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Canadian Inland Waters

Coastal Environments and the Cleanup of Oil Spills

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Environmental Impact Control Directorate
July 1982

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CANADIAN INLAND WATERS

COASTAL ENVIRONMENTS AND THE CLEANUP OF OIL SPILLS

by

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for the

Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Environment Canada

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Abstract

A spill of oil on inland waters usually results in the contamination of adjacent shorelines. The selection and implementation of appropriate and effective protection and/or clean-up methods can greatly reduce the environmental and economic impact of a spill. This manual provides a set of guidelines for the protection and clean-up operations in inland waters.

Part I outlines the type of shorelines, their characteristics and inland shore-zone processes. Both the effect and persistance of oil on these shorelines are discussed. In Part II, methods of protection and clean-up for each shoretype are described along with their limitations and environmental effects. Among the techniques considered is cleaning by natural processes.

The text description is supplemented by a series of checklists, designed to aid in response decisions and in localized spill response planning.

Résumé

Le déversement d'hydrocarbures dans les eaux continentales a habituellement pour effet d'en polluer les rives. Grâce à des méthodes efficaces de protection ou de nettoyage, ou des deux, on parvient à en réduire considérablement les répercussions environnementales et économiques. Le choix et l'application de ces méthodes font l'objet du présent guide.

Dans la partie I, on décrit les types de rives, leurs caractéristiques et les processus propres à ces zones. Il est aussi bien question de la persistance des hydrocarbures que de leurs effets sur ces rives. Dans la partie II, on décrit, pour chaque type de rive, les méthodes de protection et de nettoyage à appliquer, leurs limitations et leurs effets sur l'environnement. Parmi les procédés considérés figure l'auto-épuration.

On a de plus inséré des listes de contrôle, pour faciliter l'intervention ainsi que la planification des mesures à appliquer en cas de déversements localisés.

Foreword

The study was initiated by Mr. N. Vanderkooy, Manager of the Environmental Emergency Branch. Mrs. J. Huehn acted as the scientific authority.

This report summarizes previous manuals prepared by E. Owens on shoreline protection for specific areas.

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INTRODUCTION

A spill of oil on inland waters usually results in the contamination of adjacent shorelines. The selection and implementation of appropriate and effective protection and/or clean-up methods can greatly reduce the environmental or economic impact of a spill. The purpose of this manual is to provide a set of guidelines for shoreline protection and clean-up operations in inland waters (lakes and rivers).

In order to be of practical value, the text is brief. The primary information source for this manual is report EPS 3-EC-79-2, "The Canadian Great Lakes: Coastal Environments and the Cleanup of Oil Spills", available from the Environmental Protection Service, Environment Canada. This report contains a more detailed description of the tables and checklists presented here and should be consulted for further information. Additional material is contained in EPA-600/7-79-187, "Manual of Practice for Protection and Cleanup of Shorelines", prepared for the U.S. Environmental Protection Agency. This manual, which was not available during preparation of the E.P.S. Great Lakes report, contains a very detailed account of the applicability and effectiveness, as well as the procedures for selection, of shoreline protection and clean-up techniques for ocean coasts, lakes and rivers. A separate E.P.A. manual for salt marshes is available and could be adapted for freshwater marsh environments. The three reports noted above are referenced on page 33.

Two of the primary ingredients for effective spill response operations are planning and training. A necessary component of planning for a spill is the collection of relevant environmental information required to assess shoreline sensitivity, oil persistence and spill impacts. This information would also be required to determine the feasibility, effectiveness and effects of response methods. If this data is not collected prior to a spill incident, valuable time can be lost. Contingency planning, therefore, not only involves the definition of responsibilities and the organization of the response team, but also includes the development of an adequate knowledge base from which decisions can be developed.

One of the objectives of this manual is to outline the types of information that are required to describe shorelines for spill impact assessment and for the selection of response methods. The manual is in two sections; the organization of the text is indicated below (Fig. 1). Part I deals with information requirements both prior to, and at the time of, a spill. Part II presents guidelines for the selection of response methods and a summary of the applicability of each method.

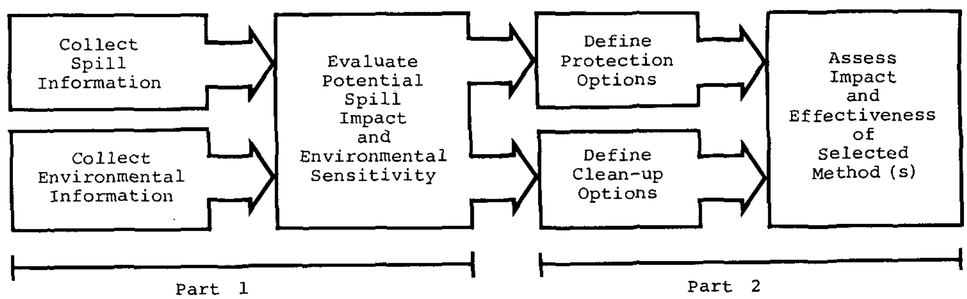

Figure 1. Report organization.

The checklists are designed to be used in the field to collect relevant information, (i) as part of spill response planning, and (ii) at the time of the spill incident. The lists serve as guidelines that help to identify important types of information that would be necessary for response decisions. In particular, they are designed for local pre-spill shoreline surveys and, for example, could be of value in gathering information on sections that would have a high protection or clean-up priority.

As it is not possible to develop a contingency plan that provides hard and fast rules for spill response, it is particularly important to be as prepared as possible. One important aspect of contingency planning is the acquisition and collation of information that can be used to (a) assess the impact and persistence of stranded oil, and (b) select appropriate response methods for different sections of shoreline. It should be emphasized that usually little time and resources are available at the time of a spill incident to undertake shoreline surveys or to compile information, so that the effectiveness of a response is often a function of the level of effort that has been given to pre-spill planning.

PART I - SHORELINE AND SPILL INFORMATION

Shoreline Types

The character of the shoreline upon which oil becomes stranded is a primary factor in determining the effects of the spill and the protection and cleanup methods that may be applicable. A section of shoreline can be described in terms of a series of factors (Fig. 2) which contribute to the overall character. The two most important factors are (a) the shore-zone materials (or substrate), and (b) the energy level at the shoreline.

The primary classification of shoreline types based on materials is given in Table 1. This classification is necessarily simplified and many shores are composed of more than one type, for example, a rock platform that is backed by a sand or pebble beach. On inland waters, shorelines are frequently mud or dirt banks (cliffs) that are easily eroded by waves or currents. The shoreline description of an area should include information on both the materials (sediments, rock, etc.) and the width of the shore zone.

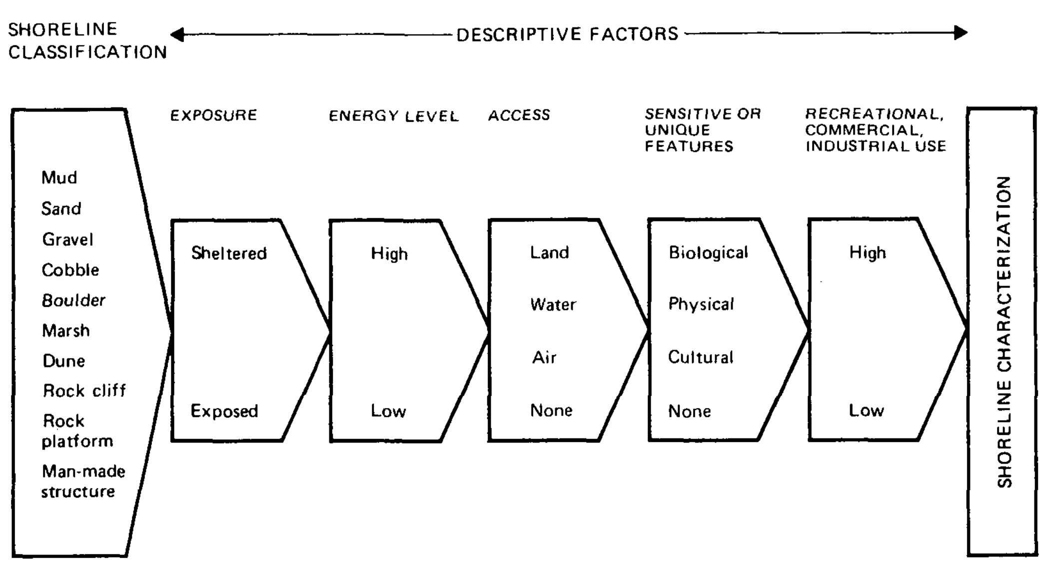

Figure 2. Shoreline categorization.

TABLE 1. Shoreline Categorization

Shore-zone Material	Grain Size (mm)	General Descriptive Features
MUD	≤ 0.06	• Low 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; the mud deposits are often covered with a thin film of water than 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^{o} -40^{o} beach slope • Subjected to seasonal erosion and deposition cycles as a consequence of the varying levels of incoming wave energy • Closely packed substrate with a low water infiltration rate
PEBBLE	2.0-50	• Narrower and steeper beach slope than sand beaches • Storm ridges often present to the landward side of the berm; ridge height increases with exposure to wave energy
COBBLE	50-256	• Narrower and steeper beach slope than sand beaches • Storm ridge usually present to the landward side of the berm; ridge height increases with exposure to wave energy
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
MIXED SEDIMENT	all sizes	• Poor sediment sorting results from low wave-energy levels in many instances • Frequently the size of sediments increases on berm or storm ridge • Low water infiltration rate where sand packs spaces between pebbles and cobbles
VEGETATION:		
marsh:		• Develop in sheltered environments which have a source of fine material • Marsh surface inundated during periods of high-water levels • Flat topography interrupted by muddy creeks or channels
dune:		• Wind-blown sand is trapped and stabilized by backshore vegetation • Removal of or damage to vegetation destabilizes dunes
ROCK:		
cliffs:		• 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:		• Typically occur in shallow waters at the base of rock cliffs • Sediment cover, if it occurs, does not provide a protective cover; wave-induced processes act directly on the rock surfaces
MAN-MADE STRUCTURES		• Any structure found on a shoreline constructed by man; materials may be rock, concrete, metal or wood • Examples include piers, boat ramps, seawalls, groins, jetties

Energy Levels and Oil Persistence

Energy levels at the shoreline are an important factor in evaluating the accumulation and persistence of stranded oil. Where energy levels are high, persistence times are low. Oil tends to accumulate in sheltered environments where energy levels are low and where there is little mechanical energy to physically break down and remove the oil. In these environments the persistence of stranded oil may be high.

The wave-energy level on lake shorelines is a function of the lake area, wind direction, coastal configuration and the presence of ice. Energy levels vary from one site to another and vary due to storm-wave action or due to seasonal variations in wind velocity. Energy levels on rivers are usually very low due to limited fetches*, but currents may be an important factor during periods of floods or storms.

Oil on the water surface becomes stranded on the shore zone as it is carried landwards by winds, waves or currents. The manner in which the oil is stranded is a function of wave conditions, water levels, and the sediment size of beach material. In calm conditions thick layers of oil accumulate at the water's edge, whereas, during periods of high waves the oil is spread over a wider area of beach. During periods of high water levels, which may be wind-induced or may be the result of seasonal variations in run-off, oil can become stranded above the normal level of wave activity. In this latter situation the oil is only affected by wave action during subsequent periods of high water levels and the expected persistence of the stranded oil is high.

On fine-grained (sand) beaches oil does not penetrate deeply into the sediments (except for spills of very light products) whereas on pebble or cobble beaches even heavy tarry oils can penetrate as much as one metre or more. The penetration depth is a function of the size of the spaces between the individual sediment particles and increases as the particle size increases. As the depth of penetration increases, the ability of waves to physically abrade and remove the oil decreases. In addition, as penetration increases the clean-up difficulties increase.

*Fetch: the area of open water over which waves are generated by wind.

The depth of oil penetration in a beach is also a function of beach changes due to normal erosion and deposition by wave action. In general, beaches are eroded by storm waves and sediment is returned to the beach by less energetic waves in the post-storm period. As a result of these cyclical changes, stranded oil can be either buried or eroded (Fig.3). If the oil becomes buried due to stranding during a depositional phase it would remain unaffected by wave action until exposed by a period of storm-wave erosion.

In most areas wind velocities and, therefore, wave heights are greatest during winter months so that beach erosion is more common at this time of the year. Beach accretion or buildup is more common in summer months. The cycles of erosion and deposition can, therefore, occur on very different time scales, one which is a weekly or monthly cycle and the other which is essentially a summer/winter cycle.

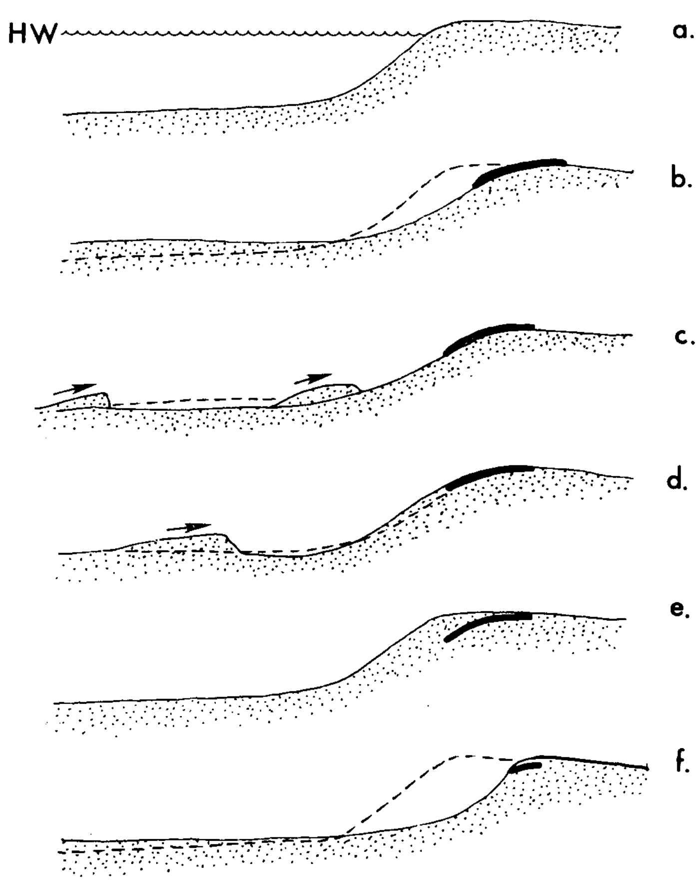

Figure 3. Sequence of storm erosion and oil deposition (b); burial (d),(e); and exposure following a second storm (f) on a sand beach (from Owens, 1977).

The formation of ice on the water surface or on the shoreline acts to halt normal shore processes. Oil on the shore that is covered by ice is buried until re-exposed by a period of thaw. Ice on the water surface reduces wave generation, so that in many areas there is no wave activity during the winter months and, therefore, natural cleaning of stranded oil is suspended.

Other factors in evaluating oil persistence are the type of oil, the thickness of the deposit, and the air temperature. The relationships between energy levels (on lakes) and the persistence factors are summarized in Figure 4, and the relationship between persistence and shoreline type is given in Table 2 (page 11).

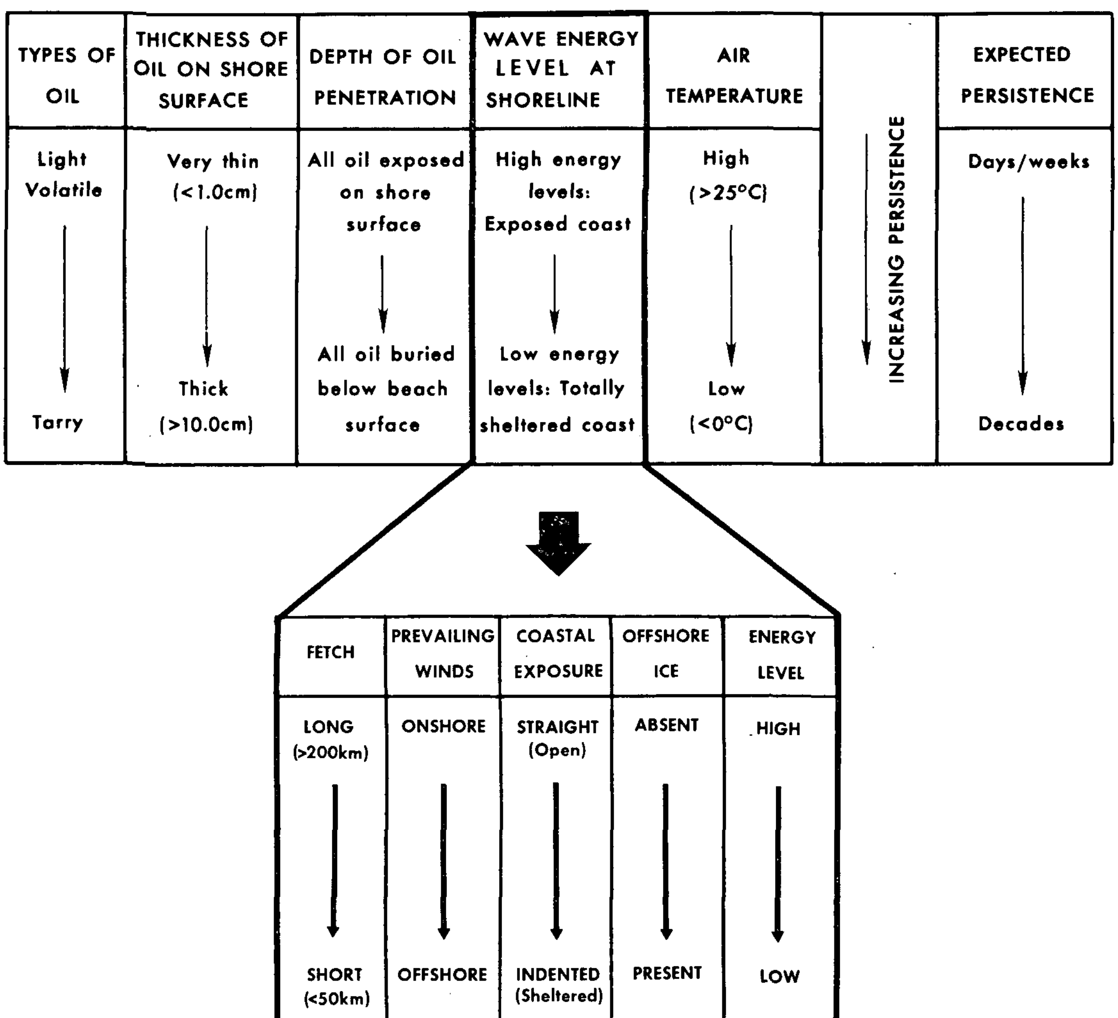

Figure 4. Shoreline energy level and persistence of stranded oil.

Checklist #1 - Shoreline Character

Checklist #1 is a guide for the collection of relevant environmental information for spill response decisions. Sediment size controls the depth of oil penetration and therefore, to some degree, the persistence of stranded oil. The sediment size and oil penetration depth are also primary controls on the effectiveness and applicability of clean-up methods.

An estimate of wave-energy levels at the shoreline can be obtained by assessing the fetch distance and shoreline exposure. In addition to the relative exposure/energy level index, which determines the potential level of energy, an estimate of seasonal variations in wind velocity must also be made to determine the actual shoreline energy level.

For river shorelines information on the dimensions of the channel and the current speed is necessary as these factors influence the accumulation and persistence of the oil and the applicability of protection and clean-up methods. Current velocity changes depending on the season (for example, high run-off due to spring snow melt) or on rainfall patterns such as storms, which can drastically alter run-off conditions.

The accessibility to the shore zone is an important factor for spill response operations on lakes or rivers. This information should be collected as part of a pre-spill inventory.

Checklist #2 - Spill Information

Most of the data required to complete this checklist is self-explanatory. In some cases only estimates, rather than actual numbers, may be available, but an attempt should be made to be as accurate as possible. This checklist can be updated as further information is received.

The volume and character of the stranded oil should be recorded for each section of shoreline and for each shoreline type. An estimate of the volume of oil can be obtained by multiplication of:

(1)		(2)		(3)
the width of the zone of stranded oil	x	the average thickness of the oil (both on the surface and within sediments)	x	the length of the contaminated shoreline section

Checklist #1. Shore-Zone Character Checklist

1. Beach Sediments and Morphology

	Substrate *	Sediment Size(s)
Lower Beach	______________	______________________
Upper Beach	______________	______________________
Backshore	______________	______________________

Debris: Cover on lower beach ____% On upper beach ____%

Beach Width: ____m Beach Length: ____m

Maximum Berm or Ridge Height (above water level): _____m

2. Shoreline Exposure and Energy Levels (for lakes)

Maximum Fetch (km) >200 _____ 50-200 _____ <50 _____

Coastline Straightness: Straight _____ Irregular _____ Indented _____

Degree of Exposure: Open _____ Partly Sheltered _____
Completely Sheltered _____

Presence of Ice or Ice Foot: Absent _____ Present _____

Relative Exposure/Energy Level: High _____ Intermediate _____ Low _____

Seasonal Energy Level: High _____ Intermediate _____ Low _____

3. River Shorelines

Channel Width (m): _____

Maximum Channel Depth (m): >10 _____ 2-10 _____ <2 _____

Current Speed (m/sec): >0.5 _____ 0.1-0.5 _____ <0.1 _____

Flow Conditions: high runoff _____ low runoff _____

4. Shoreline Access

Heavy Vehicles: Land Access: Existing _____ Required _____
Seaborne Access: YES/NO

Light Vehicles: Land Access: Existing _____ Required _____
Seaborne Access: YES/NO

Pedestrians: Land Access: YES/NO
Seaborne Access: YES/NO
Aerial Access: YES/NO

* Substrate: shore-zone material (see Table 1)

Checklist #2. Spill Information Checklist

1. Oil On Water

Source of Spill: ____________________

Is oil still being spilled?

YES - Spill Discharge Rate: ____________________

- Estimated Duration of Spill: ____________________

- Estimated Final Spill Volume: ____________________

NO - Volume of Spill: ____________________

Type of Oil: ____________________

Is oil flammable or otherwise hazardous to personnel? YES/NO

Will the oil be stranded? YES/NOT KNOWN/NO

*Where will the oil be stranded? ____________________

*Requires spill movement prediction.

2. Oil On Shore

Has the spill ceased? YES/NO

Is there a danger of more oil being washed ashore? YES/NO

Oil Viscosity: Low (fluid) ____ Moderate ____ High (semi-solid) ____

Oil Flammability: Very Dangerous ____ Potentially Flammable ____
Low Risk ____ Inert ____

Section Name or Identification ____________________

DO THIS FOR EACH SECTION

Surface Area Covered by Oil: ________%

Thickness of Surface Oil: ________cm

Distribution Across Shore Zone: ____________________

Depth of Oil Penetration: ________cm

Volume of Stranded Oil on Beach: ____________________

Shoreline Exposure: (see Checklist #1) ____________________

Wave Energy at Shoreline: (see Checklist #1) ____________________

The Impact of Stranded Oil and Shoreline Sensitivity

The impact of oil on a shoreline section depends to a large degree on the shoreline character and on the length of time that the stranded oil remains (the persistence). These relationships are summarized in Table 2, which is intended as a general guide to assessing impact and persistence. Because shorelines are subject to different physical processes and are dynamic, several factors influence impact and persistence; these are outlined in Table 3.

TABLE 2. The Impact and Persistence of Stranded Oil

SHORELINE TYPE	IMPACT OF OIL	PERSISTENCE
Coasts Without Sediment		
ROCK MAN-MADE	• oil may be reflected • coats exposed dry surfaces • wave splash can throw oil above normal limits of wave action • oil does not easily adhere to wet surfaces • thickness of oil cover decreases as steepnesss increases • oil collects in rock pools	• oil readily abraded if it is stranded below normal limit of wave activity, except in sheltered sites
Coasts With Sediment		
MUD	• mud has very small spaces between particles and these are usually filled with water, therefore, only very light grades of oil penetrate	• muds are easily transported by waves, therefore, oil can be buried • buried oil degrades very slowly in muds • surface oil may be easily removed by waves because water usually separates the oil from the mud
SAND	• only light oils can penetrate sand • heavy oils rarely penetrate more than 2 to 3 cm • penetration depths are greater during periods of high temperatures • oil is usually deposited at upper limit of wave action	• oil can be easily abraded if it is not buried and if it is within the zone of wave action • possibility of burial is high if beach is subject to wave action during storms • oil/sediment may form an "asphalt pavement", thereby increasing persistence
PEBBLE COBBLE BOULDER	• as the size of the sediments increases, the depth of penetration of all oils increases • penetration of medium and heavy oils can be as much as 1.0 m • light grades of oil may be washed through the beach and flushed by waves	• buried oil and "asphalt pavements" are very persistent • surface oil is easily abraded by waves and moving sediments
MIXED SEDIMENTS	• spaces between larger particles are filled with smaller-sized sediments, therefore, oils rarely penetrate (except light grades)	• usually low energy environments, therefore, even surface oil persists • "asphalt pavements" are common
MARSHES	• oil is usually restricted to the marsh edges • light oils are more toxic to the vegetation and can penetrate the marsh sediments • impact is less severe in autumn and winter months	• mechanical energy levels are low, but biochemical degradation is rapid if oil is not buried • marshes usually recover naturally unless the oil is very toxic or very large volumes of oil carpet the vegetation

TABLE 3. Processes That Alter The Impact and Persistence of Stranded Oil

Factors that REDUCE impact and INCREASE rates of physical breakdown and degradation of oil	Factors that INCREASE impact and REDUCE rates of physical breakdown and degradation of oil
Waves • increasing wave-energy levels • mix or breakdown oil in breaker, surf and swash zones • use sediments as abrasive tools • redistribute or erode oil on the shore • reflected waves mix or break down oil and may prevent oil reaching the shoreline	Waves • decreasing wave-energy levels • bury oil by beach accretion or by longshore migration of sediments • reduce temperature of oil • throw oil above the normal level of wave activity by the splashing action of breakers
Winds • increase rates of evaporation	Winds • redistribute sediments and bury oil on the backshore • generate storm surges and oil is deposited in lagoons (by overwash) or in the backshore • onshore winds trap oil on coast during surge, deposition then occurs above level of normal wave activity when water level lowers
Ice • ice foot prevents oil deposition on the shoreline • ice push breaks up stranded oil • ice prevents oil reaching the shoreline	Ice • prevents wave generation and lowers wave-energy levels • ice foot can enclose oil • ice push can bury oil • ice push moves oil above zone of maximum wave activity
Water Levels • low water levels cause deposition of oil in sections that would later be subject to wave or current action	Water Levels • high water levels cause deposition of oil above normal limits of wave or current action • oil can be carried onto marsh surface

The impact of stranded oil and the decision to protect or to clean up a section of shoreline are not dependent on physical factors or persistence alone. Response decisions must include the overall shoreline sensitivity, which is a function of many factors (Fig. 5). Although the actual evaluation of sensitivity involves a large number of inputs, it is possible to make some generalizations concerning impact, persistence and sensitivity of the basic shoreline environments. These generalizations are possible because a basic relationship exists between (i) shoreline type, (ii) energy levels and oil persistence, and (iii) biological habitats. For example, marshes are low-energy environments with a high biological productivity (and sensitivity). By comparison, a rock coast with high wave-energy levels has a low potential for oil persistence and a relatively low biological sensitivity. In providing a general indicator of shoreline sensitivity, Table 4 may be used as a first approximation. It is important to remember that other factors (social/economic activities, protection or clean-up feasibility, clean-up effectiveness, etc.) must also be considered when assessing the sensitivity or protection priority for a section of shoreline.

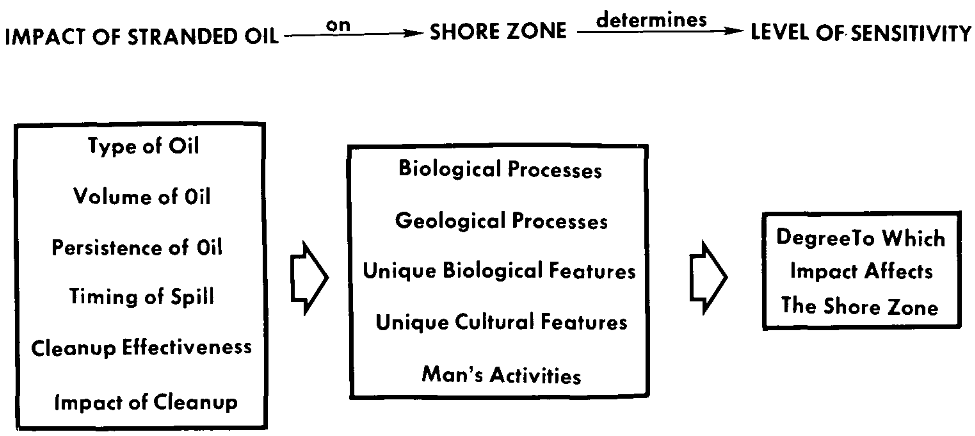

Figure 5. Factors that affect the level of shoreline sensitivity.

TABLE 4. Environmental Sensitivity of Shoreline Types

INCREASING SENSITIVITY ↑

I.	Marshes Lagoons
II.	Sheltered Rocky Coasts Sheltered Beaches
III.	Dunes Mud Flats
IV.	Pebble/Cobble/Boulder Beaches Sand Beaches
V.	Exposed Rock or Man-Made Structures

Checklist #3 - Shoreline Sensitivity

An assessment of the environmental sensitivity can be obtained using Checklist #3. In many cases the sensitivity assessment may require advice and information from biologists or geologists familiar with the shoreline in question. Estimation of the potential effects of the oil or of the clean-up operations is particularly important for the establishment of protection and clean-up priorities.

Checklist #3. Shore-Zone Sensitivity Checklist

Impact Factors

Type of oil: ______________________________

Is oil on shore?

YES - Volume Stranded (from Checklist #2): ______________

NO - Volume of Spill: ______________________

Expected Persistence of Oil: Days ____ Months ____ Years ____ Decades ____

Month of Year: ______________

Can cleanup be effective? (from Checklist #5) YES/NO

Would cleanup have an impact (from Checklist #5) YES/NO

If YES, describe: ______________________________

____

Shore Zone Character

Shoreline Type (from Checklist #1): ______________________

Rare or Endangered Biological Species: Absent ____ Present ____

Natural Biological Recovery Potential: <1 Yr. ____ Years ____ Decades ____

Natural Geological Recovery Potential: <1 Yr. ____ Years ____ Decades ____

Recreational Use of Shore Zone:
None ____ Low ____ Moderate ____ High ____ Very High ____

Commercial Use of Shore Zone:
None ____ Low ____ Moderate ____ High ____ Very High ____

Biological Impact of Oil:
None ____ Low ____ Moderate ____ Severe ____ Critical ____

Impact of Oil on Rare or Endangered Species:
None ____ Low ____ Moderate ____ Severe ____ Critical ____

Biological Impact of Cleanup:
None ____ Low ____ Moderate ____ Severe ____ Critical ____

Geological Impact of Cleanup:
None ____ Low ____ Moderate ____ Severe ____ Critical ____

PART II - SHORELINE PROTECTION AND CLEANUP

Protection Priorities and Methods

In cases where sufficient time is available, it may be possible to identify threatened sections of sensitive shoreline and to deploy effective protection equipment to prevent oil reaching the shoreline. The primary method of offshore protection involves the use of booms to exclude, contain and remove, or divert oil on the water surface. A different method of protection involves the dispersal of oil by chemical agents if regulatory approval is given.

Protection of long sections of shoreline is seldom practical due to the limited availability of equipment and resources. Therefore, decisions on the priority deployment of equipment involve assessment of the relative sensitivity of different sections of shoreline. Sensitive shoreline features or habitats can be identified by pre-spill inventory programmes so that this information is immediately available to the on-scene commander. After protection priorities are established, some assessment of the feasibility and effectiveness of available techniques is required to determine if the protection objectives can be achieved. An example of the types of decisions involved in selecting appropriate booming methods for different environmental conditions is given in Figures 6 and 7.

The principal shoreline protection methods are briefly described in Table 5. A distinction is made in this table between those methods which can be used on the surface of the water and those which are used on the shoreline itself. Table 6 indicates which onshore protection methods are suitable for the primary shoreline types.

Checklist #4 - Shoreline Protection

A decision on the desirability of protection for a section of shoreline can be reached by considering the first three questions on the checklist. The third question should be answered only after questions 4 to 8 have been evaluated. Shoreline protection should be considered if the answer to any one of these five questions is "YES". Before a decision is made to implement a protection operation, questions 9 to 11 must be answered to determine if protection is in fact feasible. If the answer to any one of these three questions is "NO", then a protection operation should be reconsidered.

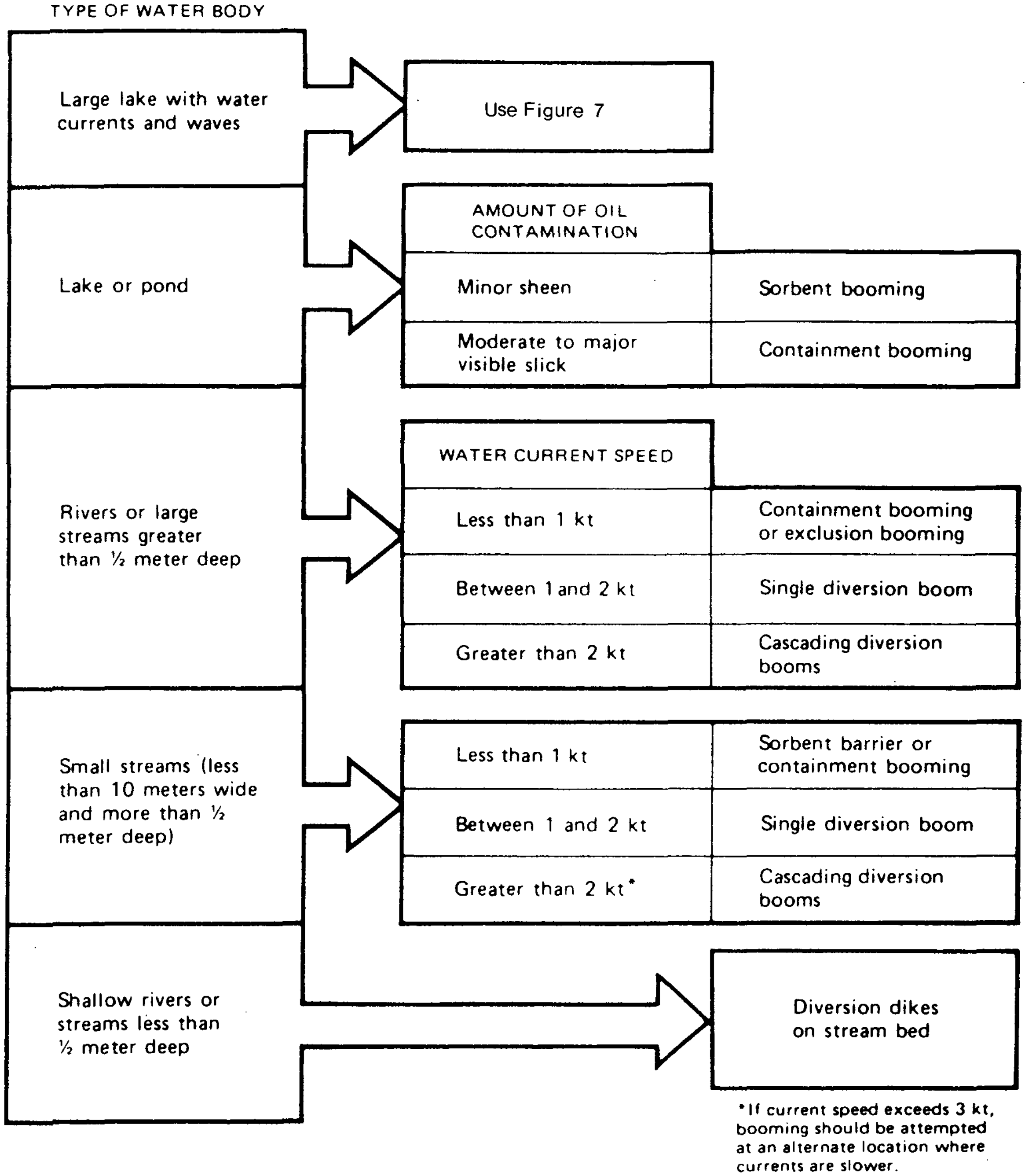

Figure 6. Decision guide for the selection of offshore protection methods on inland waters.

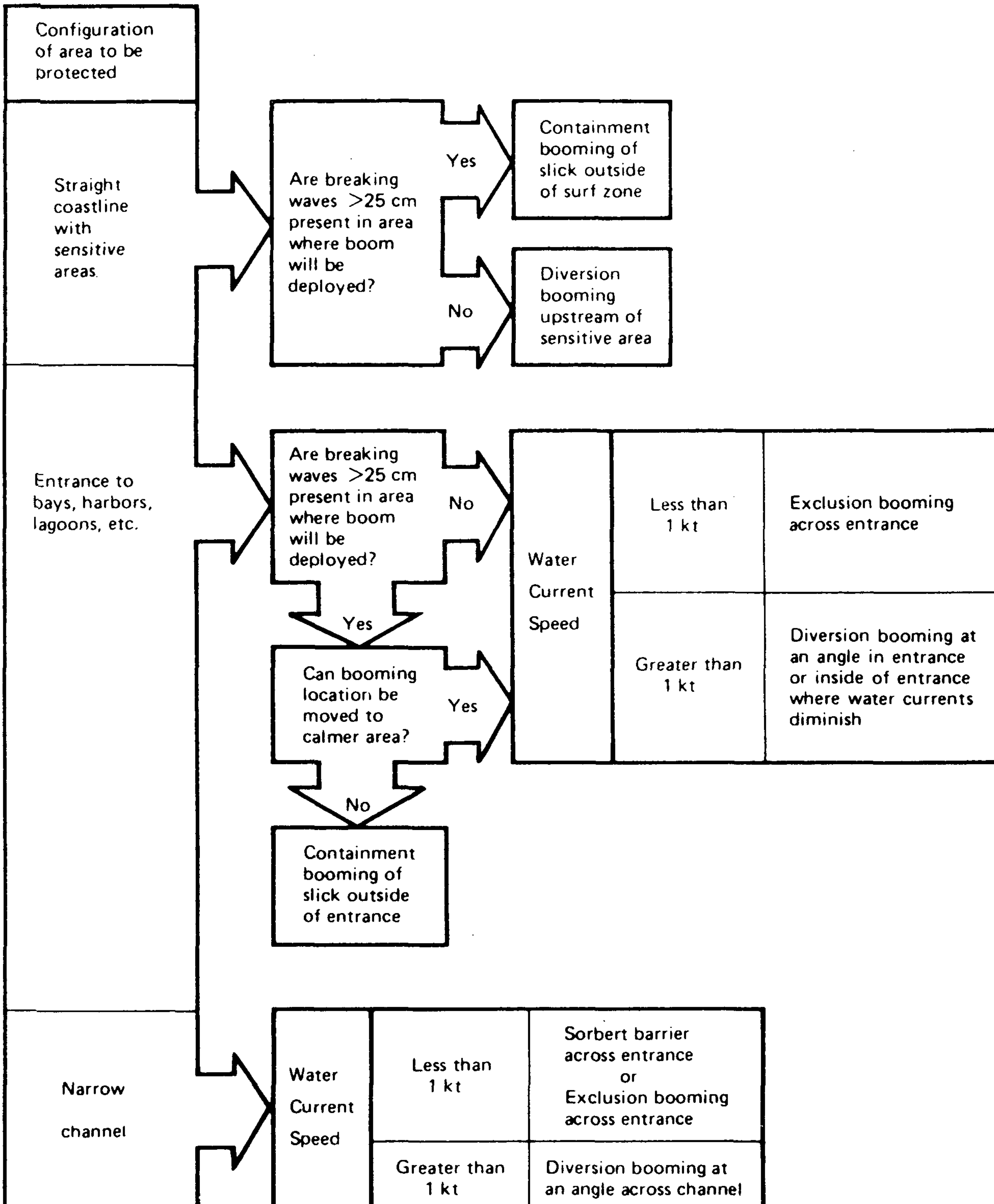

Figure 7. Protection decision guide for coastal waters.

TABLE 5. Shoreline Protection Methods

OFFSHORE	METHOD	APPLICABILITY
EXCLUSION BOOMING	• deployed across or around oil • oil removed from water surface	• to protect small bays, harbours, inlets or river mouths • currents <0.5 m/s, wave height <25 cm
DIVERSION BOOMING	• deployed at an angle to approaching oil • diverts oil away from sensitive areas	• where currents >0.5m/s, and wave heights <25 cm
CONTAINMENT BOOMING	• deployed around oil • oil removed from water surface	• current <0.5 m/s • not applicable for large slicks
SORBENT BOOMING	• deployed across approaching oil • oil absorbed by boom	• quiet waters • small slicks
DISPERSION AGENTS	• reduce surface tension of oil by application of chemicals • oil is then dispersed more rapidly into the water	• requires permission of regulatory agencies • increases oil mobility, therefore, stranded oil has greater potential to penetrate beach sediments
COLLECTION AGENTS	• increase surface tension of oil by application of chemicals • oil is prevented from spreading	• decreases oil mobility, therefore, stranded oil has a reduced capacity to penetrate beach sediments

ONSHORE	METHOD	APPLICABILITY
SORBENTS	• applied manually or mechanically to the beach before oil is stranded • oil/sorbent is then removed manually or mechanically	• prevents penetration of oil into substrate • sorbent pads preferable to loose-fibre materials for ease of collection • synthetic products have higher sorbtion capacity than natural materials • usually a labour-intensive method
SURFACE TREATMENT AGENTS	• applied to shore zone before oil is stranded • prevents oil from adhering to the substrate	• applicability and effectiveness not yet fully assessed • may be difficult to apply on long sections of shore • oil must be flushed from the shore and agent removed if it does not degrade naturally
COLLECTION AGENTS	• applied along water line before oil is stranded • reduces natural dispersion of oil	• reduces area of shoreline contamination • reduces penetration into beach
DYKES AND/OR DITCHES	• ditch up to 1 m deep dug parallel to shore at upper limit of wave action • sediment removed used to build dyke on landward side of the ditch • on pebble-cobble beaches can fill ditch with sorbents to collect oil and prevent oil penetration	• prevents oil being washed onto the backshore • can be constructed mechanically along long beach sections • ditch acts as a collector of oil which can be removed with buckets, hand pumps, or vacuum pumps
DAMS	• used for shallow streams where booms cannot be deployed	• acts as a boom for exclusion of oil • can be constructed to allow water to flow through dam

TABLE 6. Onshore Protection Methods and Shoreline Types

SHORELINE TYPE	ONSHORE PROTECTION METHOD(S)
ROCK MAN-MADE	• sorbents may be useful on low angle slopes
MUD	• sorbents could be effective if collection can be achieved without mixing oil/sorbent into uncontaminated muds
SAND PEBBLE	• ditch/dyke system could be used to protect backshore • sorbents could prevent or reduce penetration and facilitate the removal of oil
COBBLE BOULDER	• no available effective onshore protection • retrieval of sorbents is difficult • ditch/dyke system is too permeable but could stop oil from washing over into the backshore or could be used in conjunction with sorbents
MIXED SEDIMENTS	• can be treated in the same manner as sand/pebble beaches
MARSHES	• ditch/dyke system could protect the marsh edge if the marsh is flanked by sand deposits • dykes across the marsh channels could prevent oil from penetrating into the backshore marsh areas

Shoreline Clean-Up Factors and Methods

A clean-up response does not usually involve a time limitation so that careful consideration can be given to selection of the most appropriate course of action. Factors such as rates of natural cleaning, the effectiveness of each technique and the potential impact or damage of a technique should be considered in the selection processes. Although time is not a critical element if cleanup is considered necessary a response should be initiated as rapidly as possible to prevent penetration of oil into shoreline sediments or release of oil onto the water surface.

The two most important factors in a clean-up decision are: (a) is the rate of natural shoreline cleanup acceptable?, and (b) will clean-up activities cause more damage than that caused by the oil alone? If cleanup is required and would not incur unacceptable damage, then selection of the most appropriate method is based upon: (c) the volume of stranded oil, (d) the shoreline type, (e) the depth of oil penetration, and (f) shoreline accessibility. The character of the shore and backshore morphology determines the accessibility of a particular site. The major accessibility categories for spill response operations are outlined in Table 7. Decision guides for the

Checklist #4. Shoreline Protection Checklist

	YES	NO
1. Will the oil become stranded?		
2. Would the shoreline be cleaned naturally in an acceptable period of time?		
3. Would the section of shore zone be seriously affected by the impact of oil?		
Impact of Stranded Oil		
4. Would the oil seriously endanger flora or fauna?		
5. Would the impact on flora and fauna be long-term?		
6. If shoreline cleanup is necessary, would this affect beach stability (e.g., by sediment removal)?		
7. Would the presence of the oil affect man's use of the shore section?		
8. Would protection be more effective than cleanup?		
Protection Feasibility		
9. Is sufficient time available to implement the protection operation?		
10. Would the method(s) be effective?		
11. Are sufficient equipment, materials and manpower available?		

Methods

12. What is (1) the most applicable method? ______________________

(2) the most applicable alternative? ______________________

TABLE 7. Shoreline Accessibility

LAND ACCESS

1. Roads or tracks that can support heavy equipment or trucks, with direct access to the shore zone or beach.

2. Tracks or trails that provide access to the shore zone for light vehicles.

3. Tracks or trails that provide only pedestrian access.

4. Inaccessible by land.

WATER ACCESS

1. Unobstructed beach or shoreline access for boats and barges.

2. Shallow-water access for small boats only.

3. Inaccessible by water.

AIR ACCESS

1. Flat ground available for helicopter access.

2. Inaccessible by air.

selection process for shorelines are given in Figures 8 through 11. The available clean-up methods are summarized in Table 8, which includes notes on the applicability and impact of each method. The term trafficability, which appears in the figures and table, refers to the operational ability for a particular piece of equipment and is usually related to the bearing capacity of the shore-zone sediments.

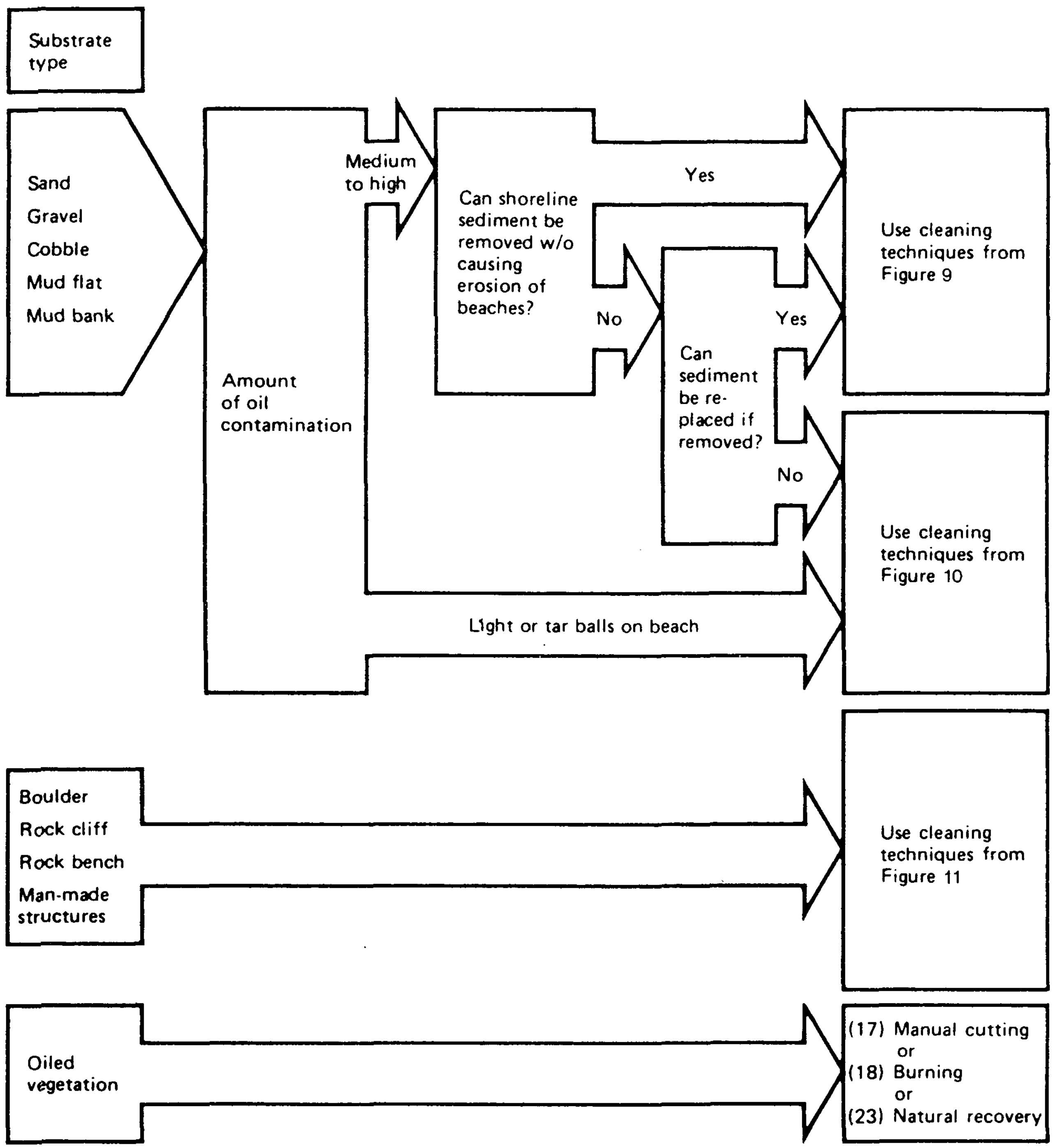

Figure 8. Key to shoreline clean-up decision guides. (Note: numbers in parantheses refer to clean-up methods described in Table 8.)

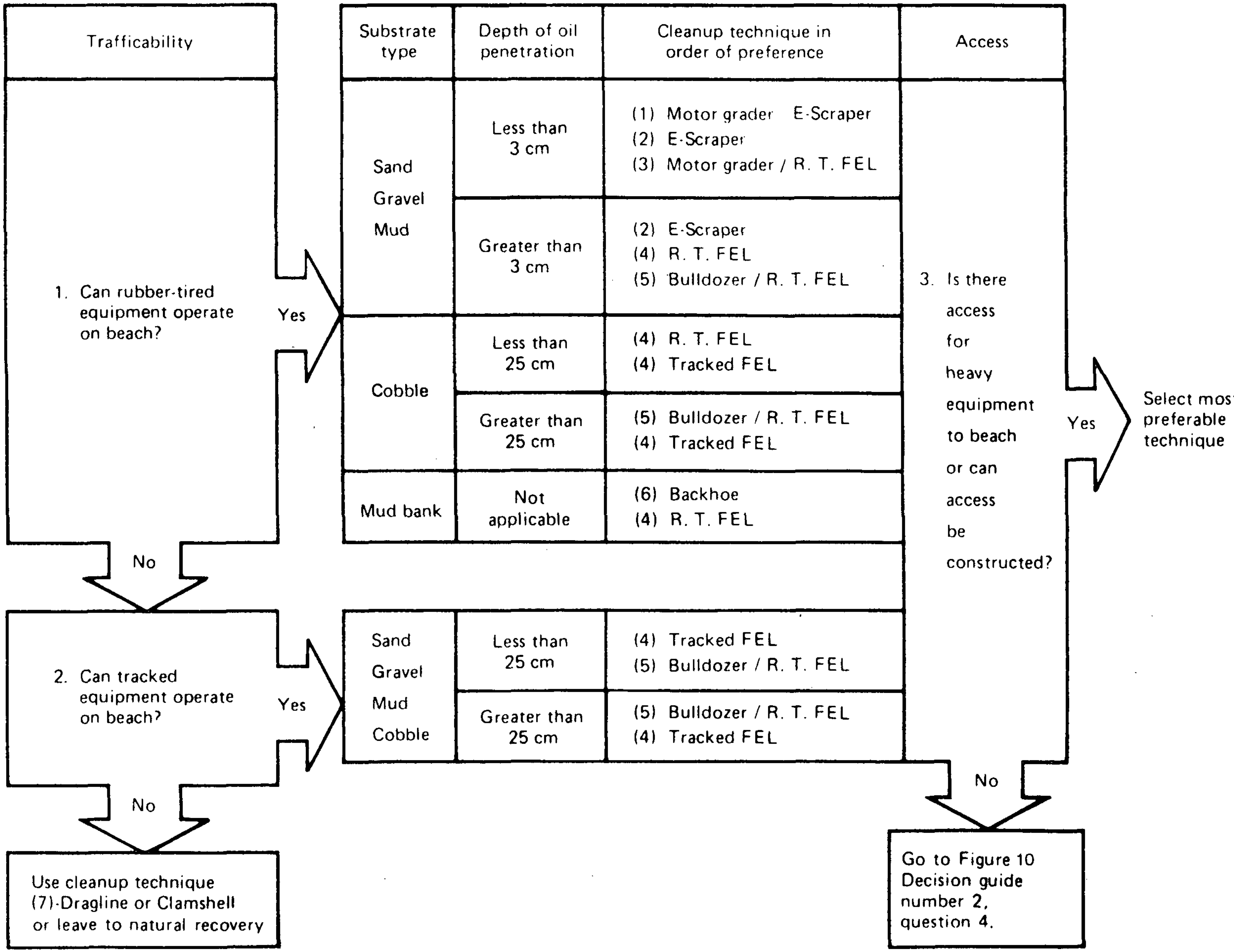

Figure 9. Clean-up decision guide number 1.
FEL = front-end loader; RT = rubber-tired.

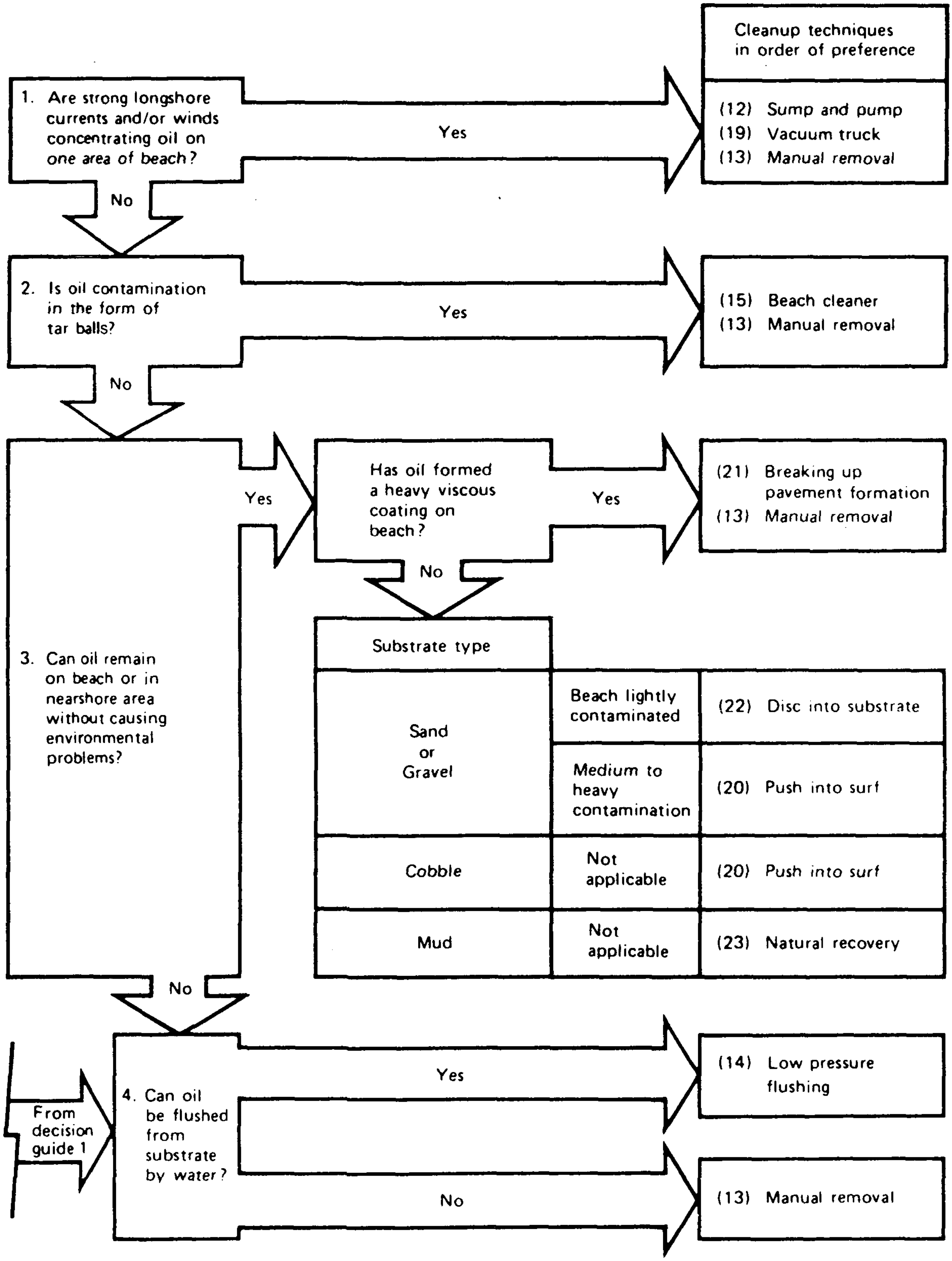

Figure 10. Clean-up decision guide number 2.

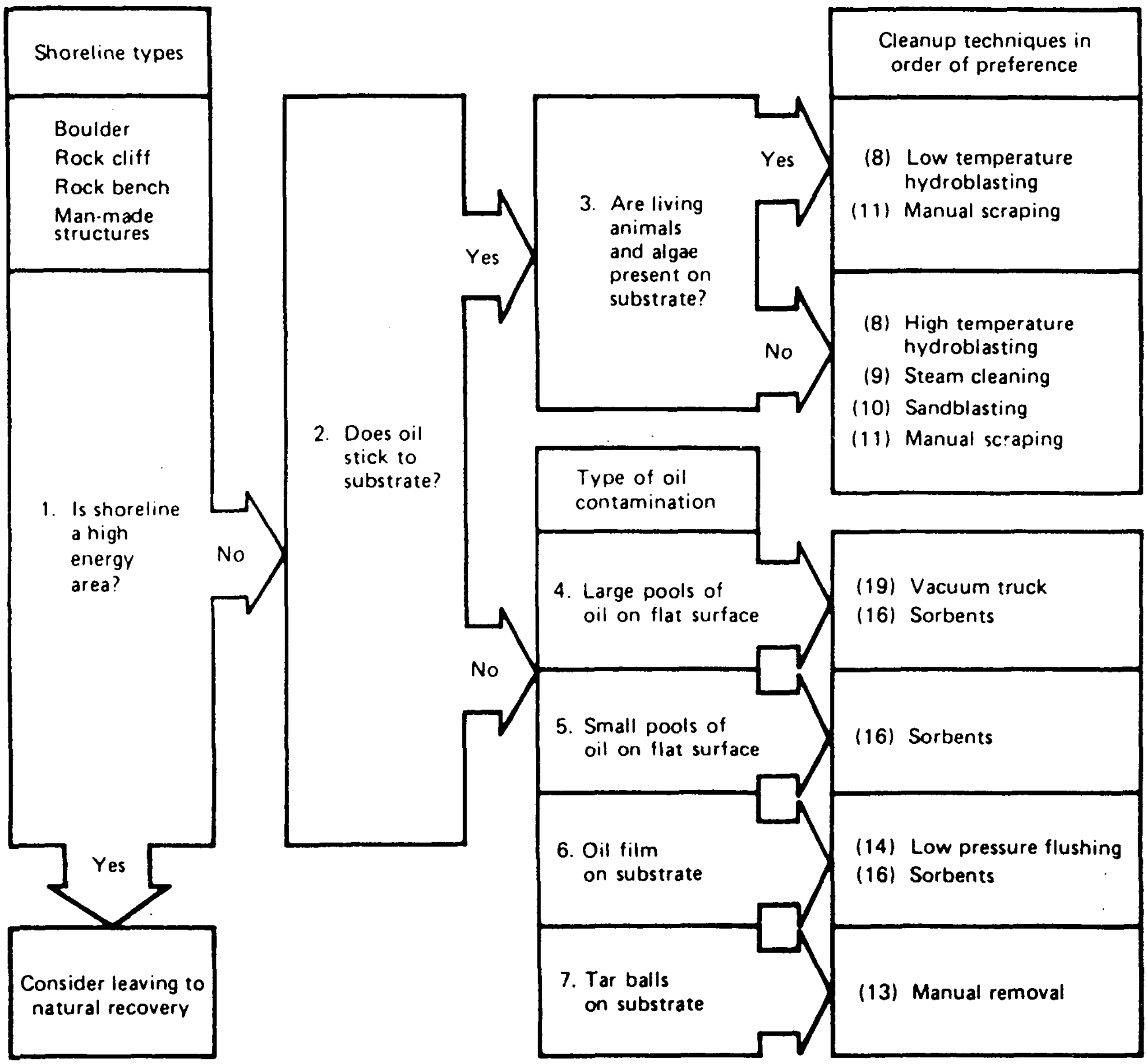

Figure 11. Clean-up decision guide number 3, for boulder, rock or man-made shores.

TABLE 8. Shoreline Clean-up Methods

Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements	Physical Effect of Use	Biological Effect of Use
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.	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.	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.	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.	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.	Removes only upper 3 cm of beach.	Removes shallow burrowing polychaetes, bivalves, and amphipods. Recolonization 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.	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 loaders 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.	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.	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.	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.	Used to remove oil contaminated sediment (primarily mud or silt) on steep banks.	Heavy equipment access. Stable substrate at top of bank.	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.
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.	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 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.	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.	Used to remove oil coatings from boulders, rock, and man-made structures.	Light vehicular access. Recovery equipment. Fresh water supply.	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.	Used to remove thin accumulations of oil residue from man-made structures.	Light vehicular access. Oil must be semi-solid. Supply of clean sand.	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.	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.	Selective removal of material. Labour-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.

TABLE 8. Shoreline Clean-up Methods (cont'd)

Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements	Physical Effect of Use	Biological Effect of Use
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 conjunction with diversion booming.	Heavy equipment access. A longshore current present.	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.
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.	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 where it is channeled to recovery points.	Used to flush light oils that are non-sticky from lightly contaminated mud substrates, cobbles, boulders, rocks, man-made structures, and vegetation.	Light vehicular access. Recovery equipment	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 downslope of cleanup.
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.	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.	Used to remove pools of light, nonsticky oil from mud, boulders, rock, and man-made structures.	Foot or boat access. Disposal containers for sorbents.	Selective removal of material. Labour intensive activity can disturb sediments.	Foot traffic may crush organisms. Possible ingestion of sorbents by birds and small animals.
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.	Disturbs sediments because of extensive use of labour; 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 down-wind 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.	Causes heavy air pollution; adds heat to substrate, can cause erosion if root system 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 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.	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.
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.	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. 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; or where thick layers of oil have created a pavement on the beach surface.	Heavy equipment access. High energy shoreline.	Disruption of sediments. Leaves oil on beach.	Disturbs shallow and deep burrowing organisms.
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.	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.	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.	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.

Checklist #5 - Shoreline Clean-up

The clean-up checklist includes information on the spill and on the shoreline environment from checklists #1 and #2. Several of the answers to questions in Part B can be obtained from checklist #3. If any of the questions in Part B are "YES", then a clean-up programme for that section of shoreline should be considered, provided that ALL of the answers in Parts C and D are also "YES". If the selected method yields a "NO" answer in Parts C and D, then alternative methods should be considered.

Natural Cleaning

In all spill response decisions, consideration must be given to the expected persistence of the stranded oil and to the damage that either the oil itself or the clean-up operation may incur. The assessment of these three factors will provide many of the basic guidelines for the deployment of available manpower and resources.

Probably the most basic question that should be asked is whether or not the shore zone will clean itself naturally within an acceptable period of time. In areas of wave activity it is likely that all but major spills could be cleaned naturally within a period of weeks or months. Provided that the presence of the oil during this period does not have a severe biological impact or does not conflict with other uses of the shore zone, then a suitable response may be to let the oil be cleaned naturally by the shore-zone processes.

Checklist #5. Shoreline Clean-up Information Checklist

A. Oil and the Shore Zone

Type of Oil: ____________________

Depth of Penetration: ____________________

Volume of Stranded Oil (Checklist #2): ____________________

Shoreline Type (see Checklist #1): ____________________

Shore-Zone Sediments (see Checklist #1): ____________________

Shore-Zone Exposure and Wave-Energy Levels (see Checklist #1):

____

Is ice present in the shore zone? YES/NO

B. Clean-up or Natural Recovery?

Expected Persistence of Oil:

Days _____ Months _____ Years _____ Decades _____

Would continued presence of oil be undesirable in terms of?

(a) Biological Processes	YES/NO
(b) Recreational Activities	YES/NO
(c) Commercial Activities	YES/NO
Is the level of contamination unacceptable?	YES/NO
Would oil migrate onto other shoreline sections?	YES/NO
Is immediate clean-up necessary?	YES/NO

What is the most effective/efficient clean-up method for the shoreline section?

____

C. Clean-up Feasibility

Are satisfactory equipment and sufficient manpower available?	YES/NO
Is the shoreline accessible for equipment and/or personnel? (see Checklist #1)	YES/NO

Checklist #5. (cont'd)

Can the equipment operate effectively in the shore zone? YES/NO

Would the degree of clean-up be satisfactory? YES/NO

If the most preferred clean-up method is unfeasible or would incur damage (see "D" below), what is the next suitable alternative method?

____

D. Clean-up Damage

Would the level of biological damage be acceptable? YES/NO

Would the level of geological damage be acceptable? YES/NO

Impact of Clean-up on Unique Cultural Features:

None _____ Low _____ Moderate _____ Severe _____ Critical _____

Impact of Clean-up on Recreational Activities:

None _____ Low _____ Moderate _____ Severe _____ Critical _____

Impact of Clean-up on Commercial Activities:

None _____ Low _____ Moderate _____ Severe _____ Critical _____

Notes:

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