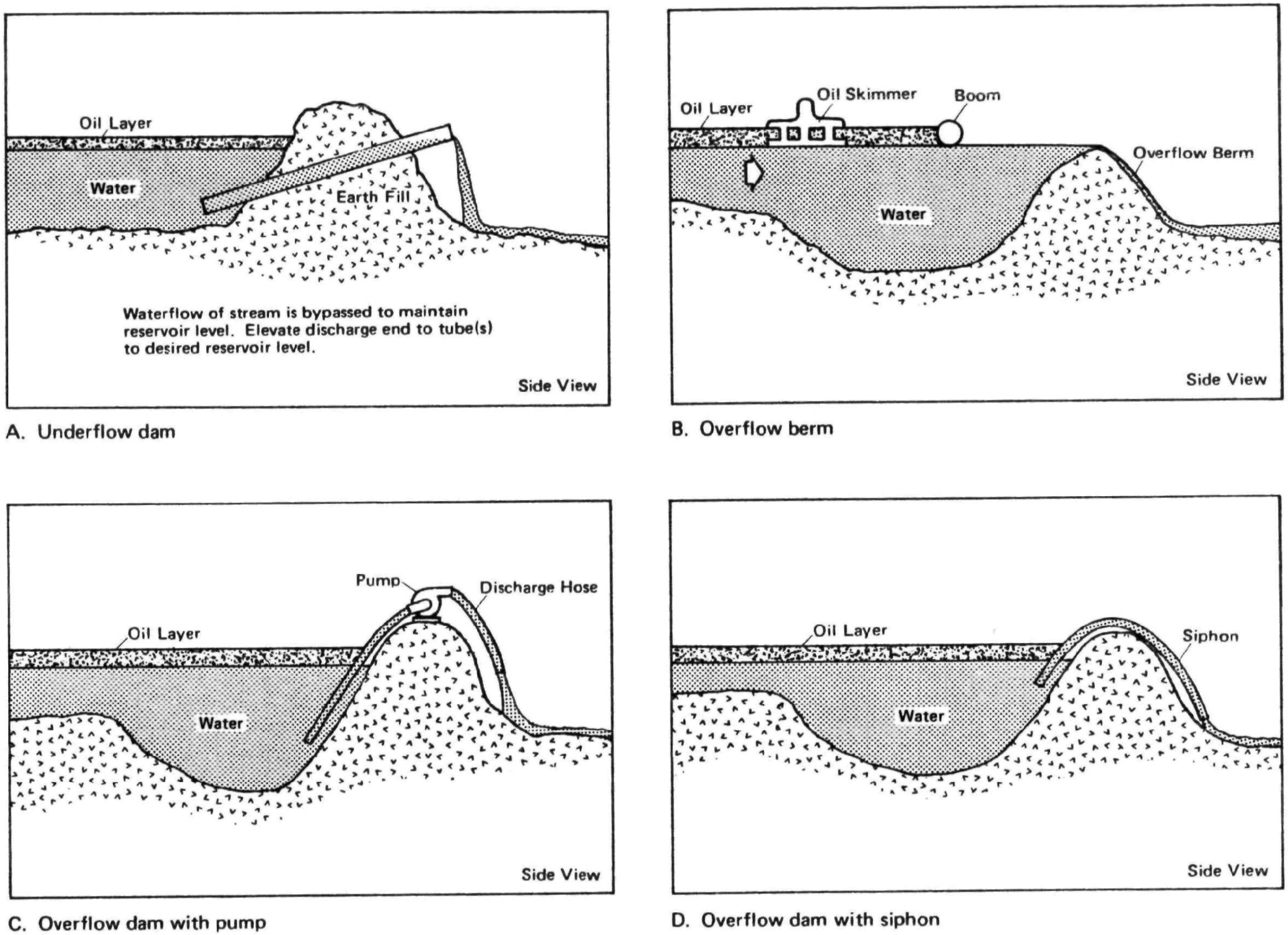


Figure 705-2. Oil containment on streams.

series of containment barriers such as chicken wire (with sorbents) structures might be used. It may be necessary to remove log jams and other debris in creeks and streams to allow effective deployment and maintenance of booms. During periods of high flow, it may be necessary to install steel nets, chicken wire, or similar devices upstream from containment devices and areas in order to protect both equipment and personnel. To facilitate cleanup and removal, spills should be diverted to an area with adequate storage.

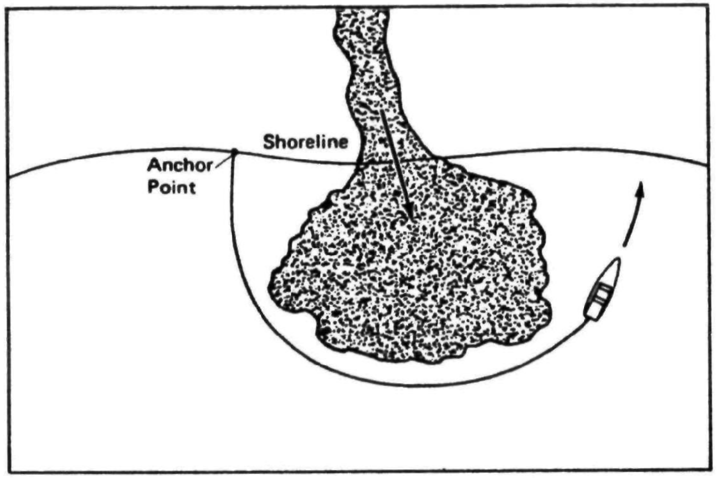
Lakes

Booms are the most useful means of containment on large lakes. The most effective technique is to encircle the spill with booms (containment booming). In the event containment booming is not a viable response technique, exclusion boom should be employed to protect sensitive areas, inlets, harbors, stream deltas, etc. Diversion booming is usually not applicable for most inland lakes as currents are typically too low to warrant its use. Strong winds can, however, create surface currents of sufficient velocity to make diversion booming an effective alternative. It should be used to protect sensitive shorelines and to assist in oil cleanup. During storm-surges or large seiches, beach berms can be constructed to protect backshore areas.

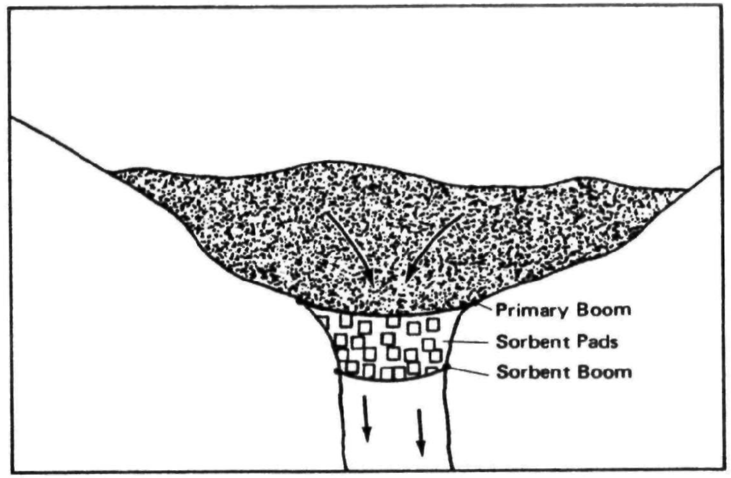
Booms deployed across the inlet stream to a lake may prevent oil from reaching the lake itself. Booming the inlet or containment booming along the shore should minimize impact on the lake. However, booming the outlet of a lake is generally more practical because the surface of the lake provides a large storage area, and the low current velocity on the lake makes dealing with the spill easier.

If oil is flowing into the lake, a boom should be secured to the shore on one side of the point of entry and deployed around the periphery of the slick by boat until the spill is encircled. As in oil containment on small lakes, sorbent booms and conventional booms deployed in tandem may be effective. Both should be deployed across the lake outlet with the sorbent boom downstream. Sorbent pads can be distributed between the two booms. This technique will pick up some of the oil that passes the conventional boom.

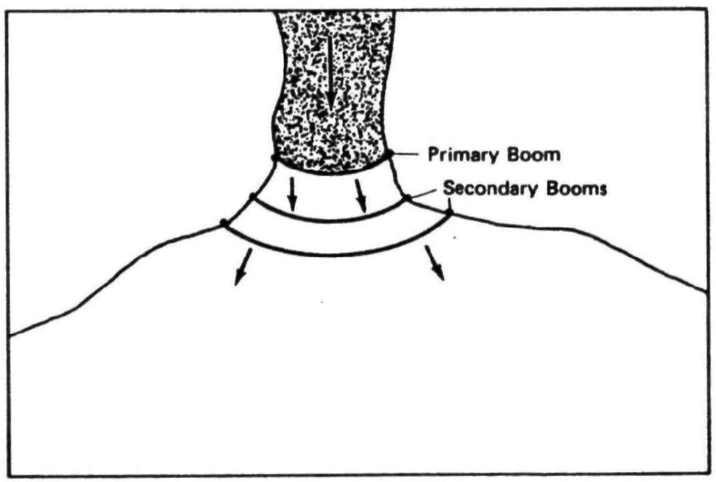
Deployment configurations for the containment booming techniques described above are given in Figure 705-3.



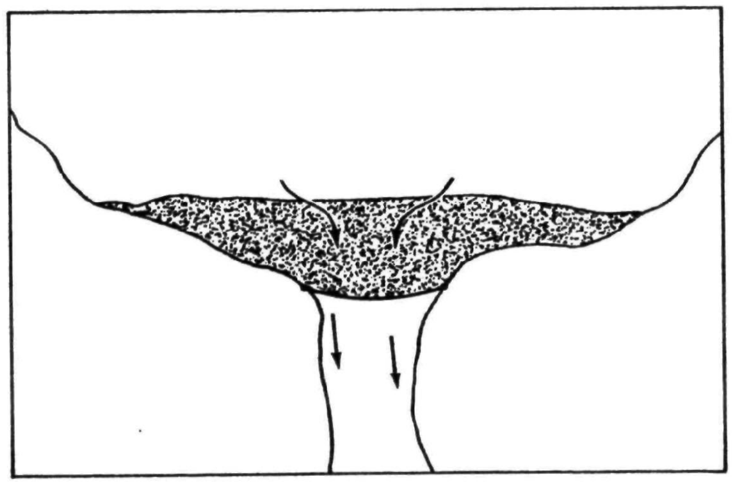
A. Containment booming at source



B. Containment/sorbent booming at lake outlet



C. Containment booming at lake inlet



D. Containment booming at lake outlet

Figure 705-3. Oil containment on lakes.

Cleanup techniques and their implementation requirements are similar for both inland and coastal shorelines (Section 805). Most techniques can be used effectively with no modifications on many inland shorelines.

Rivers

As discussed previously, booms and berms are used to divert and contain spills on large rivers. The use of one or more skimming devices is part of the containment and cleanup actions associated with booms and berms. Rocks, boulders, and sand and gravel bars may be covered with a film of oil as the spill flows downstream. Rocks and boulders can be cleaned by hand scraping or with pressurized equipment. A hand-operated skimmer with a floating head may be used in conjunction with sorbents. Gravel bars can be cleaned simply by removing the contaminated gravel and debris. Replacement with clean materials may be necessary if the quantity removed is significant. This can be accomplished with front-end loaders, drag-lines, and backhoes. For steep banks consisting of mud or dirt, contaminated sediments can be removed using a backhoe.

Since many river banks, and some lakes, have vegetation extending down into or growing in the water, plants may have to be cleaned or removed. Depending on the type of oil, low pressure flushing will usually remove most of the oil from the vegetation. If the river bank consists of stable consolidated materials, this technique can also be used to wash oil from the substrate. As with any *in situ* technique, it is imperative that booms are placed in the water around the area to be worked or slightly downstream to collect the oil that is flushed back into the water. If the current velocity is excessive, the booms may be deployed in one of the diversion booming configurations described in Section 804.

In the event low pressure flushing is not feasible, the contaminated vegetation may have to be removed by manual cutting (Section 805). Again, booms should be positioned to collect any oil that may become freed during the cutting and removal.

Lakes

The primary means of containing and cleaning up spills on large lakes is the use of booms, sorbents, and skimmers. Booms are used for containing and concentrating the oil. Skimmers should be used to remove the oil from the water surface, transferring it to storage for subsequent disposal. Sorbents should be used for spills of small volumes and for final cleanup of larger volumes. Self-powered skimmers with onboard storage will be needed if the oil is not concentrated adjacent to the shoreline where smaller floating skimmers or vacuum pumps could be used.

Cleanup along the shoreline is done in much the same way as along a river. Contaminated vegetation can be clipped and removed. Sand and gravel can be removed and replaced. Sorbents can be used to pick up small slicks, and sorbent booms deployed to clean up continuing seeps of oil.

Shorelines of small ponds can be cleaned by hand or with sorbents and small pumps with skimming heads. Contaminated grasses (except where there are soil erosion constraints) and debris may have to be removed by hand, if required. Hydroblasting equipment can be used to clean rocks and boulders, which may also be scraped by hand. Small slicks can be removed from the water surfaces with sorbents or small skimmers.

707 IMPACTS OF CLEANUP

The impacts of the cleanup techniques used on inland shorelines are similar to those for coastal areas. One difference, however, relates to the consequences of sediment removal. Although the energy levels of inland waters are typically low with no tidal effects, the removal of contaminated sediments can lead to erosion of stream shorelines and biological effects downstream due to increased sediment loading.

Rivers

Sediment removal from river banks may cause accelerated erosion. River currents act to erode materials from the banks naturally at a slow rate. Sediment removal can weaken the stability of the river banks creating an increase in the erosion rate.

Low pressure flushing can also accelerate erosion if used on unconsolidated shorelines. The flushing itself can erode sediments into the water and allow the currents to further the process.

Large scale erosion can increase turbidity and induce sedimentation of the river bottom downstream. Sedimentation can 1) bury organisms and their habitats, 2) disrupt fish spawning activities or bury and suffocate eggs should the sediment cover the gravel bottom of a spawning ground, 3) reduce O_2 levels due to the increased biochemical oxygen demand of the organic load, 4) have direct turbidity effects (e.g., making it difficult for fish to find food), and 5) add a toxic load from the introduced sediment.

The construction of berms or dams from stream bed materials may destroy some organisms inhabiting those materials but the impact should be short-term. If the berms or dams are not removed after cleanup operations are completed, they may disrupt migration and spawning activities of some fish.

Lakes

Sediment removal from the shorelines of lakes and other inland water bodies is not expected to cause substantial erosion problems due to the absence of currents or significant wave energy. Extensive sediment removal may, however, allow storm runoff to erode loose sediments into the lake. Increased human and heavy equipment activity in the area may produce the same erosion effects by loosening the soil and destroying vegetation.

Accelerated erosion and subsequent sedimentation may begin to fill in small ponds or lakes and adversely affect fish and benthic organisms. Sedimentation can also cause algae blooms through the release of nutrients trapped in the sediments.