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Manual of Practice for Protection and Cleanup of Shorelines:

Volume II
Implementation Guide

Interagency Energy/Environment R&D Program Report

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MANUAL OF PRACTICE FOR PROTECTION AND CLEANUP OF SHORELINES

Volume II
Implementation Guide

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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 volume a product of the above efforts supplements Volume I Decision Guide. This volume provides a detailed discussion of the factors involved in the decision making process and includes; oil characteristics, behavior and movement of oil, shoreline characterization and sensitivity, protection and cleanup priorities, implementation requirements, and impacts associated with cleanup operations. The manual also presents criteria for terminating cleanup operations and a discussion on handling oily wastes.

This project is part of the continuing program of the Oil and Hazardous Materials Spills Branch, IERL-Ci, to assess and mitigate the environmental impact of oil spills.

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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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801 COLLECTION OF INFORMATION

Implementation of an effective response to an oil spill requires that information necessary for the decision process be obtained quickly and accurately. Knowledge of prevailing meteorological and hydrological conditions, locations of sensitive and unique features, and existing shoreline topography is essential to a sound response. Ideally, much of this information could be collected for each coastal region before any oil spill incident. Additionally, local sources can be identified ahead of time to ensure rapid collection of information.

This section discusses what information is required, some of the possible sources, and the information that can be obtained before a spill occurs. In addition, this section serves as background for the Information Checklists in Section 200. Summaries of major information sources for the checklists are given in Tables 801-1 and 801-2.

Hydrological Data

Generally, larger scale hydrological phenomena are predictable; annual publications are available yielding information on tides and currents for the coastal areas of the United States.

Data on tides can be obtained in the following documents, published annually by the National Oceanic and Atmospheric Administration (NOAA):

- Tide Tables - High and Low Water Predictions: East Coast of North and South America (Including Greenland)
- Tide Tables - High and Low Water Predictions: West Coast of North and South America
- Tidal Current Tables: Atlantic Coast of North America
- Tidal Current Tables: Pacific Coast of North America and Asia

TABLE 801-1. INFORMATION SOURCES FOR GENERAL OIL SPILL DATA CHECKLIST

Subject	Source(s)
Spill Data	Visual observations
Oil characteristics	Section 301, owner of spilled oil
Meteorological data	National Weather Service, U.S. Coast Guard local radio stations, airports, harbors, marinas, *U.S. Coast Pilot* publications
Oceanographic data	Visual observations, ocean current charts, *U.S. Coast Pilot* publications

Tidal current charts for some areas are also available through NOAA. These charts depict, by means of arrows and figures, the direction and velocity of the tidal current for each hour of the tidal cycle. The charts, which may be used for any year, present a comprehensive view of the tidal current movement in the respective waterways as a whole. They also supply a means for readily determining for any time the direction and velocity of the current at various localities throughout the water areas covered. These charts should be used with care as current speed, direction and time can vary from predicted valves due to weather, freshwater inflow, and other variables.

Locally, tide data may be available from marinas, nautical supply stores, coast guard stations, the weather bureau, libraries, oeprators of beaches, or bait shops. Tide data documents and charts can also be ordered from the NOAA Distribution Center at 6501 Lafayette Avenue, Riverdale, Maryland 20840.

General ocean current and circulation information can be obtained from the above sources. These currents, however, usually affect only those spills occurring at substantial distances from the shore and not significantly influenced by tidal currents.

The *United States Coast Pilot*, published by the National Oceanic and Atmospheric Administration, gives navigational information including unique features and processes for navigators of United States coastal and intracoastal waters to supplement nautical charts. Figure 801-1 lists the volumes and shows the limits of each volume. The *Coast Pilot* can be obtained locally at nautical supply stores or ordered from its distribution center at 6501 Lafayette Avenue, Riverdale, Maryland 20840.

Meteorological Data

Meteorological data required for oil spill response planning includes wind speed and direction, air temperature, visibility, precipitation, cloud cover, and the daily and near-future forecasts. Because this information is

TABLE 801-2. INFORMATION SOURCES FOR SHORELINE INFORMATION CHECKLIST

Subject	Source(s)
General Description	
Length and width	
Type of Substrate	Visual observation
Shoreline exposure[a]	Topographical sheets
Energy Level[a]	Nautical charts
Shoreline access	Aerial Photographs
Sensitive and unique features[a]	U.S. Fish and Wildlife Service State Fish and Game Departments State Environmental Departments State Coastal Commissions Park and Recreation Departments Local ecologists/biologists Local historical societies Environmental atlases
Recreational use	Park and Recreation Departments
Hydrological Characteristics	
Wave heights	Visual observation
Currents	Visual observation
Tidal range	Local tide tables Tidal current tables *U.S. Coast Pilot* publications
Water depth	Topographical sheets Nautical charts *U.S. Coast Pilot* publications
Sediment cycle[a]	Visual observation
Oil Contamination	Visual observation
Features/Configurations for Protection/Ceanup	Visual observation Nautical charts Topographical sheets
Other Features	Visual observation

[a]If possible, local experts should be considered as sources for this information.

Atlantic Coast
1 Eastport to Cape Cod
2 Cape Cod to Sandy Hook
3 Sandy Hook to Cape Henry
4 Cape Henry to Key West
5 Gulf of Mexico, Puerto Rico, and Virgin Islands

Great Lakes Pilot
6 The Lakes and their Connecting Waterways

Pacific Coast
7 California, Oregon, Washington, and Hawaii
8 Alaska -- Dixon Entrance to Cape Spencer
9 Alaska -- Cape Spencer to Beaufort Sea

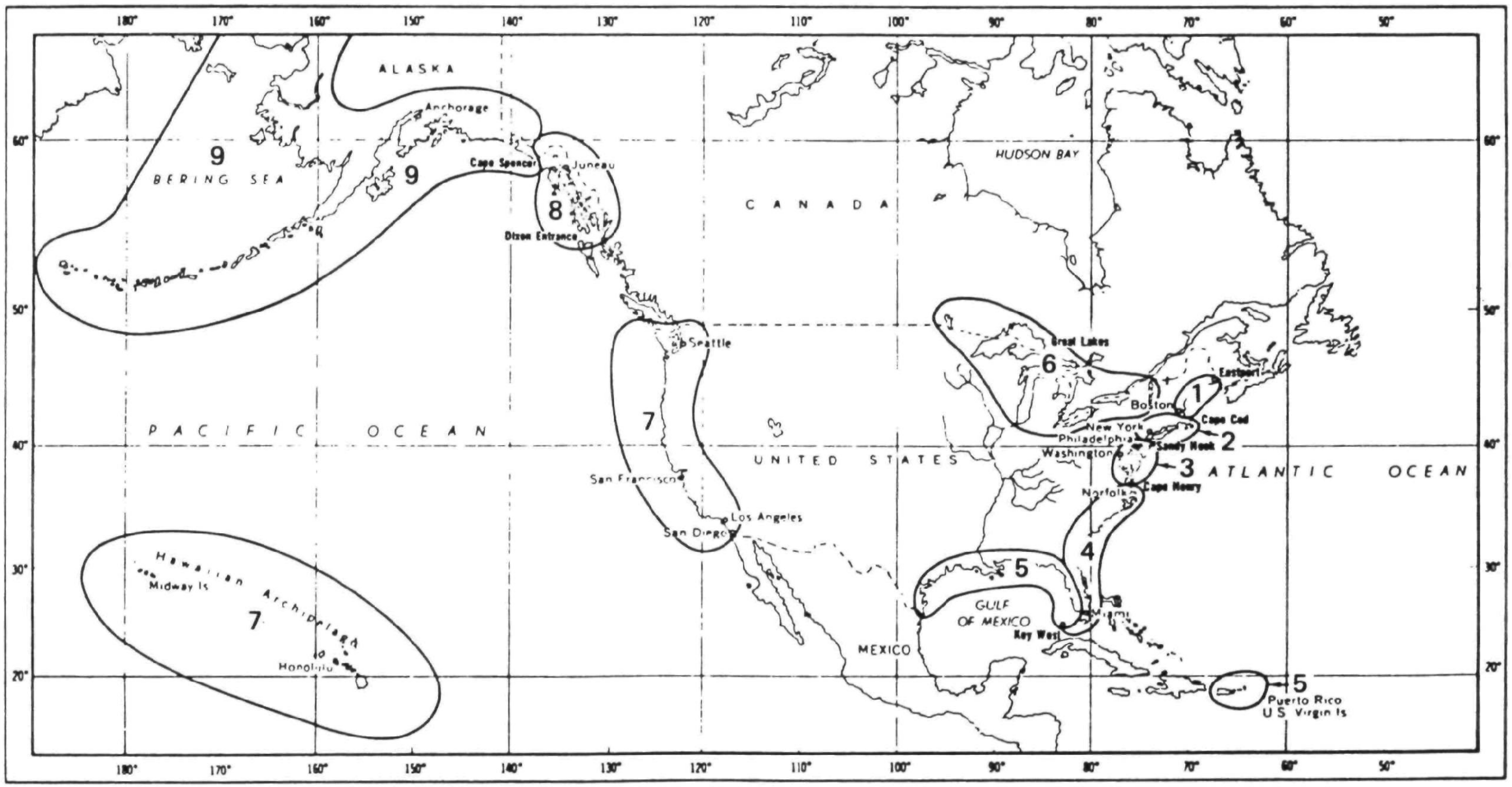

Figure 801-1. Limits of United States coast pilots.

extremely site-specific and usually cannot be accurately predicted for more than a few days in advance, it must be obtained daily during spill cleanup operations. It should be updated several times daily, especially with respect to changes in wind speed and direction and impending storm conditions.

Major sources for meteorological data are as follows:

- National Weather Service
- U.S. Coast Guard stations
- local AM and FM radio stations
- commercial radiotelephone coast stations
- local airports, boat harbors, and marinas

Information from the National Weather Service (NWS) and Coast Guard Stations is best obtained by calling the phone number listed in local telephone directories. The NWS also broadcasts weather reports on VHF-FM radio stations, which usually transmit on 162.55 or 162.40 MHz. Local marine weather service charts list transmission schedules and frequencies for weather broadcasts made by commercial and Coast Guard stations.

Another source of this information is the *United States Coast Pilot*. The pilots, as discussed previously, cover various coastal regions of the United States and include all the broadcast schedules, their frequencies, and transmitting locations. They also provide a summary of historical climatological data which can be used in the absence of long-term forecasts.

Sensitive and Unique Features

Sensitive and unique features of a shoreline include physically and biologically sensitive areas, sites of cultural or historical importance, marine mammal or sea bird rookeries, feeding or resting areas; areas of commercial or recreational importance; and certain man-made structures. Information concerning the locations and disposition of these features is usually available but often difficult to find. Therefore, as much of this information as possible should be collected ahead of time.

Probable sources of this information are as follows:

- U.S. Fish and Wildlife Service
- State Fish and Game departments
- State Coastal commissions
- State and local parks and recreation departments
- local universities and colleges
- local historical societies
- associations or organizations concerned with coastal marine life
- State Environmental departments

The U.S. Fish and Wildlife Service, and State Fish and Game departments, Environmental departments, and Coastal commissions often publish reports and bulletins dealing with the various sensitive and unique features. Some states have published environmental atlases which discuss the locations and status of most of their coastal and inland resources. These atlases generally cover the major sensitive and unique features but a visual reconnaissance of the shoreline is advised to supplement any published material.

Shoreline Topography

The description of the shoreline should be general but contain information that will apply to choosing a protection or containment technique or a cleanup method. Visual observation is usually required to obtain an adequate description of the shoreline, especially for areas which undergo significant seasonal transformations.

Nautical charts and topographic sheets however, can be used to gain much information about the shoreline and should be used to plot all data obtained. General shoreline configuration, the presence of cliffs, exposed rocks, beaches, rivers, estuaries, and wetlands, and access routes can usually be determined in advance from these charts and maps. Care should be exercised in the use of these charts and maps, however. The base maps from which many are prepared are old and may not present accurate shoreline morphology.

Nautical charts and topographic sheets are available in different scales; the larger the scale, the greater the detail shown. Charts are published by the National Oceanic and Atmospheric Administration and are available locally at nautical supply stores or can be ordered from the NOAA's distribution center at 6501 Lafayette Avenue, Riverdale, Maryland 20840. Topographic sheets are published by the United States Geological Survey and may be obtained at its local outlet and backpacking supply stores, or borrowed from a local university geology/geography department.

802 PHYSICAL AND CHEMICAL PROPERTIES OF OILS

Introduction

The term "oil" is applied to a wide variety of petroleum products ranging from crude oils to different grades of refined products.

Crude petroleum, or crude oil, is not a uniform substance and its properties vary widely from one location of origin to another and even from one well to another within the same oil field.* Crude oil may also contain dissolved gases, solids, water, and colloidal particles.

Carbon and hydrogen are the most abundant elements in crude oil, accounting for more than 95 percent of the composition. The molecular weight of hydrocarbons in crude oils ranges from a minimum of 16 to greater than 850. These hydrocarbons are separated from crude oils through boiling and vapor recovery processes. The lighter hydrocarbons generally vaporize at lower temperatures. As an example, gasoline would be one of the first products (low temperature) distilled from a crude oil, and lubricating oils are derived from a higher temperature fraction. The majority of compounds that make up residual fuels, such as bunker "C", come from the fraction left behind after most of the lighter fractions are distilled. Classifications and components of crude oils and their derivatives as shown in Table 802-1 and Table 802-2 lists the properties characteristic of typical residual fuels, while Table 802-3 lists the standards for both diesel and distillate fuel oils.

Physical Properties Of Oil

Some of the physical properties of oil are important in assessing the method of cleanup (if any) to be initiated. To a large degree, the characteristics listed below will determine how spilled oil reacts in the environment. For instance, certain questions regarding the physical properties of spilled oil and its subsequent behavior are:

Property	Question
Density	- Does the oil float or sink?
Viscosity	- Does the oil flow?
Pour Point	- Does the oil cool to the point of becoming semi-solid?
Flash Point	- Is there a threat of explosion or fire?
Surface Tension	- Does the oil tend to spread?

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*It is recommneded that the user obtain information on the characteristics of oils that are normally encountered in his area of responsibility before a spill incident occurs.

Boiling Point Range °C	-200 · -10 · 0 · 30 · 150 · 200 · 250 · 350 · 380 · 520 · 1000+
General Classification	← Gases → ← Light Fraction → ← Middle Fraction → ← Heavy Fraction → ← Residue →
Main Components	← Gases → (*dry* … *wet*); ← Gasolines → (*light* … *heavy*); ← Fuel Oils →; ← Asphaltenes →; ← Gas Oils →; ← LPG →; ← Kerosenes →; Naphthas; ← Lubricating Oils →
Hydrocarbon Range	← C_4 and lower → ← Pentane Plus → ← Liquid* → ← Solid* → C_1 · C_4 · C_5 · C_8 · C_{14} · C_{16} · C_{60}
US Bureau of Mines Correlation Index	Paraffinic Paraffinic · Paraffinic Naphthenic · Naphthenic Paraffinic · Naphthenic Naphthenic
Base Classification	Paraffinic (Light) · Mixed (Aromatic) · Naphthenic (Heavy) · Asphaltic
Typical API Gravity Range	38° 47° · 37° 30° · 25° 15°
Specific Gravity	0 835 0 800 · 0 840 0 876 · 0 900 0 970

Note The classifications shown in this table are intended to be representative and no precise demarcations are implied

Source Whitehead, 1976

*State of pure hydrocarbon

Table 802-1. Classification and components of crude oil.

TABLE 802-2. OBSERVED PROPERTIES AND DISTILLATION RANGES FOR TYPICAL RESIDUAL FUEL OILS

Property			Oil Type No. 4	No. 5	No. 6
Flash Point °C		min	76	77	87
		max	133	136	207
Pour Point °C		min	-44	-44	-16.4
		max	-15.6	-6.7	21
API Gravity		min	8.8	4	3.6
		max	29.9	21.5	19.1
-Viscosity- Saybolt Universal Seconds	100°F	min	75.4	54	-
		max	45	309	-
	122°C	min	-	34.4	251
		max	-	144	853.8
Sulfur Content %			0.22-20	0.6-20	0.7-40

TABLE 802-3. COMPARISON OF STANDARDS FOR DIESEL FUEL AND FUEL OIL CHARACTERISTICS

Grade of Diesel Fuel Oil	Flash Point °C (°F)	Pour Point °C (°F)	Distillation Temperatures, °C (°F): 10% Point	Distillation Temperatures, °C (°F): 90% Point Min	Distillation Temperatures, °C (°F): 90% Point Max	Saybolt Viscosity, s[a] Universal at 38°C (100°F) Min	Saybolt Viscosity, s[a] Universal at 38°C (100°F) Max	Kinematic Viscosity, cSt[b] At 38°C(100°F) Min	Kinematic Viscosity, cSt[b] At 38°C(100°F) Max	Specific Gravity 60/60°F (deg API)
No. 1-D: A volatile distillate fuel oil for engines in service requiring frequent speed and load change	38 or legal (100)				288 (550)		34.4	1.3	2.4	
No. 2-D: A distillate fuel oil of lower volatility for engines in industrial and heavy mobile service	52 or legal (125)			282[c] (540)	338 (640)	32.6	40.1	1.9	4.1	
No. 4-D. A fuel oil for low and medium speed engines	55 or legal (130)					45.0	125.0	5.5	24.0	
Grade of Fuel Oil										
No. 1: A distillate oil intended for vaporizing pot-type burners requiring this grade of fuel	38 or legal	-18[c] (0)	215 (420)		288 (550)			1.4	2.2	0.85 (35 min)
No. 2: A distillate oil for general purpose heating for use in burners not requiring No. 1 fuel oil	38 or legal	-6[c] (20)	282[c] (540)		338 (640)	(32.6)	(37.9)	2.0[c]	3.6	0.88 (30 min)

These characteristics are often treated with laboratory precision in the petroleum industry. For the purposes of this manual, however, the physical properties of oil are addressed in an empirical manner rather than an analytical one. The answers to the questions above are neither simple nor absolute, but the methods for dealing with spilled oil should be based on field observations, even when specific information is available. A discussion of the physical properties of primary concern follows.

Density

The density of an oil is important in spill assessment for two main reasons: First, the density of an oil determines whether it will sink or float; heavier oils can collect sediment, entrain water, and become heavy enough to sink. Second, once it has been determined that an oil will float, the height that the oil floats in the water, or its "freeboard effect", determines the surface area upon which wind forces may work; an oil which floats high in the water presents more sail area and will be more easily moved by the wind.

The density of oil is measured as specific gravity. Specific gravity is a comparison between the weight of a substance and that of fresh water at 15.6°C (60°F), which is assigned a value of 1.0000. Therefore, an oil that floats will have a specific gravity less than the value of the water. The specific gravity of sea water ranges from about 1.02 to 1.07. Therefore oil will usually be slightly more buoyant in sea water. The density of liquid oil is inversely proportional to the temperature.

Density measurement units commonly encountered in oil work are A.P.I. gravity and specific gravity. One can calculate A.P.I. gravity from the specific gravity by using the formula:

$$\text{A.P.I. gravity} = \left[\frac{141.5}{\text{specific gravity corrected to } 60°\text{F}} - 131.5\right]$$

It can be seen that a substance with a specific gravity of 1.0 will have an A.P.I. gravity of 10.0°; it should also be remembered that a high value for A.P.I. gravity represents a light oil and a low value corresponds to a denser oil.

Viscosity

The measure of a fluid's internal friction, or its resistance to flow, is known as viscosity. The viscosity of an oil affects the rate of spreading of the slick, penetration of substrate, and persistence. It also affects cleanup operations. Viscosity is variable and will decrease as an oil's temperature is elevated.

The viscosity of an oil can be measured in several ways. One is to allow a known volume of oil to flow through a standard orifice at a particular temperature. The time required for this experiment can be used to describe the oil's viscosity, and is commonly expressed in seconds. Low viscosity oils are those which have a light, or more fluid, consistency; high viscosity oils are those which tend to be tarry or thick.

The methods of measurement for determining viscosity are similar, as stated earlier, but the sample size and orifice dimensions vary. Table 802-4 shows the relationship between viscosity units. Saybolt seconds units are commonly used by industry in the U.S., while kinematic viscosity has been used more by the scientific community.

Pour Point

The pour point of a material is the temperature at which it begins to flow. Oil may be solid or semi-solid during cool nights and fluid during the day, or solid when immersed in cool water and fluid when warmed past the pour point while stranded on land. These situations require different cleanup methods, and if round-the-clock cleanup efforts are carried out, daytime strategies and equipment could differ from night operations.

The pour points of petroleum products can differ greatly. Some crudes and residuals may have pour points in excess of 27°C (80°F), while light distillates such as light diesel fuel can be as low as -51°C (-60°F). The pour point information is used in conjunction with ambient air and water temperatures when selecting the cleanup methods to be employed and predicting the behavior of the oil itself.

Flash Point

The flash point of an oil is the lowest temperature above which its vapors will ignite momentarily, and is important in evaluating the explosion and fire hazard potential for working around exposed oil. Light distillates such as gasoline or crudes with low boiling points should be considered dangerous; operations around oils with low flash points* should be avoided because of these risks.

Surface Tension

The surface tension of oil dominates the spread of a slick as it becomes thin. The viscous surface-tension spreading of oil on water is caused by the high surface tension of the water itself. This surface tension force (Y_W) acts to "pull" the oil outward thus causing it to spread. Two other forces, however, tend to effect contraction of the oil. These are the surface tension of the oil (Y_o) and the interfacial tension between the oil and water (Y_{ow}). Because the surface tension of water (Y_w) is typically larger than the sum of the surface tension of oil and water ($Y_o + Y_{ow}$) the spreading pressure of the oil F is positive and the oil continues to spread as is shown in the equation below:

$$F = Y_W - (Y_o + Y_{ow})$$

*A low flash point is one close to or lower than ambient air temperatures.

TABLE 802-4. RELATION (APPROXIMATE) BETWEEN ENGLER DEGREES, SAYBOLT AND REDWOOD SECONDS, AND KINEMATIC VISCOSITIES AT THE SAME TEMPERATURE

Engler Degrees	Saybolt Universal Seconds	Saybolt Furol Seconds	Redwood Standard Seconds	Kinematic Viscosity (centistokes)
2.5	83	13.9	74	15.5
2.75	92	14.5	81	17.5
3	101	15.2	88	19.5
3.25	110	15.9	96	21.5
3.5	118	16.5	104	23.5
3.75	126	17.2	112	25.3
4	135	18	119	27.4
4.25	144	18.8	127	29.3
4.5	152	19.5	134	31.1
4.75	160	20.3	142	33.0
5	169	21	150	34.9
5.5	186	22.5	165	38.7
6	203	24	181	42.5
6.5	220	25.6	196	46.3
7	237	27.2	211	49.9
7.5	253	28.7	225	53.5
8	270	30.3	240	57

Source: Neild, 1965.

Therefore oils with a low surface tension will tend to spread more rapidly on water.

It is possible to modify the interfacial tension of an oil/water system: a) dispersants are used to reduce the interfacial tension of the system, thereby encouraging mixing, solubility, and spreading behavior; b) collectants are used to modify the surface tension of water to the point of causing oil to contract upon itself. Surface tension data for some crudes are shown in Table 802-5.

TABLE 802-5. SURFACE TENSION AND THEORETICAL SPREADING DATA FOR VARIOUS CRUDE OILS

Type of Oil	Surface Tension Dynes/cm	Interfacial Tension Sea Water/Oil Dynes/cm	Initial Spreading Pressure on Salt Water, Dynes/cm	Thickness (mm) of slick from spillage of 100 m^3 of oil after spreading for: 10^2 sec	10^3 sec	10^4 sec	10^5 sec
Libyan (Brega)	23.1	13.9	35	2.28	0.49	0.11	0.02
Iranian Heavy	24.3	25.5	22	3.27	0.70	0.15	0.03
Kuwait	24.1	24.9	23	2.10	0.45	0.10	0.02
Iraq (Kirkuk)	23.7	16.9	31	2.57	0.55	0.12	0.03
Venezuela (Tia Juana medium)	24.1	19.2	29	2.55	0.55	0.12	0.03

Source: Nelson-Smith, 1973, and John Frazer, 1978.

Chemical Properties of Oils

The chemical and physical properties of an oil are both determined by the molecules that make up the oil, and thus, they are closely related. The following chart provides pertinent questions about the chemical characteristics of oils (Table 802-6).

TABLE 802-6. EFFECTS OF CHEMICAL CHARACTERISTICS ON OIL BEHAVIOR

Questions Concerning Chemical Behavior of Oil	Chemical Characteristic		
	Boiling Point Range	Solubility	Aromatic Content
1) Will the oil's characteristics change with weathering and time?	+	+	-
2) Will the oil be toxic to marine life?	0	+	+
3) Will the volume of oil decrease (evaporate or dissolve)?	+	+	-

NOTE: + = high importance.
0 = some importance.
- = low importance.

The chemical properties of major concern are solubility, boiling point range, and aromatic content. Table 802-7 shows some characteristics of compounds commonly found in crude oils. Crudes are commonly classified by the dominant hydrocarbon group, and an oil that is made up largely of paraffins is therefore paraffinic, etc.

Boiling Point Range

Boiling point range (BPR) is important in identifying the low boiling fractions of oils. The low boiling fractions are volatile and will evaporate readily. The remaining oil will become thicker (more viscous) as the lighter fractions are liberated over time. The net result is a thicker, denser oil and a reduced volume as the weathering process proceeds.

The boiling point range can also be used to deduce the approximate makeup of oils. The BPR usually helps to indicate the homogeneity of an oil, with crudes being generally characterized by a broad BPR and distillates and residuals by fairly narrow BPRs.

An oil that has a BP above ambient temperature can undergo measurable volumetric changes through evaporation. Kuwait crude from the *Torrey Canyon* soon lost most of its fractions up to BP 300°C and it is believed that as much as one-third of the total spill volume was lost through evaporative processes.

TABLE 802-7. CHARACTERISTICS OF SOME LIGHT HYDROCARBONS FOUND IN CRUDE OIL

Compound	Carbon Number	Boiling Point (°C)	Density (SG)	Solubility in Water	
PARAFFINS					
Methane	1	-161.5	0.424	90 ml/1 (20°C)	
Ethane	2	- 88.5	0.546	47 ml/1 (20°C)	(gases)
Propane	3	- 42.2	0.542	65 ml/1 (18°C)	
Butane	4	- 0.5	0.579	150 ml/1 (17°C)	
Pentane	5	36.2	0.626	360 ppm (17°C)	
Hexane	6	69.0	0.660	138 ppm (15.5°C)	
Heptane	7	98.5	0.684	52 ppm (15.5°C)	
Octane	8	125.7	0.703	15 ppm (15.5°C)	
Nonane	9	150.8	0.718	c. 10 ppm	
Decane	10	174.1	0.730	c. 3 ppm	
Undecane	11	195.9	0.741		
Dodecane	12	216.3	0.766		
Tridecane	13	235.6	0.756		
Tetradecane	14	253.6	0.763		
Pentadecane	15	270.7	0.769		
Hexadecane (Cetane)	16	287.1	0.773		
Heptadecane	17	302.6	0.778		
NAPHTHENES					
Cyclopropane	3	- 33		"slight"	
Cyclobutane	4	13			
Cyclopentane	5	49.3	0.751		
Methylcyclopentane	6	71.8	0.749		
Cyclohexane	6	80.7	0.779		
Methylcyclohexane	7	100.9	0.769		
Ethylcyclopentane	7	103.5	0.763		
Ethylcyclohexane	8	131.8	0.788		
Trimethylcyclohexane	9	141.2	0.777		
AROMATICS					
Benzene	6	80.1	0.879	820 ppm (22°C)	
Toluene	7	110.6	0.866	470 ppm (16°C)	
Ethylbenzene	8	136.2	0.867	140 ppm (15°C)	
p-Xylene	8	138.4	0.861		
m-Xylene	8	139.1	0.864	c. 80 ppm	
O-Xylene	8	144.4	0.874		
iso-Propylbenzene (Cumene)	9	152.4	0.864		
n-Propylbenzene	9	159.2	0.862	60 ppm (15°C)	
Naphthalene	10	217.9	1.145	c. 20 ppm	
2-Methylnaphthalene	11	241.1	1.029		
1-Methylnaphthalene	11	244.8	1.029		
Dimethylnaphthalene	12	262.0	1.016		
Trimethylnaphthalene	13	285.0	1.01		
Anthracene	14	354	1.25		

Source: Nelson-Smith, 1973.

Solubility and Aromatic Content

The three major components of crude oils are: 1) paraffins, 2) naphthenes, and 3) aromatics.

1. Paraffins are saturated straight chain hydrocarbons.
2. Naphthenes are saturated ring hydrocarbons.
3. Aromatics are highly stable ring hydrocarbons.

The original term "aromatic" comes from the pleasant smells often associated with naturally occurring compounds.

Aromatics are important in spill analysis because these chemicals have been shown to be more toxic than the other hydrocarbons and this property may be magnified by the relatively high solubilities of the aromatics (refer to Table 802-7). However, the aromatic hydrocarbons also tend to be relatively volatile and can evaporate rapidly. Benzene and toluene are especially soluble in comparison to other hydrocarbons and readily go into solution up to 820 and 470 ppm, respectively. Because of their stable form, the aromatics tend to resist degradation in the environment more than the paraffins or napthenes.

803 GENERAL SHORELINE INFORMATION

This section provides technical information concerning coastal processes, hydrological regimes, access and trafficability, meteorology, and sensitive and unique features.

Coastal Processes

Coastal processes that affect oil contamination of shorelines deal primarily with sediment transport on and off a beach. A beach begins below the surf zone of a shoreline and extends landward to the limit of storm wave activity usually marked by a storm ridge, vegetation, dunes, or a cliff. Beaches are generally divided into three areas: the backshore, intertidal, and nearshore. A profile of a typical beach is shown in Figure 803-1.

Backshore

The backshore area of a beach is located above the berm or level of normal wave activity. Exposure of the backshore to wave activity occurs only during exceptionally high tides or storm surges. Oil deposited in the backshore during these times can only be affected by wave action during subsequent exceptional high tides or storm surges.

Backshore areas can be biologically productive and sensitive as well as difficult to clean. Debris, trash, and/or log accumulations and vegetation are frequently present in the backshore and could cause cleanup difficulties. However, the location of this debris can provide a useful indicator of where the oil may concentrate by determining the maximum limit of the water level at the time of the last high water or storm level. The maximum inland distance that oil can be expected to be deposited during these periods of high water levels can then be estimated from the debris line. Special effort should be taken to protect backshore areas from contamination as soil penetration is likely and cleanup difficult. Damage to vegetation on sandy backshores could result in severe wind erosion problems.

Intertidal

The intertidal zone is the area of the beach extending from the low water mark to the high water mark. Oil contacting a shoreline under normal conditions will be deposited within this area. On high-energy shorelines, the heaviest concentrations of oil occur along the upper intertidal area. The lower intertidal zone usually remains wet, and because oil does not readily adhere to a wet surface, oil in this area can be refloated by a flooding tide and carried to the upper parts of a beach. Oil deposited in the upper intertidal zone is, however, usually eroded rapidly if wave action is present. In low-energy environments or where large volumes of oil are washed ashore, oil can coat the entire intertidal zone.

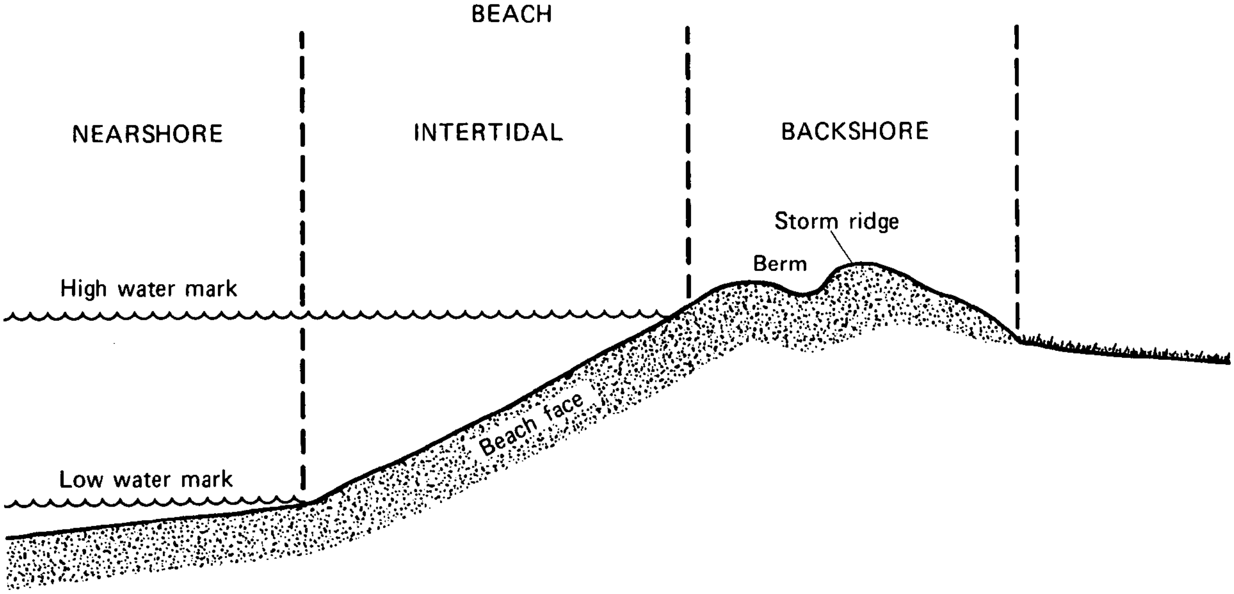

Figure 803-1. Typical beach profile.

Nearshore

The nearshore zone is located below the low water mark and within the zone of wave-generated processes. Because this area is always submerged, it receives little contamination except for the small amount of oil that sinks or from oil-coated sediments eroded from the shoreline.

Coastal Hydrological Regime

Beaches typically undergo erosion and deposition cycles that form the basis for sediment transport. These cycles occur both daily and seasonally and are controlled by the hydrological regime. The primary hydrological factors involved are waves, storms, tides (range and current), and longshore currents.

Waves

The generation of waves results from the interaction of winds and gravity with surface water. Waves transmit energy through the water at an energy level which is determined primarily by wind velocity and duration, and by fetch. The most important aspect of waves or wave-generated processes is that the energy is dissipated on or near the beach.

The transfer of wave energy to the beach has direct effects on oil. Mechanical energy from breaking waves or swash causes the physical dispersion and breakdown of oil on the water and on the shoreline. Oil is subject to dispersion in the breaker and swash zone where mixing of water and oil can result in emulsions such as "chocolate-mousse." Oil on the shoreline itself can be dispersed as individual particles, then returned to the water by backwash action. The rate at which wave-induced degradation processes occur is directly related to level of incoming wave energy.

The transport and redistribution of sediments through wave action is the most important effect of energy transfer on a shoreline. This transport and redistribution causes the sediments to act as an abrasive tool on stranded oil. The extent of this abrasive action is highly dependent on the size of the sediments and the level of wave energy. Because sand is more readily transported, oil stranded on a sandy beach will break down much more rapidly from abrasion than will oil on a comparable cobble beach having a similar energy level.

On shorelines with large seasonal differences in wave-energy levels, especially the west coast of North America, beaches will erode away during seasons of high wave energy (winter), with construction or deposition predominating during seasons of low wave energy (summer). Storms will often erode beaches, to be followed by construction during the post-storm period.

Oil deposited on a shoreline during a depositional cycle can become buried within a relatively short period of time, resulting in significant cleanup difficulties. If deposited during an erosion cycle, the oil is quickly returned to the water, which increases the potential for recontamination.

A detailed description of this phenomenon taken from Owens (1977) is as follows:

> During an erosion phase on a beach, sediments and oil would be removed and transported into the nearshore area. This would lead to a rapid breakdown of the oil particles as the particles are rolled around by wave action. If oil is deposited on a beach immediately following the erosion phase, but before recovery has commenced, the oil on the beach would be buried as constructive waves return sediment by the landward migration of ridge systems. Figure 803-2 shows this type of situation where a beach (a) is eroded and the oil is then deposited on the remnant berm during or after the storm (b). As the beach recovers, a small ridge (c) migrates up the beach within a few days (d) and eventually the large ridge system will restore the eroded berm (e). The buried oil would then only be exposed during a period of further beach erosion (f).

In the same context Owens describes the effects of storm-induced wave activity on cobble beaches previously contaminated with oil:

> On cobble beaches, however, sediments would be transported towards the storm ridge and the oil would become buried [Figure 803-3]. As the cobble beach is eroded, the layer of buried oil is exposed in the beach face. If oil is stranded on a cobble beach over a long time period, several erosion-deposition cycles can lead to exposure of more than one layer of oil in the beach face.

In areas where no beach exists and only cliffs and rocky shorelines are present, the available wave energy depends on the slope of the intertidal area. If the slope is shallow (i.e., a shore platform), energy is dissipated by bottom friction and waves breaking on the platform. If the slope of the intertidal area is steep, all or most of the wave energy is transmitted to the rocks or cliffs. In these situations, wave energy is frequently transmitted seaward as the wave is reflected. Turbulent conditions may be present near the shoreline as a consequence of reflected waves colliding with incoming waves. Oil slicks approaching such an area may not be deposited on the shore but can be trapped in the turbulent area, resulting in dispersion of oil into the water column. Oil deposited on rocky shorelines or cliffs is subjected to high levels of mechanical energy as the waves reach the shore, and is broken down and transported away.

Waves can also have detrimental effects on protection and cleanup efforts. Booms deployed in or near the surf zone may be ineffective if wave height exceeds 25 cm. At this height the waves will generally wash the oil over the boom unless it has substantial freeboard.

Tide

The tide is a rhythmic, alternate rise and fall of the water level of the ocean and the bodies of water connected with the ocean. The tidal range is the difference in height between consecutive high water and low water

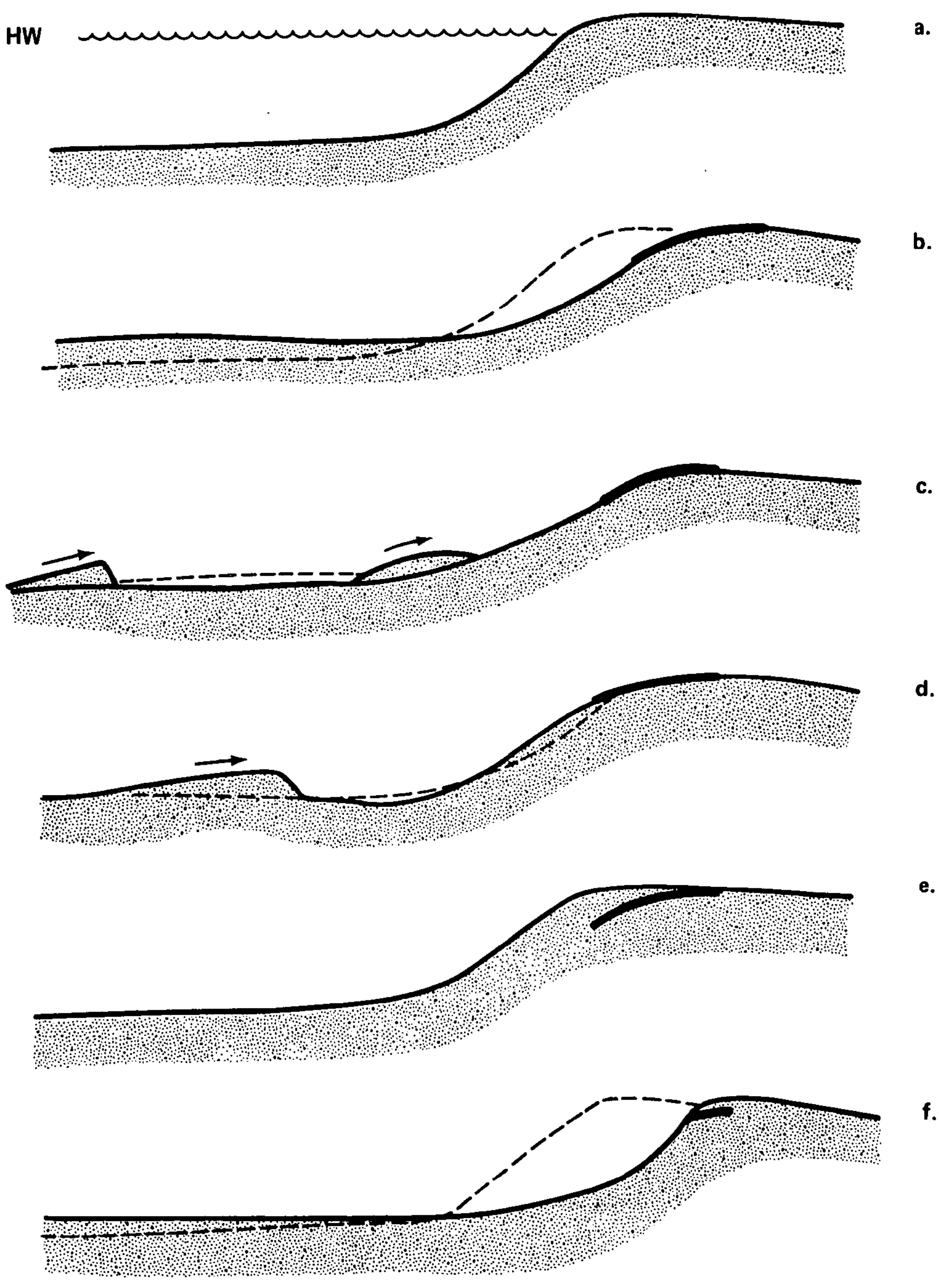

Figure 803-2. Sequence of storm erosion and oil deposition (b), burial (c) (d) (e), and exposure following a second storm (f) on a sand beach (from Owens, 1977b).

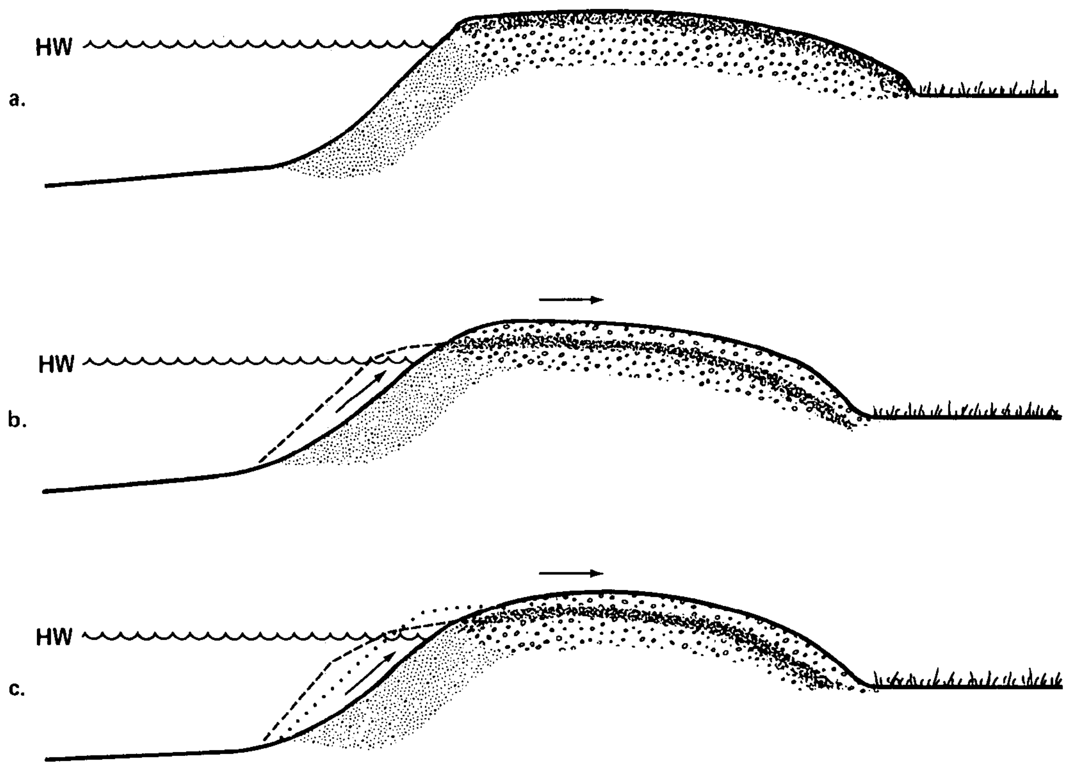

Figure 803-3. Effects of storm-wave activity on oil stranded on a cobble beach: (a) oil is deposited above the high-water level (HW) during storm conditions, a second storm erodes the beach and waves push material onto the upper beach to cover the oil (b) ; a subsequent storm continues the process, gradually exposing more of the buried oil layer (c) (from Owens, 1977b).

at a given place. The vertical rise and fall of water creates an associated horizontal movement of water, the tidal current. The ebb tide and current are associated with the fall of the water level, and the flood tide and current with the rise of the water level. Ebb currents are generally stronger than flood currents; stream discharge aids the seaward movement of the ebb current and works against the landward movement of the flood current.

In open water, the tidal current is not as significant as it is in coastal inlets, intertidal channels, shallow bays, and estuaries where the constriction of the waterway can greatly increase current velocities during the ebb and flood periods. During flood tide, oil can be transported into sheltered lagoons or back areas of marshes; should this happen, oil may be stranded there. Because wave energy in this environment is minimal, natural degradation rates related to littoral processes would be slow. Strong ebb currents can, however, pull trapped oil from these areas and into open water where the potential for contamination of previously cleaned or unaffected shorelines becomes a problem. Tidal currents, or any currents, are a major factor in protection and cleanup efforts utilizing booms. Because currents in excess of 1 knot can cause boom failure, booms should be placed in low-current areas.

Tides are responsible for daily erosion and deposition cycles on a beach. Ebb tides erode material from the beach while flood tides deposit the same materials back on the shoreline. These daily cycles result in temporary burial or removal of oil on a beach.

Longshore Currents

Longshore currents are those formed by waves approaching a shoreline at an angle. This creates a current which flows parallel, and close to, the shoreline as shown in Figure 803-4. Longshore currents are the major force in sediment transport.

Sand beaches with longshore currents commonly develop a type of rythmic topography called beach cusps. Should these beaches become oiled, the longshore movement of sediments would slowly lead to a breakdown of the oil cover. This migration pattern is, in fact, a sequence of continuous erosion and deposition that would cause the oil to be broken down into smaller particles which would then be buried or transported seaward. Figure 803-5 illustrates this process.

Access and Trafficability

Access to, and trafficability of a shoreline area is important in determining what approach should be taken for the protection or cleanup of that area. Access can be evaluated by locating existing roads or large trails leading to the shore.

If no roads exist, the general topography of the area should be evaluated to determine if a road could be built, providing no alternatives exist

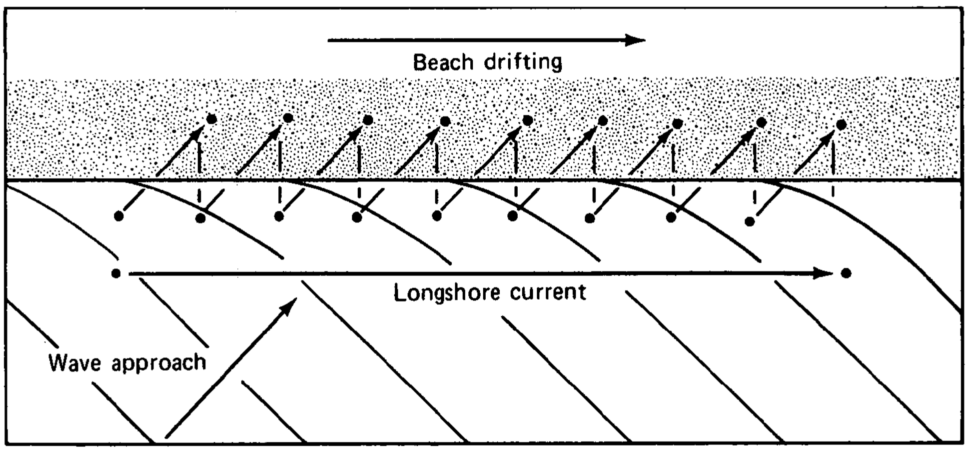

Figure 803-4. Waves approaching a beach obliquely produce a longshore current and a longshore drift of sediments by swash and backwash action (from Bird, 1968).

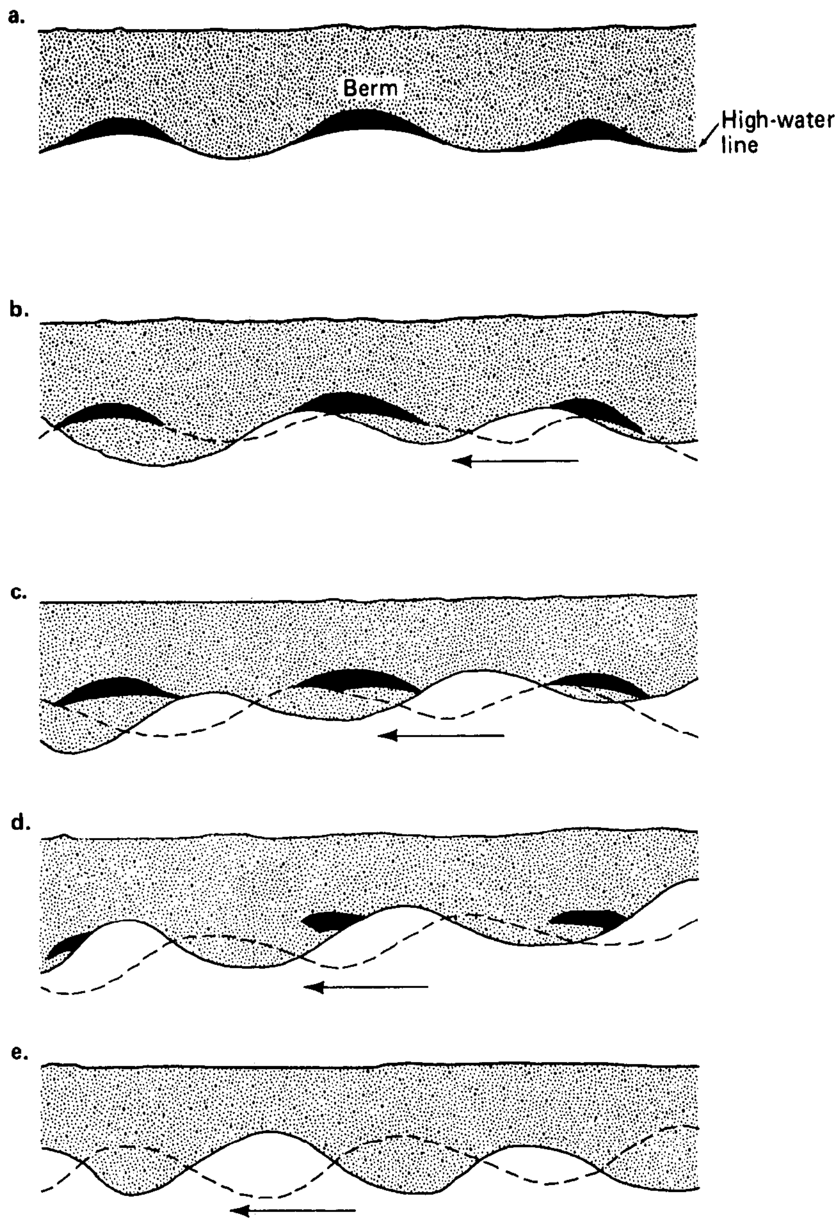

Figure 803-5. View of the effects on oil deposited at the high-water level by migrating rhythmic topography.

and approval is obtained from the appropriate agencies. Access and topography can usually be determined from U.S. Geological Survey maps and some nautical charts. Access can also be established from most detailed road maps.

The trafficability of a shore refers to the bearing strength of the sediments to permit passage of vehicles and people. Compactness of the surface materials is the primary factor in determining trafficability. Mud or very loose sand might require special vehicles to transport equipment and personnel in and out of the affected area. Sandy, well-drained (dry) soils that are relatively flat and have a firm feel when walked on normally will support most types of light vehicle traffic. Damp, clayey soils that can be walked on without sinking can generally be modified to support limited light vehicle traffic. Poorly drained muds and clays and very loose sands in which body weight causes sinking of several centimeters or more cannot normally be modified to permit safe operation of vehicles.

If a cone pentrometer is available it can be used to determine the trafficability of a sandy shoreline area with reasonable accuracy, as described below. A cone pentrometer is a field instrument consisting of a stainless steel cone mounted on a shaft in such a way that the cone can be forced into the soil surface by hand. A proving ring and calibrated-dial assembly are used to measure the load applied. The penetration resistance is termed the "cone index" and is a measure of the shearing resistance of the soil.

The cone pentrometer is positioned vertically on the beach and pressure is applied by placing both palms on the top of the shaft and pushing the pentrometer 9 cm (6 inches) into the soil. At the same time, bend over and record the reading (called the "cone index value") on the dial as shown in Figure 803-6.

The process is repeated 20 to 30 times along and across a beach in both the intertidal and backshore areas. The values for each area are averaged, which gives a cone index value for the foreshore and backshore of a beach. This value can then be compared with the minimum cone index values given in Table 803-1. If the cone index value of the beach is greater than the cone index value listed for the desired equipment, then the piece of equipment can operate on that beach. For example, if the backshore of a beach had a cone index value of 45, then a rubber-tired front-end loader and elevating scraper could probably operate on the beach with reduced tire pressures, but a motor grader might become immobilized.

Oftentimes, if the trafficability of a substrate is too low to support heavy equipment, the tire pressure can be lowered to increase traction and prevent immobilization. Table 803-1 lists the minimum cone index values for three types of heavy equipment with tire pressures of 40 and 20 psi. Tire pressures of 40 psi or greater are recommended for use under normal earthmoving operations.

Figure 803-6. Obtaining cone index value with cone pentrometer.

TABLE 803-1. MINIMUM CONE INDEX VALUES

Equipment Type	Tire Pressure 20 psi	Tire Pressure 40 psi
Rubber-tired front-end loader	10-20	22-44
Motorized elevating scraper	25-42	70-105
Motorized grader	38-50	90-115

Meteorological Considerations

Wind

During spring tides or storm surges where oil is deposited on the berm of the shoreline, wind-transported sediments could bury the oil, especially if the wind is off the land. The effect of such burial, however, reduces the rate of weathering and aging; it also increases the possiblity of recontamination if subsequent strong winds, storm surges, and high water levels uncover the oil.

If a strong wind is blowing onshore it can trap oil against the shoreline. Deposition of the oil would then occur either during an ebb tide or as the water level falls following a wind-induced storm surge. If the surge is heavy enough, oil can be deposited onto backshore areas or into sheltered lagoon environments.

Wind speed and temperature also directly affect weathering rates of the oil. Wind stimulates the process of evaporation, resulting in an increase in oil density as the light fractions or volatiles are removed.

Temperature

Air and water temperatures can affect the behavior of the oil and the nature of the protection and cleanup technique used. Temperature significantly affects oil viscosity, evaporation rate, and burning characteristics, and can directly impact the performance of cleanup personnel and equipment. Extremely low temperatures can cause the oil to behave like a solid mass and may require a special recovery device. Elevated temperatures decrease oil viscosity, resulting in deeper penetration into shoreline sediments, remobilization of oil formerly adhering to rocks and vegetation, and mobilization of oil in stockpiles of debris.

The weathering process of the oil is directly related to temperature. Evaporation and biodegradation rates are affected by changes in temperature. Local climate and time of year, with respect to temperature, are critical elements in estimating the persistence of the oil, and therefore also in estimating the need for protection of a beach or cleanup of an affected beach.

Precipitation

Knowledge of rainfall predictions can be very helpful in determining what method of protection and/or cleanup will be used. Direct rainfall can cause recontamination by washing oil from the shorelines back into the water. It is also effective in leaching oil from contaminated debris and vegetation. Reduction in shoreline trafficability and general deterioration of operating conditions can also be caused by heavy rainfall.

Debris

The type of debris commonly found on shorelines (especially coastal) consists primarily of wood, plastic bottles, styrofoam, stranded logs, and other miscellaneous floating objects. It is deposited on the shore at the upper limits of wave action or storm surges. If the debris becomes contaminated with oil, cleanup operations become more difficult. The presence of large numbers of stranded trees and logs would increase the cleanup difficulty due to their size and weight. Physical barriers can be constructed to prevent oil from mixing with the debris. Floating objects and debris can clog pumps and skimmers and should be avoided or removed during cleanup activities. Oil contained in stranded debris can be washed off by rain or refloated during high water, thus recontaminating the shoreline.

Sensitive or Unique Biological Features

Sensitive or unique biological features along a shoreline are threatened or contaminated with oil during a spill event. Because of the high visibility of important biological features in an area and the limitations in time, manpower, and equipment in responding to a spill, rapid identification of these features becomes a key component of the protection and cleanup decision-making process.

Local and regional biological experts can provide information on the nature and location of sensitive or unique features and, where needed, assign relative values to competing features. The relative importance of competing features can vary with the season, severity and duration of the expected impact, and potential for recovery. For example, during a winter spill a waterfowl feeding area along a southeastern coast may be considered more valuable when large numbers of birds are present than would a recreational shellfish area that is used almost exclusively in the summer. Their relative standing might then be reversed during a summer spill depending on the type and expected persistence of the oil, relative recovery times for both the feeding and shellfish areas, and the availability of similar shellfishing areas outside the zone of contamination.

A shoreline can be classified as biologically sensitive or unique if one or more of the features listed below are present. Specific examples of each feature are included in an effort to expose the user to the types of concerns that will arise after a spill. Again, because special or unique biological features are highly visible and attract considerable public attention when impacted, and because these features should partially dictate protection and cleanup decisions, local and regional biological experts should be consulted for more site-specific information and recommendations.

1. Rare, Threatened, Endangered, or Protected Species

- Any species on Federal or State special status lists.
- Relatively few expected in marine areas, some in estuaries, most in fresh water.
- Sensitivity will depend on the reason the species uses the aquatic habitat, duration of use, importance of the habitat to successful completion of the species life cycle, and public and political concern for the species.
- In general, sensitivities in decreasing order are: 1) resides in aquatic habitat and completes whole life cycle in one place, 2) habitat essential for breeding purposes, 3) habitat essential for feeding purposes, and 4) habitat essential for resting and other intermittant uses.

2. Reserves, Preserves, and Other Legally Protected Areas

- Areas protected by some legal mandate or areas locally recognized as important for scientific ecological reasons.
- Areas of special biological significance.
- Ecological preserves.
- Wildlife and/or waterfowl sanctuaries and refuges.
- Scientific research areas.

3. Waterfowl Rookery or Concentration Areas

- Shoreline areas (rookeries) used for breeding, nesting, and fledgling activities.
- Open-water areas (concentration) used for resting, feeding, and breeding.
- Sensitivity will depend on which species are present; number, extent, reason for use of the habitat; and susceptibility to oil impacts.
- In general, sensitivities in decreasing order are 1) diving ducks, 2) swimming and surface-feeding waterfowl, 3) gulls, terns, etc., 4) shorebirds, and 5) water-associated birds.

4. Mammal Rookeries, Calving Grounds, and Concentration Areas

- Sensitivity will depend on which species are present; number, extent, reason for use of the habitat, and susceptibility to oil impacts.

- In the marine environment, rookeries, and calving grounds are generally more sensitive to oil impacts than are concentration (haul-out) areas.

- In freshwater systems, species with total dependence on the water environment (e.g., beavers) are more sensitive to oil impacts than are species that breed on the water, which are, in turn, more sensitive than species that feed in the water.

5. Species of Commercial Importance

- Clams and oysters.

- Crabs, shrimp, lobsters.

- Finfish (including spawning in intertidal and shallow streams).

- Algae.

- Aquaculture sites (shellfish, algae, finfish, lugworms).

- Fish bait (lugworms, clams, ghost shrimp).

- Sensitivity will depend on season, economic value of the local harvest to the area, and susceptibility to oil impacts.

6. Species of Recreational Importance

- Clams, oysters, mussels.

- Crabs, shrimp, lobsters, ghost shrimp, lugworms.

- Finfish (shoreline fishing areas, spawning areas for grunnion, salmon, bass, and other fish).

- Abalone.

- Sensitivity will depend on season, use, and susceptibility to oil impacts.

804 PROTECTION TECHNIQUES

Efforts to protect a shoreline from an oil spill should be initiated immediately upon the spill's detection. Rapid and effective response is necessary to limit the spread of oil and/or to reduce or eliminate damage to the environment. The protection procedures depend upon the location(s) and the circumstances of the spill, its potential movement, and the area(s) to be protected.

The protection techniques, their uses, and environmental effects are listed in Table 804-1. Procedures for each protection technique are discussed in this section and include information regarding how the technique is used, its limitations, logistical requirements, and a detailed description of the conditions affecting deployment. In addition, diagrams depicting typical boom deployment configurations and dam cross sections are also given. Although each technique is discussed separately, spill circumstances may require the simultaneous use of several techniques.

Table 804-1. PROTECTION TECHNIQUES

	Protection Technique	Primary Use of Protection Technique	Environmental Effect of Use
Booming	1. Exclusion Booming	Used across small bays, harbor entrances, inlets, river or creek mouths where currents are less than 1 knot and breaking waves are less than 25 cm in height.	Minor disturbance to substrate at shoreline anchor points
Booming	2. Diversion Booming	Used on inland streams where currents are greater than 1 knot; across small bays, harbor entrances, inlets, river or creek mouths where currents exceed 1 knot 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 causes heavy shoreline oil contamination on downstream end
Booming	3. Containment Booming	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 knot.	No effect on open water; minor disturbance to substrate on inland anchor point
Booming	4. Sorbent Booming	Used on quiet water with minor oil contamination.	Minor disturbance to shoreline at anchor points
Berms & Dams	5. Beach Berms	Used on sandy, low energy beaches to protect the upper intertidal area from oil contamination.	Disturbs upper 60 cm of mid-intertidal zone
Berms & Dams	6. Berms and Dams	Used on shallow streams or rivers where booms are not available or cannot be deployed, or where dams are part of the hydrological control system.	Disturbs stream or river bottom, adds suspended sediments to water
Animal Protection	7. Bird Warning System	Used in bird nesting areas, feeding areas, flyway stopovers.	Not applicable

Exclusion Booming

Use

Used across small bays, harbor entrances, inlets, and river or creek mouths where currents are less than 1 knot and breaking waves are less than 10 to 15 cm in height.

Description of Technique

Harbors and Inlets. Enclosure booming involves deploying the boom in a static mode, i.e., placing or anchoring the boom between two or more stationary points. This method is used primarily to prevent or exclude oil from entering harbors and marinas, breakwater entrances, lagoons, and inlets. Many of these entrances or channels have tidal currents exceeding 1 knot or surf breaking in the opening. Under these conditions, booms should be placed landward from the entrance in quiescent areas of the channel, harbor or inlet. Exclusion booms should also be deployed at an angle to a shoreline when possible (preferably in the direction of the wind) to guide oil to an area where vacuum trucks or skimming equipment can recover the oil. In many cases, the deployment of a secondary boom behind the primary boom is desirable to contain oil that may spill under the primary boom. Exclusion booming of harbors or inlets may require that a small work boat be stationed at the upstream end of the boom to open the boom for boat traffic entering or leaving the harbor. Figures 804-1 and 804-2 show typical exclusion booming deployments for harbors and inlets.

Estuaries. Exclusion booming of estuaries or rivers where sand bars are present can pose problems in boom placement. Because high currents can be expected in entrance channels, boom placement should be attempted on the landward side of the entrance where current velocities drop. This point is generally discernible by ripples and boils. Sand bars commonly form in this area and should be avoided in booming as is indicated in Figure 804-3. Note the secondary boom and positioning to direct oil toward recovery areas.

Stream Deltas. Many streams which empty into bays, harbors, or rivers are characterized by a delta at the stream mouth, which can provide spawning grounds for some fish. These deltas at certain times of the year may require protection, particularly if they are exposed by tidal fluctuations. If water currents across a delta are less than 1 knot, an exclusion boom should be deployed. Because the stream deltas normally extend beyond the mainland at low tide, boom deployed around the perimeter of the delta will have to be anchored at several locations in the water, as well as on the shoreline. A typical exclusion boom deployment to protect a delta is shown in Figure 804-4. If possible, the boom should be placed seaward from the low tide line so that it will float throughout the full tide cycle. If the area requiring protection is too large, the boom should be deployed so that the delta above the midtide line is protected.

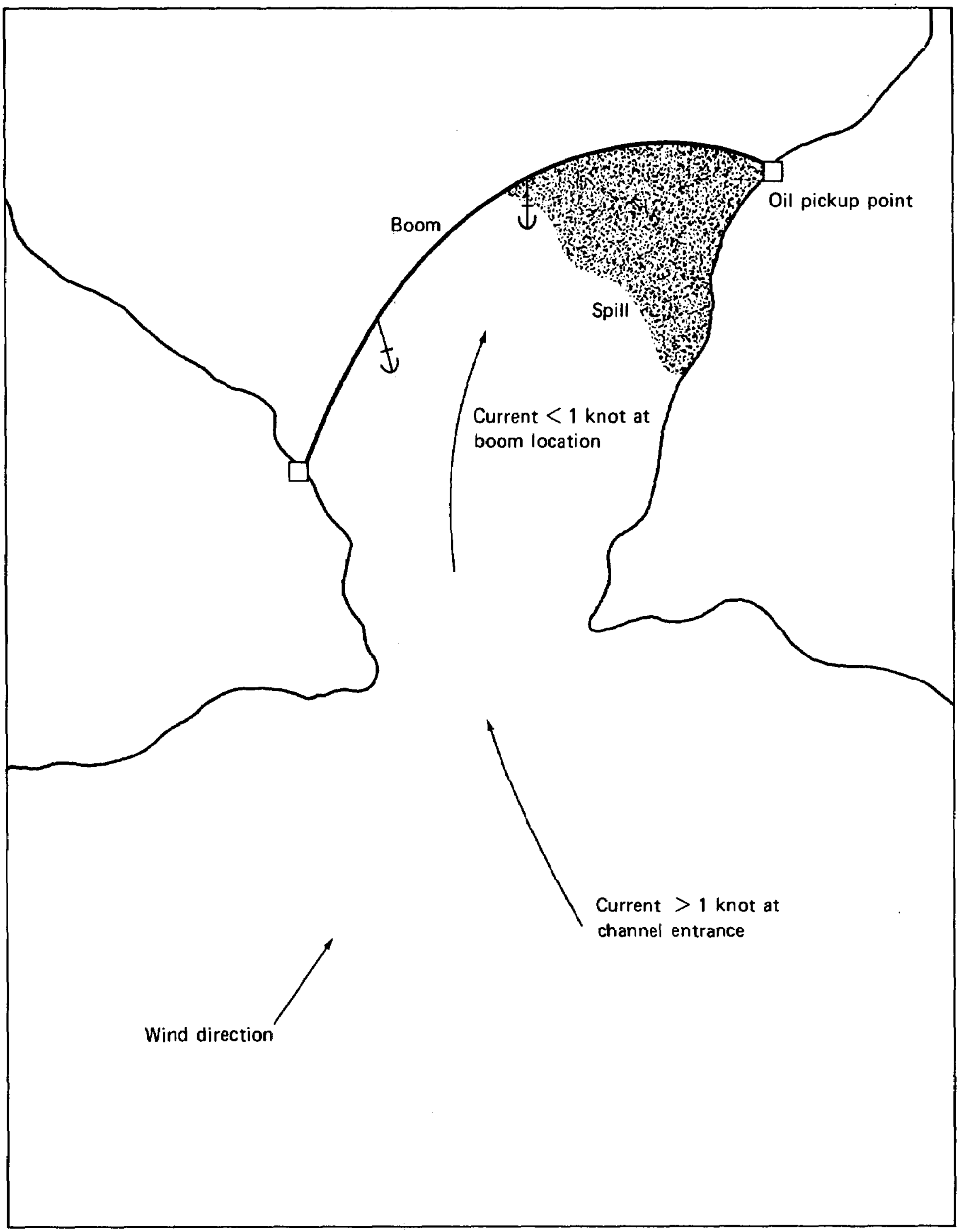

Figure 804-1. Enclosure booming at inlet with high channel currents.

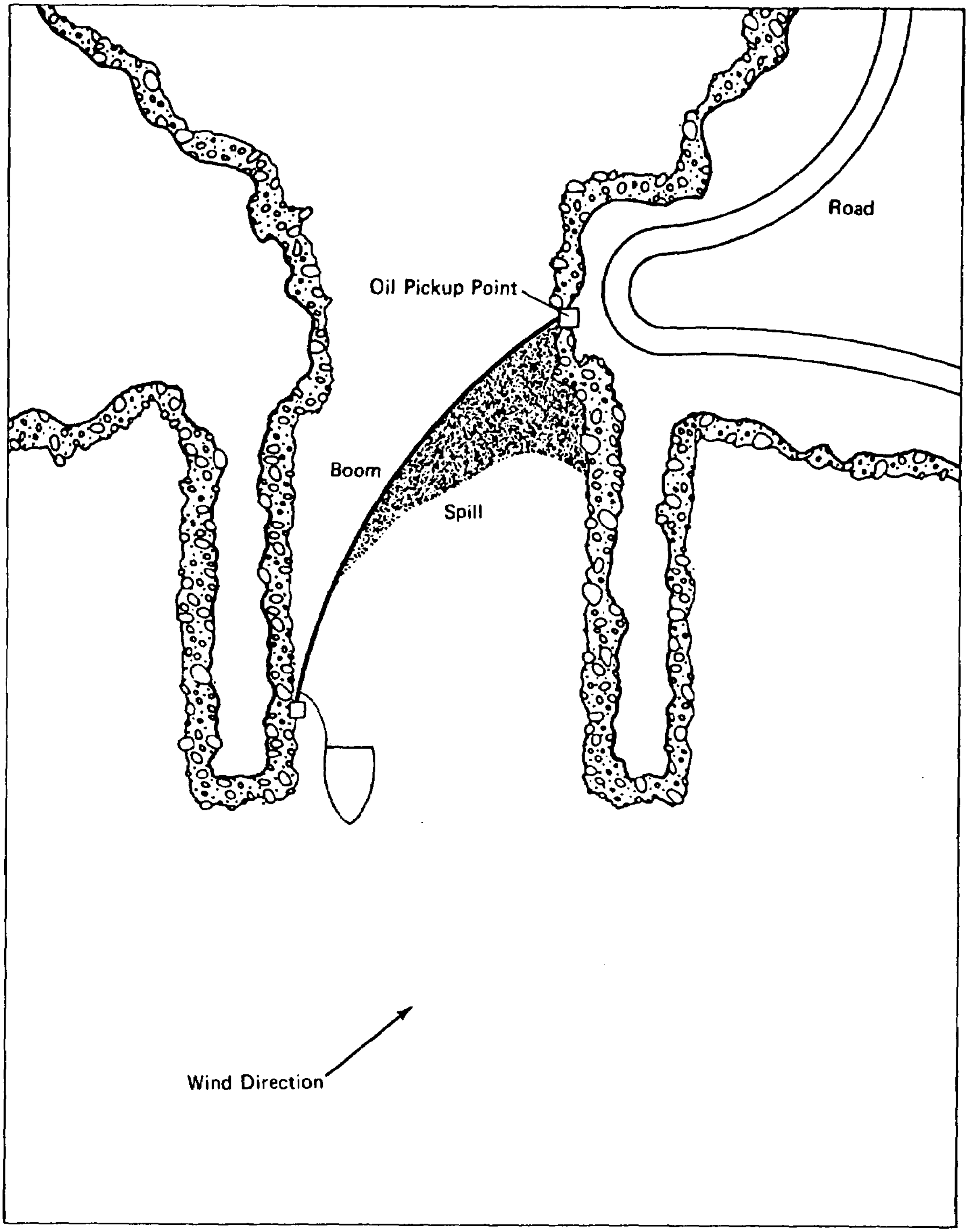

Figure 804-2. Boom at harbor entrance.

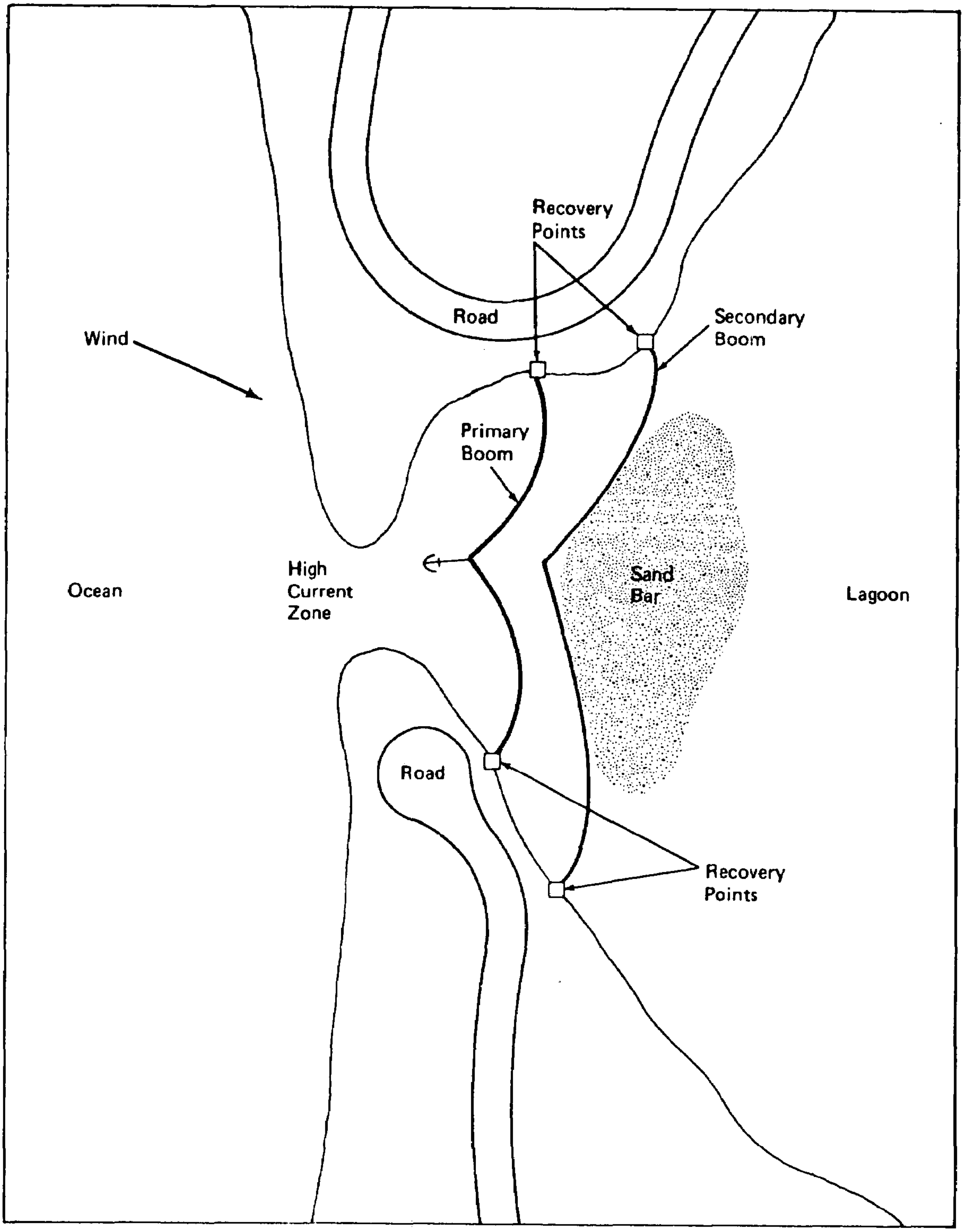

Figure 804-3. Hypothetical estuary entrance booming.

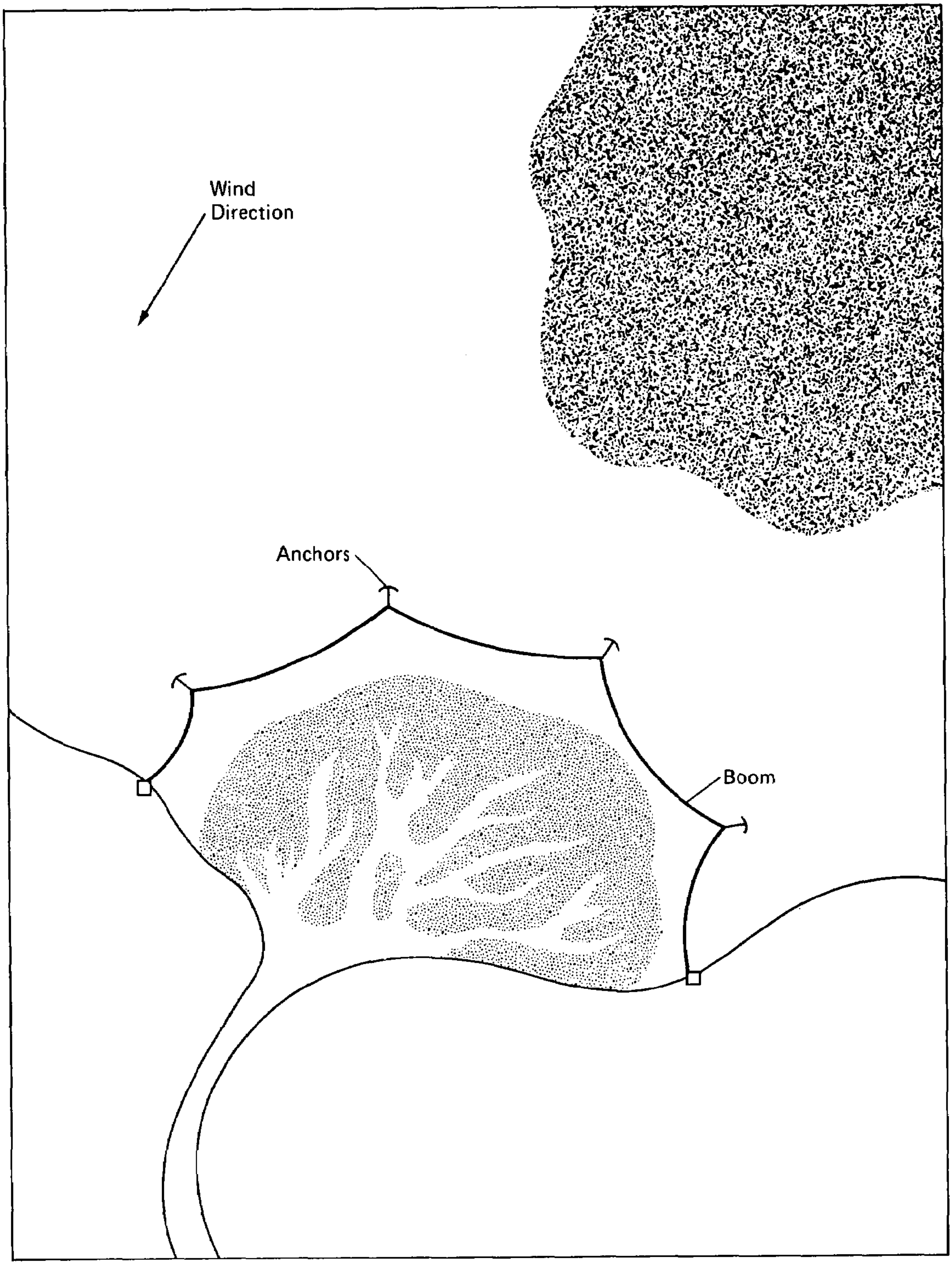

Figure 804-4. Exclusion booming of a stream delta.

Logistics

Specific manpower and equipment requirements will depend on the length and type of boom used and the nature of the area in which it is deployed. Deploying heavy duty large booms will require more personnel and larger boats than deploying small, lightweight booms. Table 804-2 gives a range of logistical requirements for exclusion booming.

TABLE 804-2. LOGISTICAL REQUIREMENTS PER 305 METERS (1000 FT) OF BOOM

	Calm Weather or Light Boom	Rough Weather or Heavy Boom
Personnel	3	5
Support	1 workboat - 6 to 9 m (20 to 30 ft) plus crew	1 workboat - 12 to 15 m (40 to 50 ft) plus crew
Material	6 anchors plus anchor line and buoys	12 anchors plus anchor line and buoys

Limitations on Use

Exclusion booming can be effective if the water currents are less than 1 knot, breaking waves are less than 25 cm, and water depth is at least twice the boom depth in other than intertidal areas. Exclusion booming in most areas will require two booms to be deployed across an intertidal zone to an attachment above the high-tide mark; therefore a flexible curtain-type boom should be used. This type of boom will react more favorably to tidal level fluctuation than a rigid fence-type boom.

Diversion Booming

Use

Diversion booming should be used where the water current in an area is greater than 1 knot or if the area to be protected is so large that the available boom would not be sufficient to contain oil or protect the shoreline. In addition, diversion booming is useful for diverting oil from sensitive areas to other shoreline locations that are less sensitive and/or more easily cleaned up.

Description of Technique

Diversion booms should be deployed at an angle from the shoreline closest to the leading edge of the approaching oil slick to deflect oil toward shore, where pickup of pooled oil is more effective.

When the boom is at right angles to the current, surface flow of water and oil is stopped. At current speeds greater than about 1 knot, vortexes (whirlpools) and entrainment (oil droplets shearing off from the underside of the oil layer) will drag the oil down beneath the skirt, rendering the boom ineffective. If the boom is placed at an angle to the current, surface flow is reduced and diverted permitting the oil and water to move downstream along the boom into the collection area and/or against the shore. The reduction in current speed perpendicular to the boom is related to the decrease in the angle of the boom relative to the direction of current flow.

The first of two possible methods of diversion booming involves two or more lengths of boom ranging from 30 m (100 ft) to 152 m (500 ft) placed in a cascading formation in the water. The lead boom intercepts the oncoming oil slick and diverts it toward the shore. Subsequent booms placed downstream of the lead boom continue the diversion process until the slick is directed to the recovery area.

The following list summarizes the deployment procedure used for this technique:

1. The lead boom is placed in the water and towed by a small work boat to a predetermined position to completely intercept the slick. The up-current end is anchored in place.

2. The deployment vessel is maneuvered to the down-current end where the boom is pulled toward the shoreline until the optimum angle is achieved and then anchored in place.

3. The first two steps are repeated with each successive boom until the end of the last boom reaches the recovery area. The leading end of each boom is positioned approximately 7.5 to 9 m (25 to 30 ft) behind the trailing end of the previous boom in a slightly overlapping configuration. Figure 804-5 shows the placement configuration of three lengths of boom.

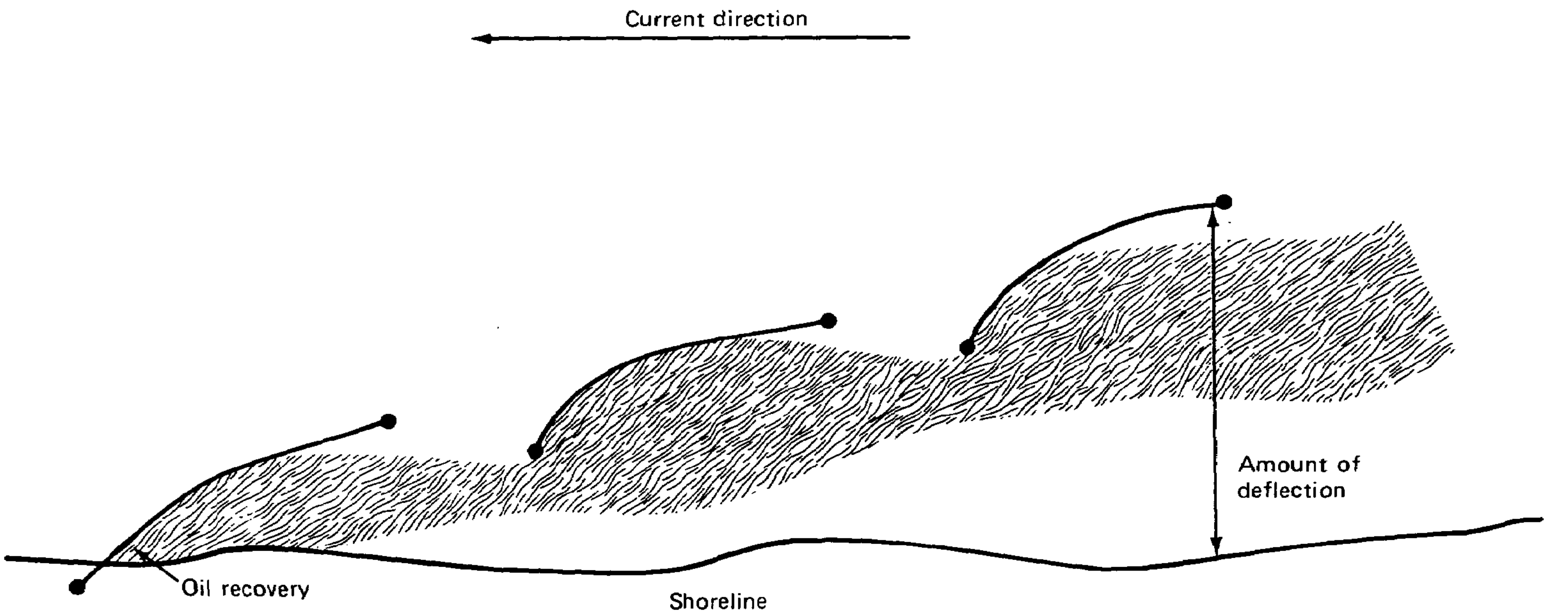

Figure 804-5. Placement configuration of 3 lengths of boom
(cascading deflection booms).

4. The booms are fixed in place by dropping overboard an anchor that is attached to a buoy float by a line equal in length to water depth plus 1.5 m (5 ft). The buoy is then fastened to the boom end with a short length of line. Because the current will naturally cause the booms to bow slightly, additional anchors may be required along the length of the boom to minimize this effect.

The second method of diversion booming is similar to the first except that only the diverting boom is used to direct the oil onto the shoreline. One end of the diverting boom is anchored to the shoreline and the free end is angled by the vessel as shown on Figure 804-6. The advantage of this method is that it can be set up in less time and with less equipment than the cascading booms method. Both are most effective on shorelines with limited wave activity. The primary disadvantage is that the shoreline around the recovery area must be cleaned.

The optimum angle of boom deployment is dependent on the current speed and the length and type of boom used. To avoid boom failure in strong currents the angle must be smaller than in weak currents. The same relation is true with regard to boom length. The optimum deployment angle decreases as boom length increases.

The various types of booms available have varying degrees of stability under increasing current conditions. The more stable the boom, the larger the optimum deployment angle for a given current speed. In general, booms with a high ratio of buoyancy to weight, with tension members located at the top and bottom edges and booms with horizontally oriented floatation collars resist pivoting and have good stability under most conditions. Figure 804-7 shows cross sections of the three most stable types of booms and their optimum deployment angles under different current speeds.*

Since diversion booms cause a significant reduction in surface current, successive booms can be deployed at increasingly larger angles as the current decreases.

Logistics

The specific manpower and equipment requirements will depend primarily on the width of the approaching slick and the current speed. The type of boom and angle to which it is deployed also affect the requirements. Deploying large, heavy duty booms will require more personnel and larger boats than deploying small, lightweight booms (see exclusion booming). Booms deployed at small angles in high current areas require greater boom lengths to cover the same width as those deployed at greater angles. Table 804-3 gives the logistical requirements for diversion booming.

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*Results of tests performed by Canadian Environmental Protection Service on the St. Clair-Detroit river system.

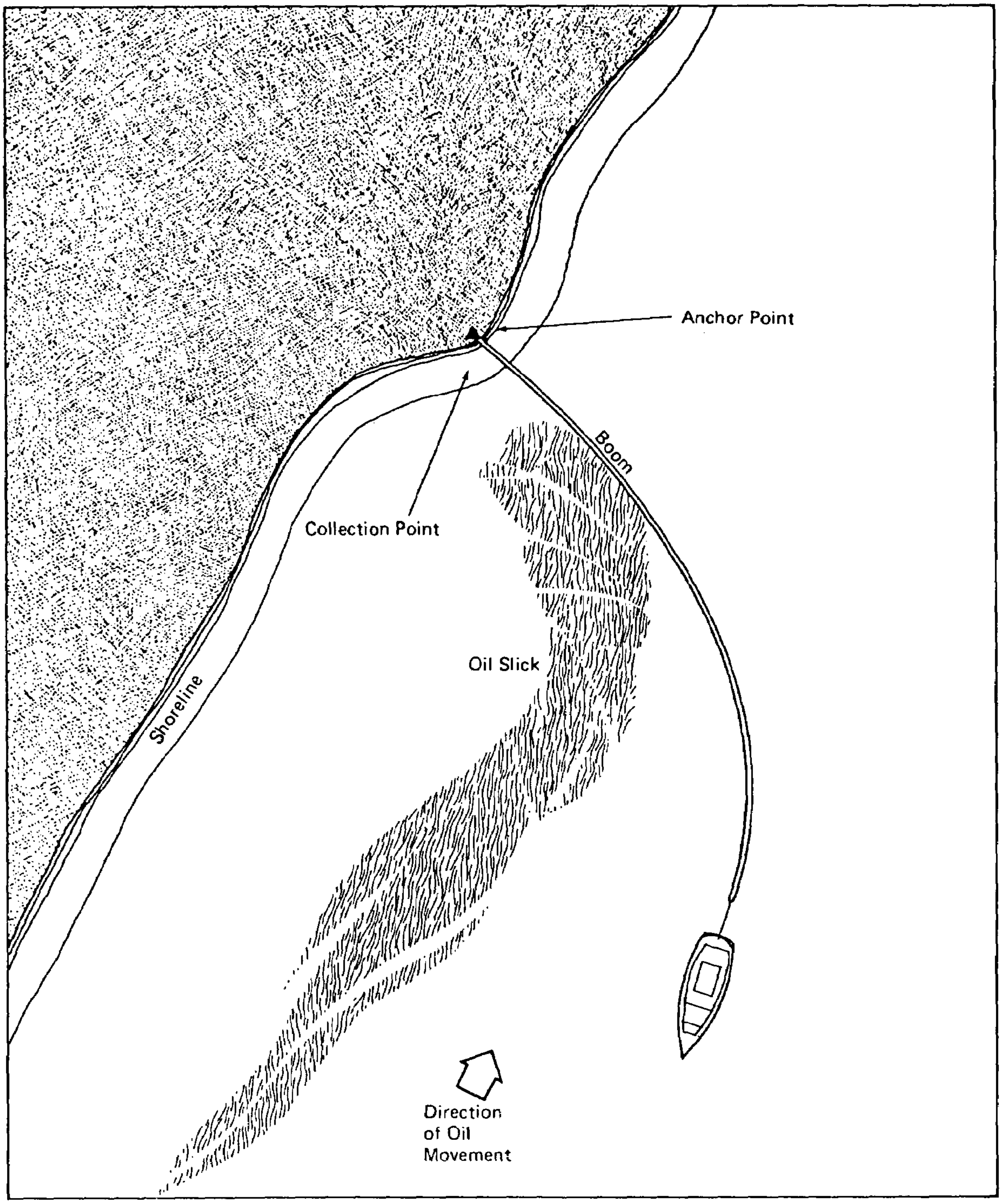


Figure 804-6. Diversion booming along shoreline.

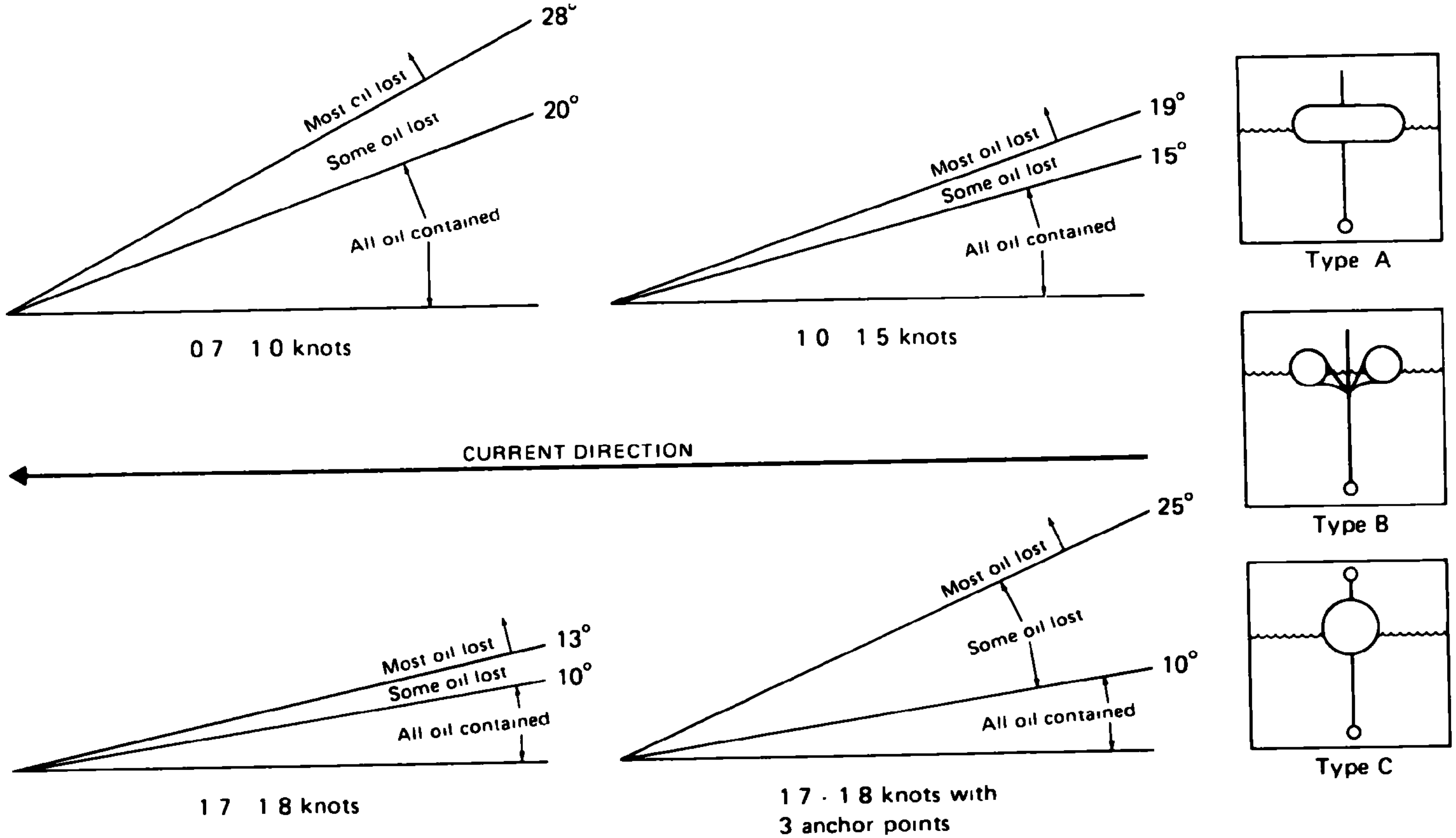


Figure 804-7 Cross sections of 3 high-stability boom types and optimum deployment angles under various currents using 61 m/200 m long booms

TABLE 804-3. LOGISTICAL REQUIREMENTS FOR DIVERSION BOOMING FOR DEFLECTION[a] IN A 1.5-KNOT CURRENT

Item	Single Boom 15 m (50 ft) Deflection	Cascading Booms 45 m (150 ft) Deflection
<u>Equipment</u>		
• Total boom length	61 m (200 ft)	183 m (600 ft)
• Anchors	1	6-9
<u>Personnel</u>	3-4	4-6
<u>Support</u>		
• Workboat (6 to 9 m)	1	1
• Recovery units	1	1-2

[a]Deflection is the lateral displacement across a current between the upstream and downstream ends of a boom or series of booms.

Containment Booming

Use

Used on open water to surround an approaching oil slick as a means of protecting shoreline areas where surf is present and the oil slick does not cover a large area. Also used on inland waters where currents are less than 1 knot.

Description of Technique

Oil on water forms a slick and spreads into shapes dictated by surface currents, winds, and physical boundaries. In the absence of physical boundaries, a circular, elliptical, or triangular slick will be formed. A circular slick is formed when there are no significant surface currents or winds. An elliptical shape is formed by moderate surface currents and winds. High winds and strong currents will create a more triangular-shaped slick. The triangle will widen (spread) as the slick moves away from its source. Wave action, generally caused by wind, will rapidly distort these shapes, eventually forming streamers or windrows of oil. Therefore it is important to try to contain an oil spill before it becomes too wide for effective containment and it breaks into streamers.

The direction of wind and current must be considered in deploying boom Boom should be deployed downwind or in the direction of the surface current, around the leading edge of the floating slick, and then back into the wind or current, as shown in Figure 804-8. This technique will minimize the amount of time the boom is pulled perpendicular to winds or currents. The boom will drift into a U shape.

A spill that is fully contained by booms is best cleaned by a skimmer (preferably self-propelled) placed inside the boomed area. The oil will tend to concentrate against the boom in the direction of the wind and current. and current. The skimmer should move to this area and continually position itself to skim the thickest area, as shown in Figure 804-9. When skimming becomes inefficient - after most of the spill has been removed or for small spills (less than 1 barrel) - sorbent pads or sorbent rolls may be used. Loose sorbent materials, however, should be avoided where possible. Sorbents should be used only with contained spills.

Logistics

The equipment and manpower requirements depend primarily on the size of the slick to be contained. Heavy duty or exceptionally long booms may require additional personnel for handling but would usually be limited to one or two workers. Table 804-4 gives the logistical requirements for containment booming of a 150-m and 250-m diameter spill.

Limitations

Boom required for containment was based on a catenary rather than a complete encircling of a spill. Since the area of the catenary will change

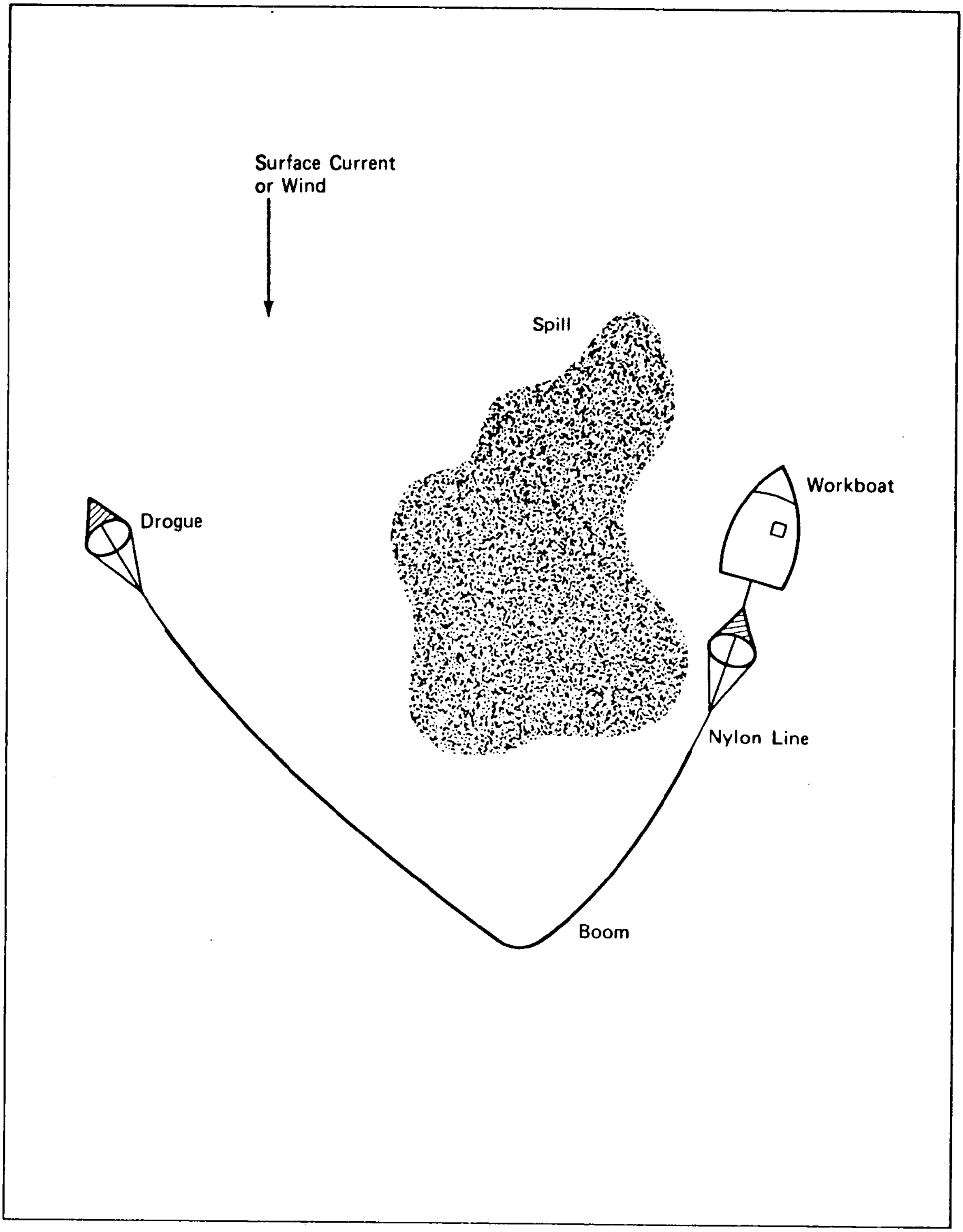


Figure 804-8. Boom deployment method.

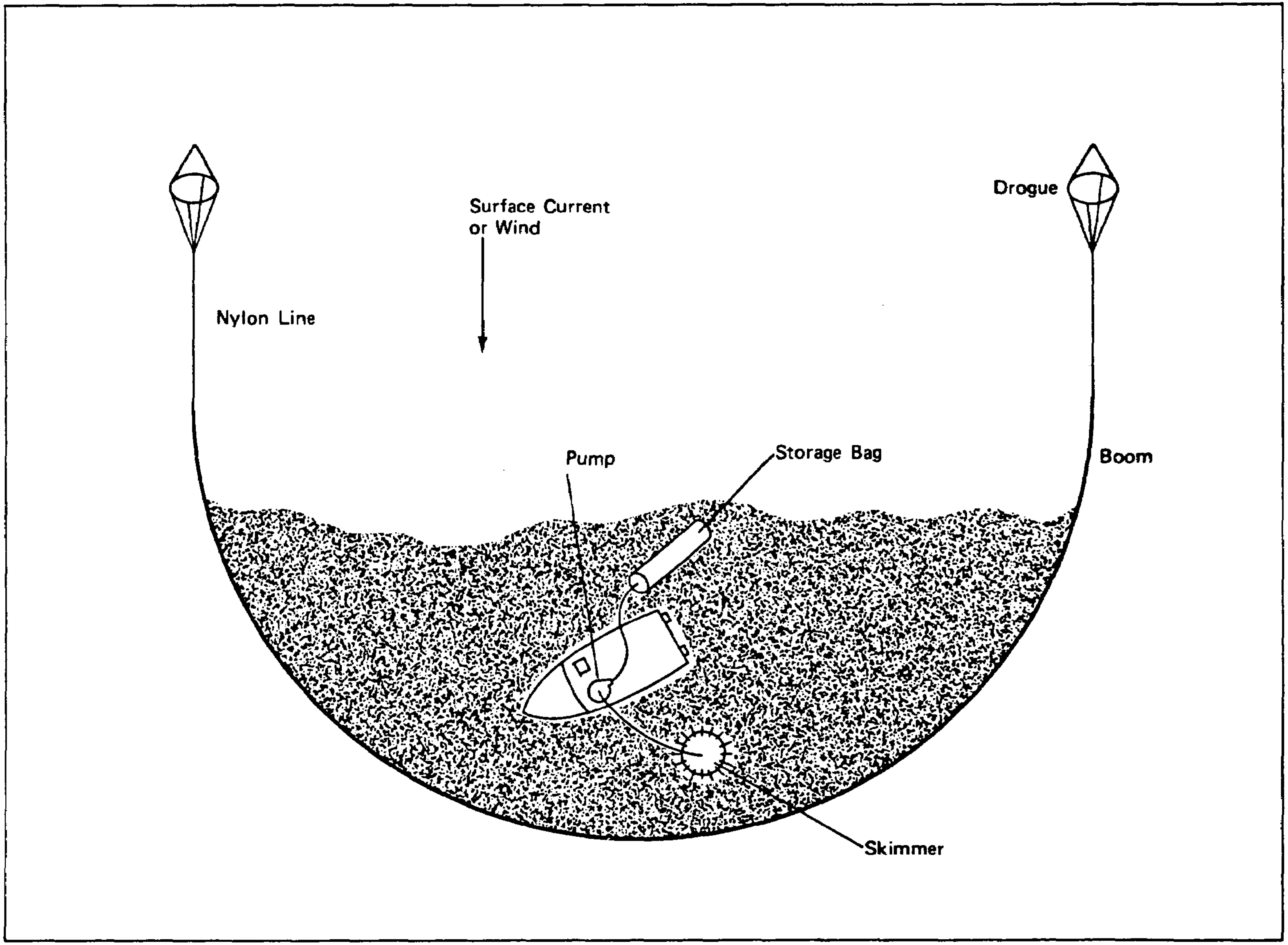


Figure 804-9. Containment: open water.

with a number of variables (i.e., towing speed, wind, current, skirt depth, etc.) it was assumed that maximum area would be realized, which is in the form of a semi-circle. Furthermore, it was assumed that a boom lead of 10 percent is required on either end for towing, anchoring, or drogue deployment. Actual minimum boom requirements in real situations may exceed those given in Table 804-4.

TABLE 804-4. LOGISTICAL REQUIREMENTS FOR CONTAINMENT BOOMING

	For a 150 m (656 ft) Diameter Slick	For a 250 m (820 ft) Diameter Slick
<u>Equipment</u>		
• Boom[a]	282 m (927 ft)	471 m (1545 ft)
• Drogues	2	2
• Work boat	1	1-2
<u>Personnel</u>	Boat crew and 2 boom layers	Boat crew(s) and 2-4 boom layers/boat
<u>Support</u>		
• Skimmer	1	1
• Storage tank	1	1
• Pump	1	1

[a]Minimum amount of boom required for 100 percent containment assuming it is independent of slick thickness.

Sorbent Booming

Use

Used primarily on quiet waters with minor oil contamination. It can also be used as a backup for standard booming operations.

Description of Technique

Sorbent booms are deployed in the same manner as those booms described under exclusion booming except on a much smaller scale. They can also be laid along the shoreline to catch the oil as the tide rises. It is usually best to drive the oil into the booms with low-pressure water sprays. Once the booms are set up they must be rotated frequently to be effective.

If used as a backup for standard booming operations, the sorbent booms are deployed several feet behind (downstream of) the primary booms to trap any oil splashing over or escaping under the containment boom. They can also be deployed behind skimmers to catch any oil that evades the skimmer. Sorbent sweeps tied together often are more effective than the sorbent booms for absorbing oil when deployed in those manners mentioned above.

Permeable barriers constructed onsite and made of wire screen or mesh and sorbents can be used to contain or exclude oil from interior areas. Permeable barriers offer the advantages of non-interference with flow, conformance with bottom configuration, and response to tidal variation. Because of flow reverses in tidal areas, double barriers are required. A diagram of a typical permeable barrier is shown in Figure 804-10. While a variety of screen and mesh fencing is available, heavier materials are recommended. When subjected to high currents and debris, lighter material such as chicken wire will probably fail.

Single-sided permeable barriers may be constructed in small streams or channels having continual water flow in one direction. In this case a single line of posts are driven into the stream bottom with the screen fastened to the upstream side. Sorbent is also placed on the upstream side of the barrier only, relying on the current to hold it in place.

The screen height in both cases must be sufficient to prevent sorbent from going over the top at high tide and under the bottom at low tide. The screen mesh size must be compatible with the type and size of the sorbent used.

Logistics

The logistical requirements for sorbent booming are heavily dependent on numerous variables and cannot easily be quantified within the scope of this manual. The amount required depends on the type and quantity of oil, how the sorbent is used, where it is used, and so on.

The requirements of the permeable sorbent barrier is also dependent on many variables and again is not easily quantifiable. The variables include

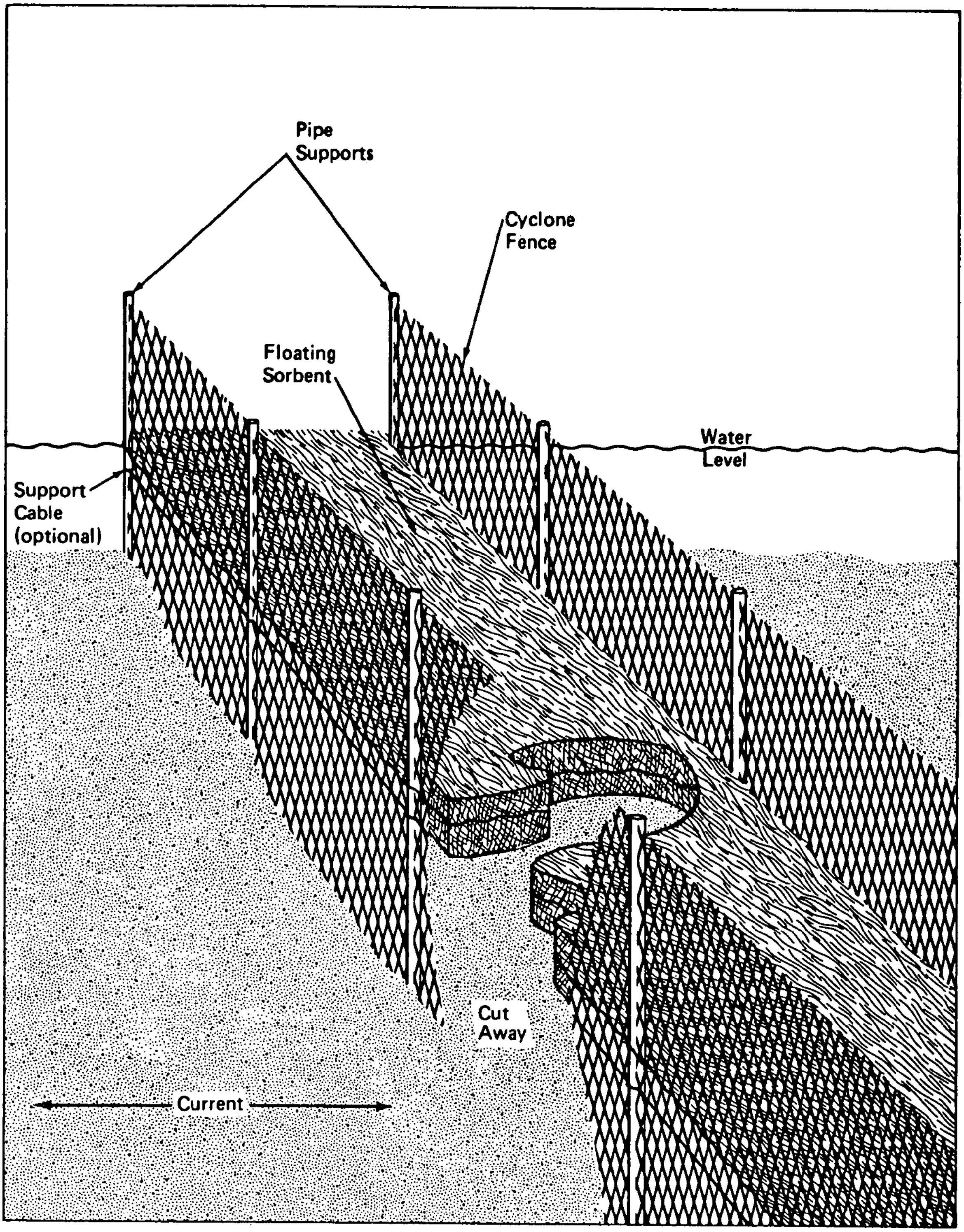


Figure 804-10. Typical permeable barrier.

stream or channel width and depth, tidal variation, current, type of screen and sorbent used, type and quantity of oil, and amount of debris in waterway.

Therefore, due to the number of variables involved, initial applications must be used as guidelines for the logistical requirements of subsequent applications.

Beach Berms

Use

Used on sandy, low energy beaches to protect the upper intertidal and backshore areas from oil contamination. Especially useful during spring tides when the high water level extends above the normal reaches for a short period of time. Oil deposited during this time usually persists until the next tide of equal magnitude.

Description of Technique

Procedures for minimizing the oil contamination of backshore areas should be instituted at the first indication of a possible shoreline pollution event. The construction of a dike or berm along the upper intertidal zone could assist in preventing incoming tides from depositing oil onto backshore areas. Berms should be approximately 2 m wide and 0.75 to 1.0 m high but are dependent on the maximum height of the incoming tide. Figure 804-11 depicts a typical beach berm.

Construction of the berms is achieved by operating a motor grader parallel to the surf line along the upper intertidal area. The blade is set at an angle to cast a windrow to one side as the motor grader moves down the beach. Several passes are usually required to attain the optimum berm height. Bulldozers fitted with angled blades can be operated in the same manner; if fitted with a straight blade, they can be used to push material up the beach into a pile forming a berm with successive, adjacent piles. A trench on the seaward side of the berm would also assist in trapping oil that comes ashore on each wave for subsequent removal.

Observations of tidal action on constructed berms indicate that the berms could successfully protect backshore areas for at least one tidal cycle, and possibly two, assuming no large storm waves or winds occur.

Logistics

Specific manpower and equipment requirements will depend on the length and height of the berm to be constructed. A bulldozer can build a berm 2 m wide by 1 m high at a rate of 300 linear meters per hour, with a motor grader being considerably faster. Under most circumstances only one motor grader or bulldozer with one operator is required unless the length of area to be protected is excessive or the berm must be constructed quickly.

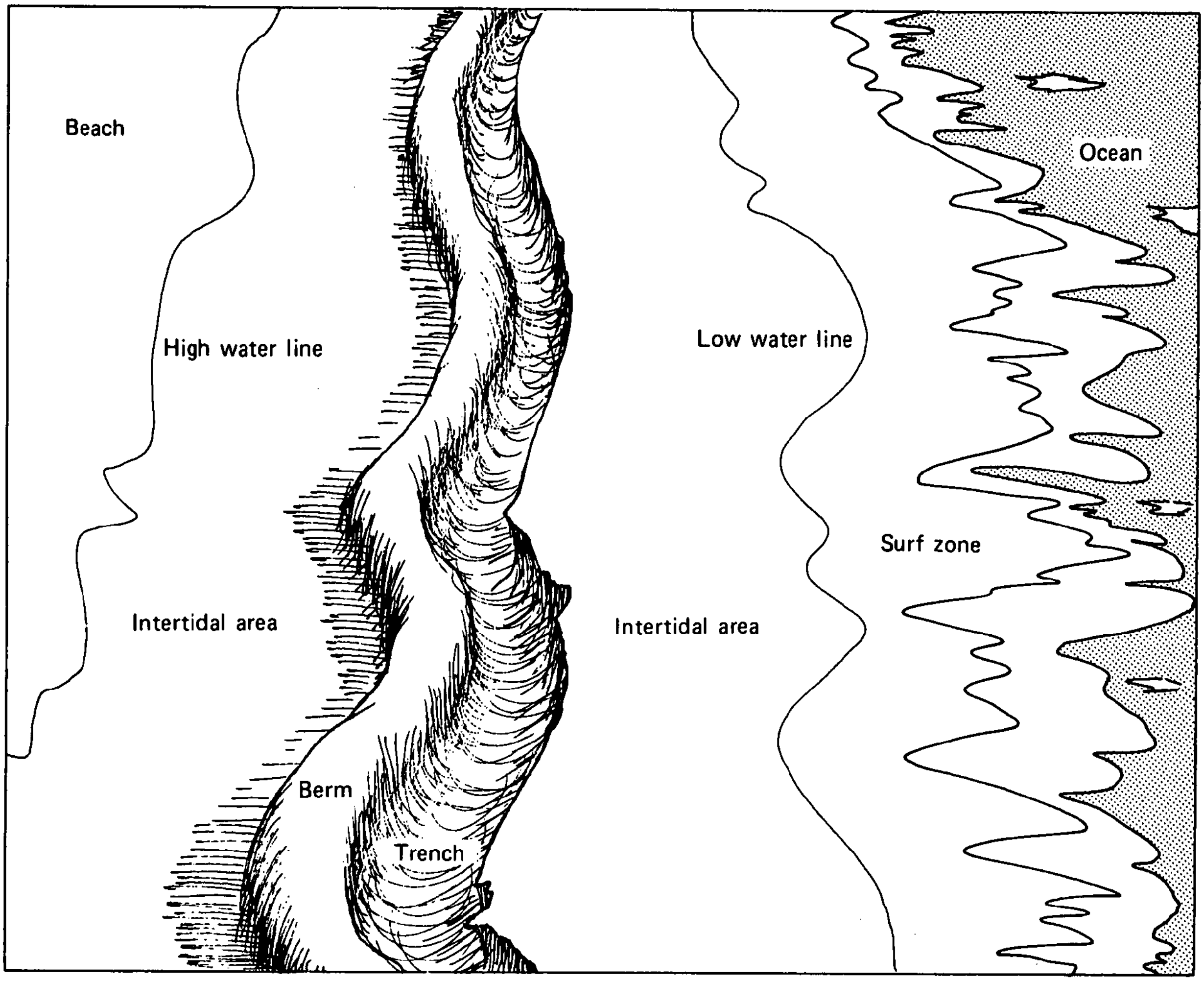


Figure 804-11. Beach berm.

Berms and Dams

Use

Primarily used on shallow streams or rivers where booms are not available or cannot be deployed, or where dams are part of the hydrological control system.

Description of Technique

Dams. There are two types of dam construction appropriate for oil spill containment: 1) the complete blocking of an actual or potential drainage course (a blocking dam), and 2) the blocking of oil flow while letting water continue downslope (an underflow dam).

Blocking Dams. Blocking dams should be constructed only across drainage courses which have little or no water flow. The dam should be situated at an accessible point where there are high banks on the upstream side. It must be well keyed into the banks and buttressed to support the oil and water pressure. It can be constructed from several types of materials including earth, snow, sandbags, and sheets of metal or wood, or from any material that blocks flow.

The dam can be built across the drainage course to form a holding pond or reservoir to contain the oil and water. Water trapped behind the dam can be pumped out by placing the suction (intake) hose at the base of the dam on the upstream side, leaving oil trapped behind the dam for subsequent removal. The discharge (outlet) hose should be placed on the downstream side. Trapped water can also be moved across the dam with one or more siphons.

Underflow Dams. For waterways with higher stream flow rates, an underflow dam can be used (Figures 804-12 and 804-13). If the dam is to be effective, the surface of the oil must always be below the lip of the dam, and the oil/water interface must be above the top of the underflow opening. To maintain the proper level, it is necessary to remove some of the water, usually through horizontal valved or inclined pipes as illustrated.

The underflow dam can be constructed by placing pipes of appropriate size on the stream bed and building an earthen or sandbag dam over the pipe across the waterway. The diameter of the pipe will depend on the flow rate of the stream and the depth of the water behind the dam. For example, a 60- to 76-cm (24- to 30-in.) diameter pipe will have sufficient capacity for a flow rate of up to 850 liters (30 cu ft) per second. If time does not allow for pipe diameter calculations, a diameter larger than that required will control flow if it is inclined at the proper angle or if a valve is used. A pair or series of dams may be required downstream if sufficient underflow cannot be maintained.

Berms. Unlike dams, which are designed either to block flow completely or to block flow with a provision for underflow, berms are constructed to control flow by diversion or overflow. For creeks and rivers, overflow berms

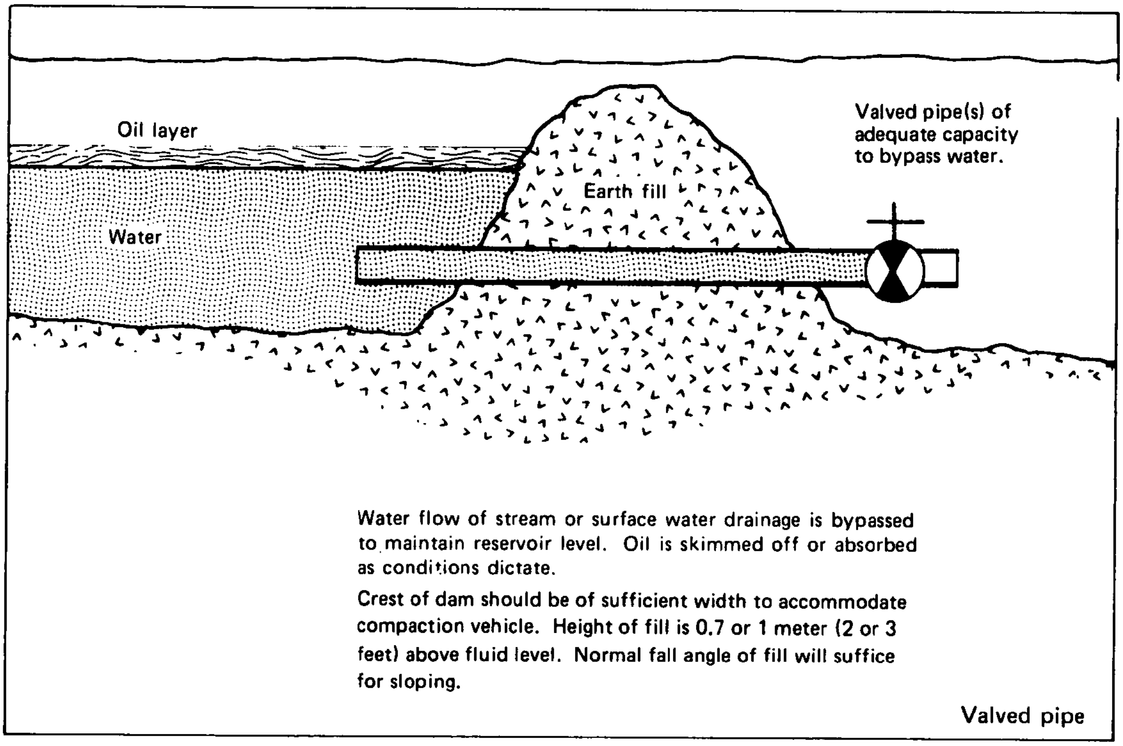


Figure 804-12. Water bypass dam (valved pipe).

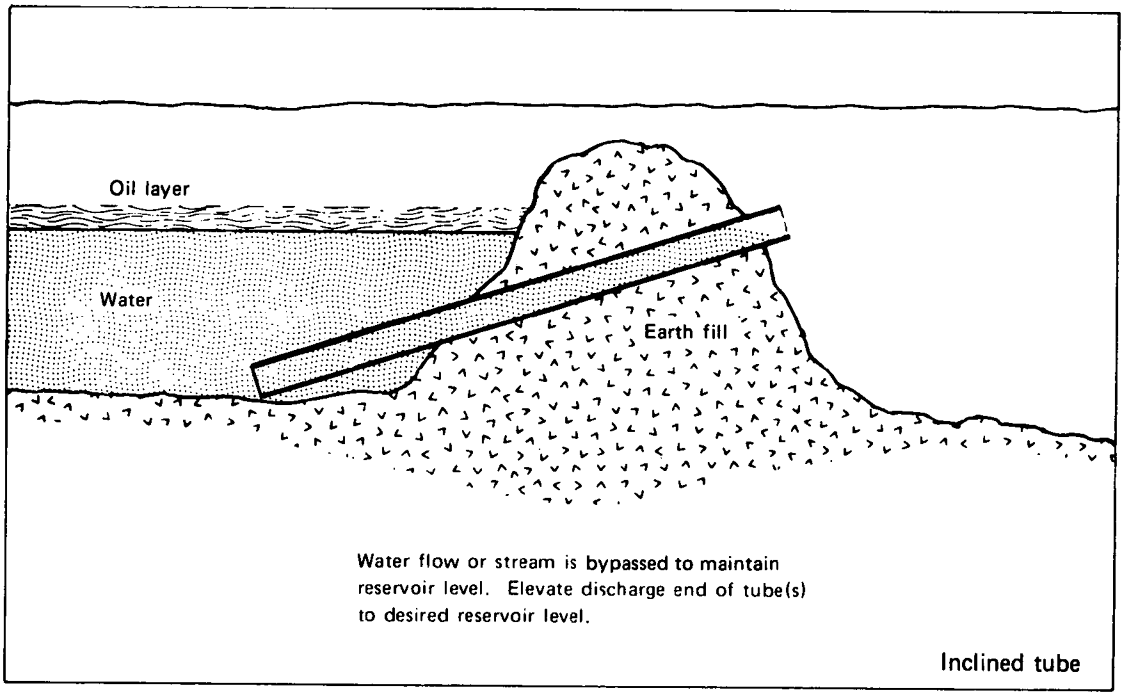


Figure 804-13. Water bypass dam (inclined tube).

(weirs) or diversion berms can be constructed from materials in the floodplains; for terrestrial spills, earth berms can be built to divert or impede flow. In fast-moving streams, berms may have to be continually maintained.

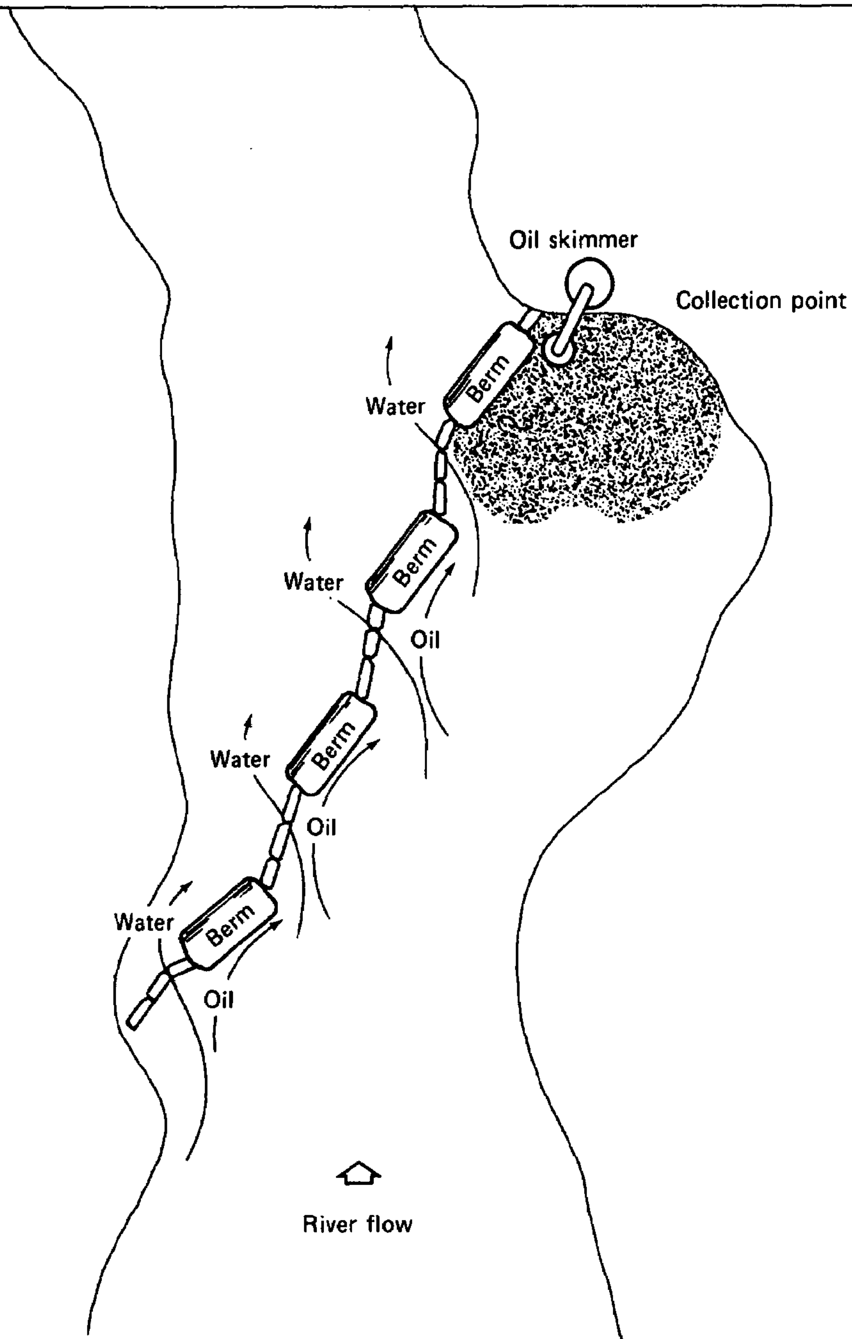
Diversion Berms. Diversion berms can be constructed from floodplain materials on large rivers (Figure 804-14). In most situations, they should be constructed in a series, connected with short pieces of boom in a pattern that forces oil to flow into a containment pit, side channel, or similar feature for temporary storage. The spacing between each berm should allow water to flow under the connecting booms while forcing oil to the side. The size and angle of the berms will be dictated by stream velocity, channel size, and oil spill volume. As these factors increase, the required size of the berms will increase, and the angle between the upstream side of the berms and the stream bank will decrease.

Overflow Berms (weirs). The purpose of overflow berms or weirs is to reduce water velocity by widening and deepening the stream. They can be constructed in smaller streams or in the side channels of larger rivers (Figure 804-15).

Overflow berms must be constructed across the entire channel. Materials should be excavated from the upstream side of the berm, creating a pool where streamflow will be retarded, permitting boom deployment and oil removal upstream from the berm. The required height and width of the berm will increase with stream depth and water velocity.

Logistics

The equipment and manpower requirements from dam or berm construction will vary with the size and type being built. Generally, a front-end loader or bulldozer is the only equipment needed for construction, with the loader being preferred. The time required for construction of a dam or berm measuring 2 m high x 4 m wide x 10 m long is approximately 1 hr for both the front-end loader and bulldozer. This assumes, however, that substrate material for for building the dam is adjacent to the site, no material is lost during construction, and access and trafficability are adequate. Table 804-5 gives the logistical requirements for berms and dams.



This represents a series of diversion berms joined by booms. They are positioned so that a spill can be diverted to a location with adequate storage and accessibility to removal equipment. If stream and spill conditions permit, one berm may be all that is required.

Figure 804-14. Diversion berms.

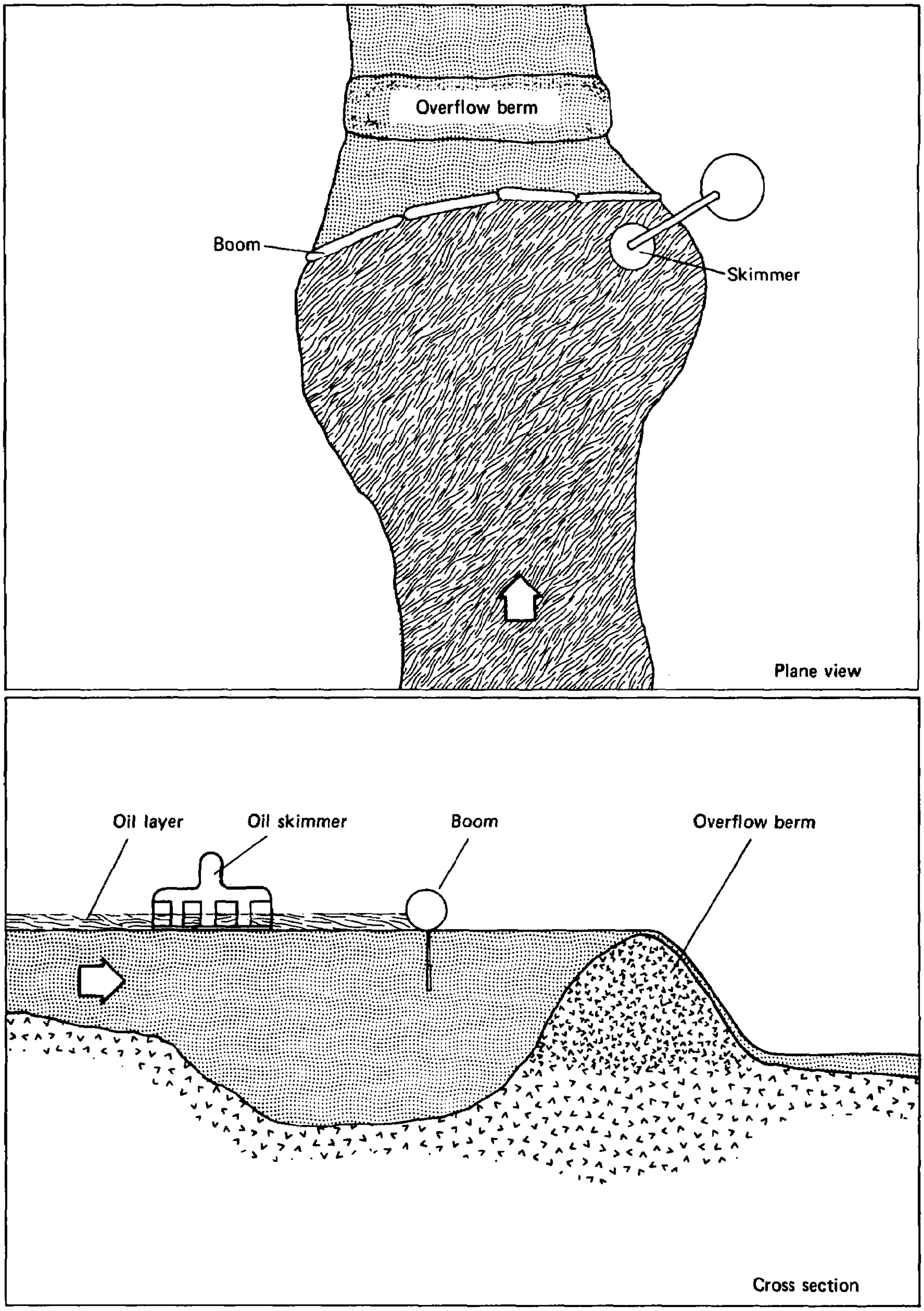


Figure 804-15. Overflow berm.

TABLE 804-5. LOGISTICAL REQUIREMENTS FOR BERMS AND DAMS

	Number Required		
	Diversion Berm	Overflow Berm	Bypass Dam
Equipment			
• Front-end loader or bulldozer	1	1	1
• Boom	3-6 short pieces	1 long piece	0
• Discharge tube (with or without valve)	0	0	1 or 2
Personnel - 1 heavy equipment operator, 1-2 workers, and 1 supervisor			
Support Equipment			
• Skimmer, pump, and storage tank	1	1	1

Bird Warning System

Use

Used in oil spill situations as a means of deterring birds from entering a contaminated area and becoming oiled. Unfortunately, most systems currently available have limited effectiveness but should, nevertheless, be implemented. It is far better to keep birds out of a spill area than to try to rehabilitate them once they have become oiled.

Description of Technique

Numerous bird warning systems have been used with varying degrees of success, including electronic sound devices that produce bird distress calls and communication jamming frequencies, pyrotechnics, gas exploders, and aircraft. Many are species specific and should not be used when a variety of birds are present. Perhaps the most consistently successful method is strategically placed human activity.

In the event of a spill situation, several units should be moved quickly to shore positions or to boats in order to cover the contaminated areas that birds are most likely to visit. It may be effective to place the warning device on a small raft in the larger oil slicks and allow the raft to drift with the oil slick. The positions of stationary units should be changed as the oil spill moves. Workers in the area must wear ear-protective devices, since noise level of some of the units is high enough to be uncomfortable or hazardous.

Propane cannons combined with shotguns using blank shells and/or crackers and abstract sound systems have been found effective in shoreline locations. Habituation does occur with most systems, therefore site rotation is advised. In the deployment of propane cannons, care must be taken not to aim the muzzle into the wind; this will cause an excess of air to mix with the propane and prevent explosive ignition of the cannon.

During the spring, beaches and nearshore areas are likely to need the the most protection since the largest bird populations consist of shorebirds and waterfowl.

During a critical situation, the first efforts to repel birds will reveal which procedures are most useful and which are inefficient or poorly designed. Subsequent efforts can be reorganized on the basis of these results.

The activities of people, boats, and machinery will usually cause the greatest disturbance to waterfowl where oil concentrations are greatest and will repel significant numbers of waterfowl from that immediate area.

Logistics

Specific requirements for manpower and equipment depend primarily on the length of shoreline and/or the size of the contaminated area. In addition to the warning systems, spills offshore require boats or rafts on which to mount the devices. Table 804-6 gives a range of logistical requirements for bird warning systems.

TABLE 804-6. BIRD WARNING SYSTEMS

Item	Number/20 Hectares of Contaminated Area	Number/Kilometer of Shoreline
System		
People	50-75[a]	25-50[a]
Sound devices	1-2	3-4
Pyrotechnics	1	2-3
Gas exploders	1-2	3-4
Aircraft	1	1
Support		
Small boats or rafts - 1 per warning device		

[a]Includes cleanup crew.

805 CLEANUP TECHNIQUES

Detailed procedures for 23 cleanup techniques are discussed in this section and inlcude formation concerning how and where each is used, their approximate cleaning rates, and the logistical requirements. In addition, illustrations are given showing how each technique is used.

To facilitate easy referencing, an index listing of the techniques and their corresponding page numbers is shown in Table 805-1.

TABLE 805-1. INDEX OF CLEANUP TECHNIQUES

Motor Grader and Elevator Scraper

Use

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 if trafficability permits.

Description of Technique

The most effective method of cleaning sandy beaches contaminated with oil is with motor graders and elevating scrapers working together. Motorized graders cut and remove the surface layer of beach material and form large windrows, which motorized scrapers pick up and haul to a disposal area. Specifically, the sequence of operational procedures for a motorized grader is:

1. Moldboard (blade) is set at 50° angle from the perpendicular to the direction of travel.

2. Grader is operated in second gear at 5 or 6.5 km/hr.

3. Grading of first pass is begun on oil-contaminated material farthest inshore, casting windrow parallel to surf line. Grading is continued to end of contaminated area or approximately 200 to 300 m in distance.

4. Grader is returned to starting point by backtracking on cleaned area.

5. Grader is repositioned for second pass so as to pick up first-pass windrow and cast second-pass windrow parallel to surf line.

6. Grader is returned to starting point by backtracking on cleaned area.

7. Grader is repositioned for third pass so as to cast a windrow from surf line side into first- and second-pass windrow. A three-pass windrow is the optimum for pickup by a motorized elevating scraper. Height of the windrow is limited to ground clearance of tractor. Figure 805-1 illustrates a three-pass technique.

When the elevating scraper is used in combination with motorized graders, its operator should:

1. Straddle the windrow formed after two or three passes by the motorized grader and lower the cutting edge of the bowl to the depth of oil penetration.

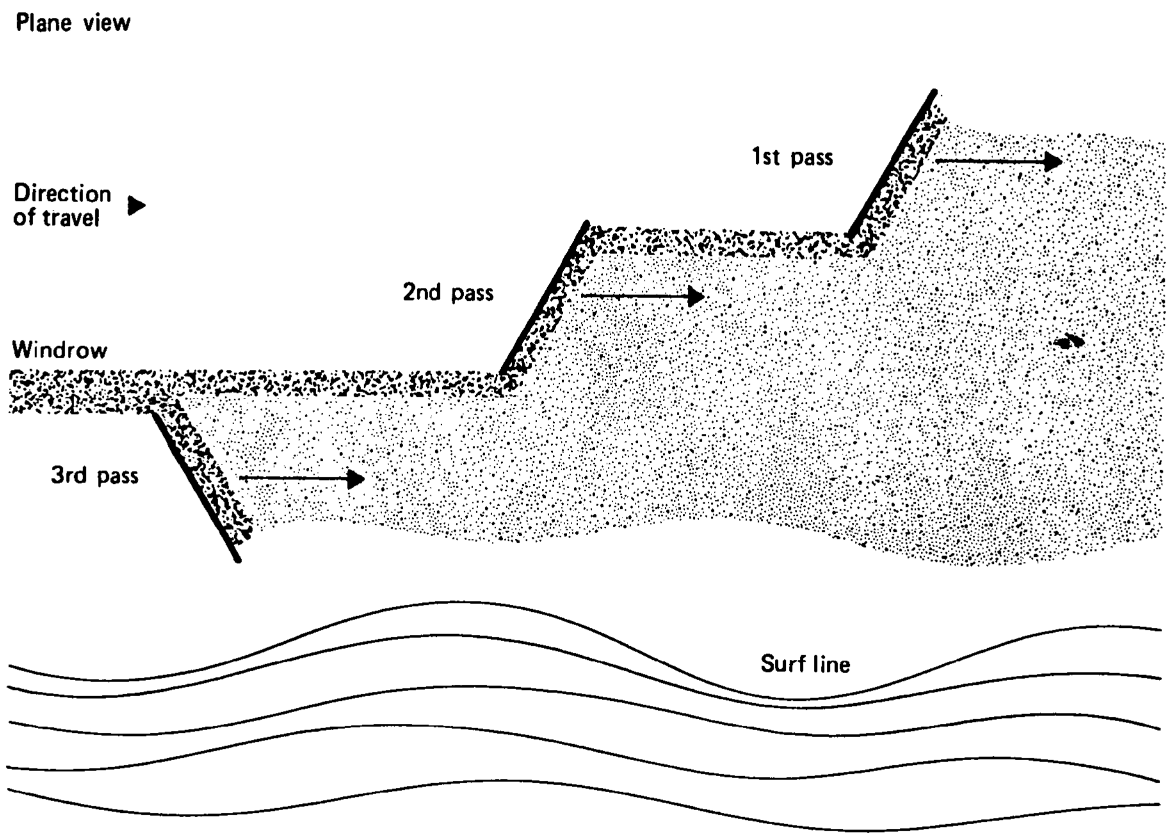


Figure 805-1. Motor grader / elevating scraper sequence.

2. Operate the scraper in first gear (low range), pick up windrow until the bowl has filled up and then stop the scraper and pick up the bowl, keeping elevator flights moving.

3. Stop elevator flights and proceed to unloading area.

Since one motorized grader can produce windrows continuously, several motorized elevating scrapers should be used simultaneously to pick up the windrows.

Cleaning Rate

The shoreline area that can be cleaned using a motor grader/elevating scraper combination is primarily dependent on the size of the scraper and the distance it has to travel from shoreline pickup area to unloading area. For a 150-m (500-ft) one-way haul distance, the cleaning rate* for the motor grader/elevating scraper combination is approximately 2.5 hr/hectare (1 hr/acre). Elevating scraper combination is approximately 2.5 hr/hectare (1 hr/acre).

Logistic Requirements

The logistical requirements for using the motor grader/elevating scraper technique will vary with the length of the haul distance between the pickup point and unloading area. As the haul distance increases more elevating scrapers will be needed to keep up a reasonable cleaning rate. Table 805-2 gives logistical requirements for a 2-km (1.2 mi) length of beach.

*Cleaning rates are based on findings in "The Restoration of Oil-Contaminated Beaches." URS, 1970.

TABLE 805-2. LOGISTICAL REQUIREMENTS FOR HEAVY EQUIPMENT

Item	For 150-m (500 ft) Haul Distance	For 600-m (2,000 ft) Haul Distance	Combined Cleaning Rate (hr/hectare)
Equipment			
• Motor Grader	1	1	
• Elevating scraper - 20 yd^3 capacity	2	4	3 - 3 1/2
• Elevating scraper - 10 yd^3 capacity	4	8	3 - 3 1/2

Personnel - 1 equipment operator for each piece of equipment and 1 supervisor

Support		Diesel Fuel Requirements (gal/hr)
• Elevating scraper	-	9-15
• Motor grader	-	3-8

Access requirements - Heavy equipment, barge or landing craft

Motorized Elevating Scrapers

Use

Motorized elevating scrapers pick up and haul material short distances to disposal or temporary storage sites. They are equipped with self-loading elevators that pick up cut material and dump it back into the hopper. Alone they are used primarily on sand and gravel beaches where oil penetration exceeds 3 cm. They also can be used to remove tar balls and flat patties from beach surface.

On beaches with low bearing capacity, the motorized elevating scraper may become immobilized. Two methods that can overcome this problem are:

1. Use a non-motorized elevating scraper pulled by a tracked bulldozer. The use of a crawler tractor greatly increases traction and permits the scraper to operate on beaches with low bearing capacity.

2. Use a tracked or wheeled tractor to push the elevating scraper unit, or use a tandem-drive elevating scraper which has as standard equipment both pusher and pusher prime mover units.

Description of Technique

When the elevating scraper is used alone, the operational procedures are:

1. Operate parallel to surf line, beginning with oil-contaminated material farthest inshore.

2. Set depth of cut to depth of oil penetration or to just skim the surface if only oil-contaminated debris is to be removed.

3. Operate scraper in first gear (low range), with the length of pass depending on the size of the scraper bowl.

4. When bowl is full, stop scraper and pick up bowl, keeping elevator flights moving.

5. Stop elevator flights and proceed to unloading area.

Figure 805-2 gives a graphic example of the cleaning pattern.

Cleaning Rate

Optimum rate of shoreline cleaning for an elevating scraper on smooth, firm beaches is primarily dependent on the capacity of the scraper and the distance to the unloading area. For a 30-m (100-ft) one-way haul distance, the cleaning rate for the elevating scraper is approximately 2.4 hr/hectare (0.95 hr/acre). Cleaning rates based on findings in "The Restoration of Oil-Contaminated Beaches," URS 1970.

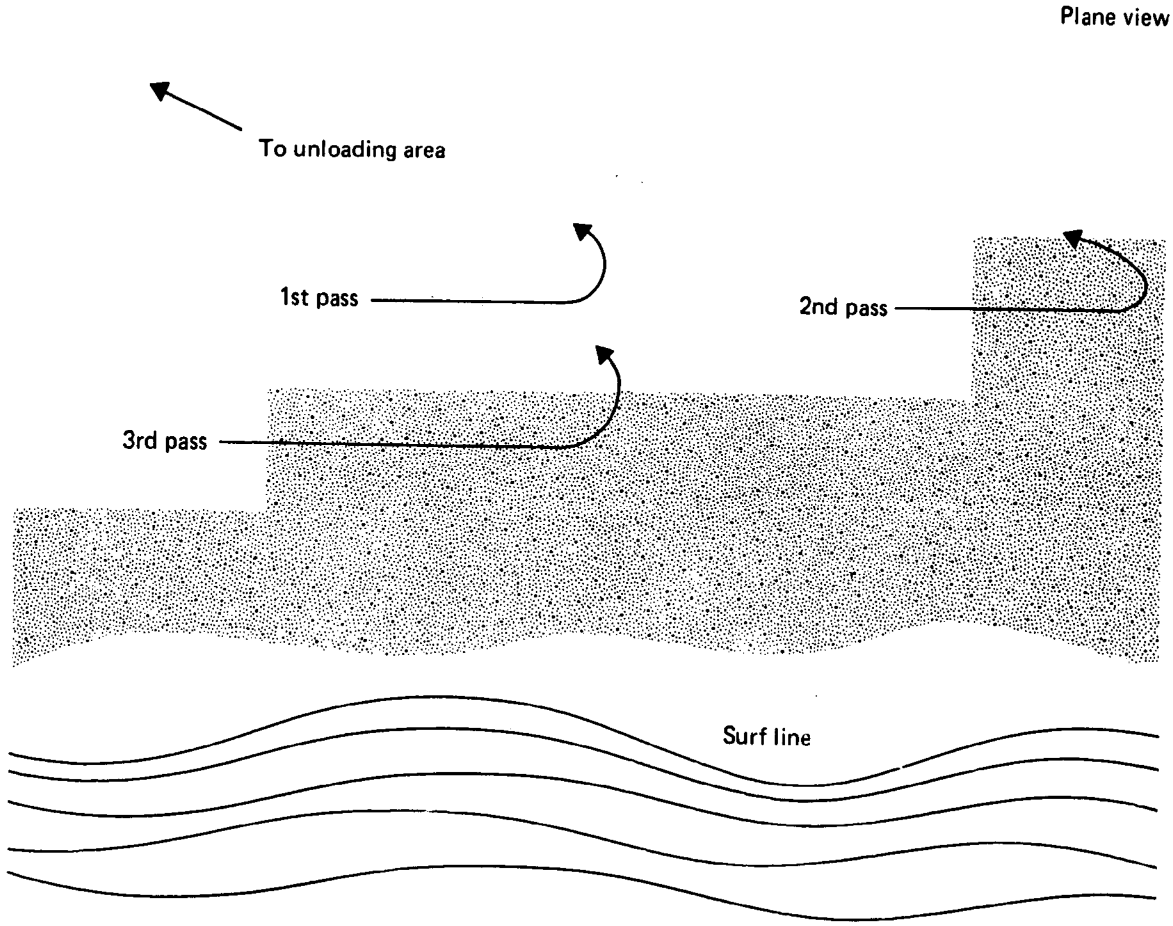


Figure 805-2. Cleaning pattern for motorized elevating scraper.

Logistic Requirements

The logistical requirements for using the elevating scraper technique will vary with the length of the haul distance between the pickup point and unloading area. As the haul distance increases, more elevating scrapers will be needed to keep up a reasonable cleaning rate. Table 805-3 gives logistical requirements for a 2-km (1.2 mi) length of beach.

TABLE 805-3. LOGISTICAL REQUIREMENTS FOR ELEVATING SCRAPER

	For 150-m (500 ft) Haul Distance	For 600-m (2,000 ft) Haul Distance	Combined Cleaning Rate (hr/hectare)
Equipment			
• Elevating scraper - 20 yd^3 capacity	2	4	3 - 3-1/2
• Elevating scraper - 10 yd^3 capacity	4	8	3 - 3-1/2

Personnel - 1 equipment operator for each piece of equipment and 1 supervisor

Support	Diesel Fuel Requirements (gal/hr)
• Elevating scraper -	9-15

Access requirements - heavy equipment, barge or landing craft

Motor Grader and Front-End Loader

Use

Used on sand and gravel beaches where oil penetration is less than 2 to 3 cm and trafficability is good. Can also be used on mud flats is trafficability permits.

Description of Technique

Windrows are formed in the same manner as described under motor grader and elevating scraper techniques. The front-end loader is used in place of the scraper to remove the windrows and transfer the material to the unloading area. For specific operating procedures of the loader itself, refer to the description of front-end loaders. Operating procedures for front-end loaders working with a motorized grader are listed below. Several front-end loaders are needed to remove windrows formed by a single grader.

1. Use 4-in-1 type bucket if available.
2. Operate tractor in first gear while loading.
3. Fill bucket only 1/2 to 2/3 full to minimize spillage while scraping.
4. Minimize traffic over oil-contaminated area when using tracked loader.

Figure 805-3 shows thes operational sequence.

Cleaning Rate

The cleaning rate for using the motor grader/front-end loader depends on the haul distance to the unloading area and the capacity and type of loader used. For a 30 m (100 ft) haul distance the rate for a 3 yd^3 capacity rubber-tired front end loader is 6 hr/hectare (2.4 hr/acre). The route for a 3 yd^3 capacity rubber tired loader is 6 hr/hectare (2.4 hr/acre). The rate of a 3 yd^3 capacity crawler type front-end loader is 8.25 hr/hectare (3.3 hr/acre).

Logistic Requirements

The logistical requirements for using the motor grader/front-end loader technique will vary significantly between the rubber-tire and crawler loaders and will also depend upon the haul distance to the unloading area. Since the crawler type loaders are much slower, more will be needed to maintain a reasonable cleaning rate. Additional loaders of both types would also be needed if longer haul distances are required. Table 805-4 gives the logistical requirements for a 2-km (1.2 mile) length of beach.

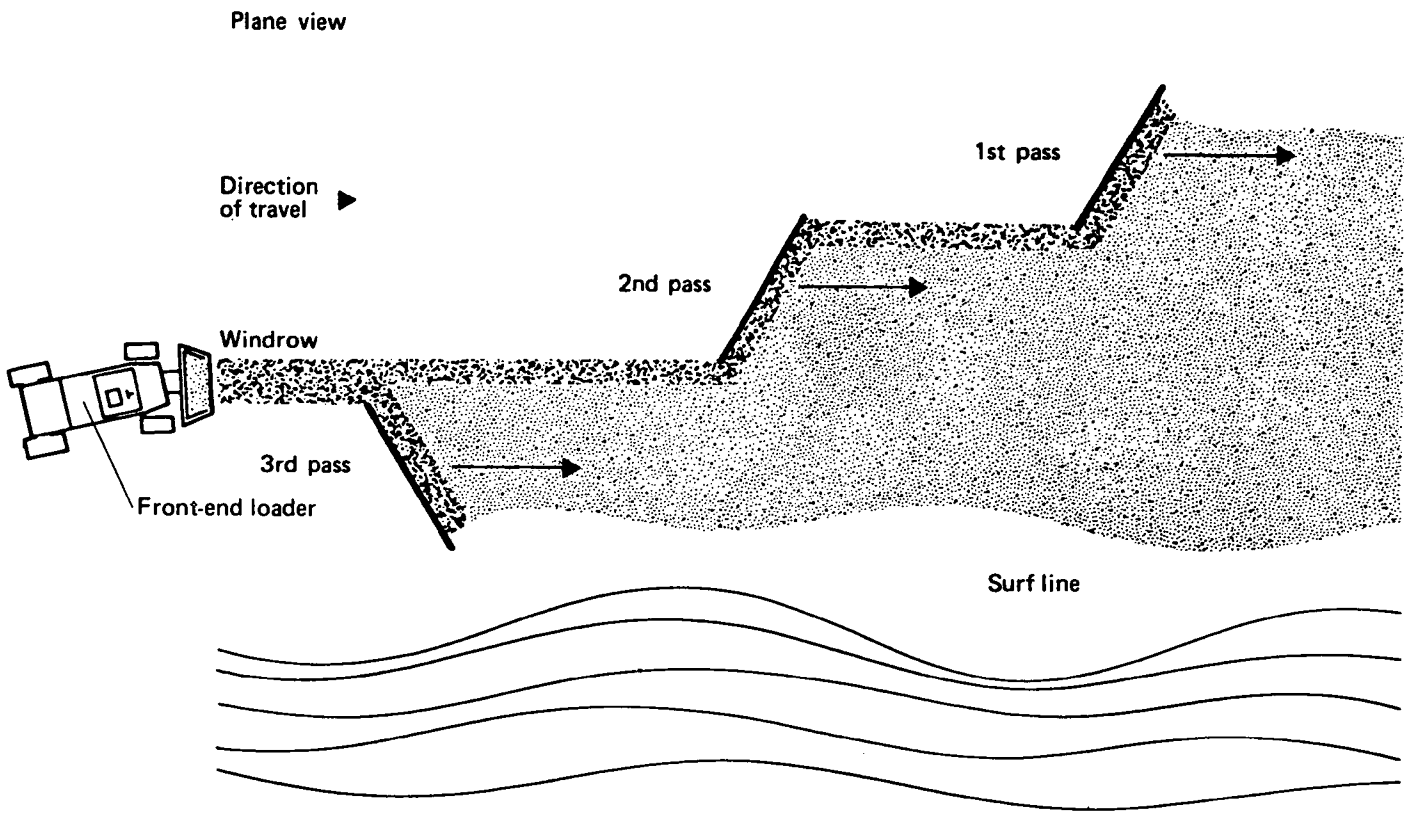


Figure 805-3. Motor grader / front-end loader operational sequence.

TABLE 805-4. LOGISTICAL REQUIREMENTS FOR COMBINATION MOTOR GRADER AND FRONT-END LOADER

Item	30-m (100-ft) Haul Distance	150-m (500-ft) Haul Distance	Cleaning Rate (hr/hectare)
Equipment			
• Motor grader second rubber-tired front-end loader	1 motor grader 2 front-end loader	1 motor grader 4 front-end loaders	3.25 - 3.75
• Motor grader and crawler (tracked) front-end loader	1 motor grader 2 front-end loaders	1 motor grader 6 front-end loaders	4.0 - 4.5
	No. of 10 yd^3 Truck Loads Per Hour	No. of 20 yd^3 Truck Loads Per Hour	
• Dump Trucks	19[a]	10[a]	

Personnel- 1 operator for each piece of equipment and 1 supervisor

Support	Diesel Fuel Requirements (gal/hr)	Bucket Capacity (yd_3)
• Motor grader	3-8	
• Front-end loader	5-5.1	2
(rubber-tired)	13.5-14.5	5
• Front-end loader	4.5-5	1.7
(crawler)	11.5	4
• Dump truck	6-12	

Access requirements - heavy equipment, barge, or landing craft

NOTE: Cleaning rates based on loaders with 3 yd^3 2/3 full.

[a]Based on the cleaning rate of 4 hr/hectare (1.6 hr/acre) and 575 m^3 hectare (304 yd 3/acre) of material removed.

Front-End Loader - Rubber-Tired or Tracked

Use

Used on mud, sand, or gravel beaches when trafficability is poor and oil penetration is light to moderate. Front-end loaders are designed for digging and loading, and for limited transport of material. Buckets are made in different sizes and weights for different kinds of materials and work conditions. Buckets for wheeled and crawler tractors range from 75 to 10 yd^3.

Front-end loaders equipped with slot buckets, which allow loose sand to fall through the slots, should be used to remove large quantities of oil-contaminated debris such as kelp and driftwood. Previous beach-restoration experience indicates that front-end loaders should be used primarily for loading material into trucks from stockpiles or from windrows formed by motorized graders.

Description of Technique

When the front-end loader is used alone the operational procedures are:

1. Use 4-in-1 type bucket if available.
2. Operate tractor in first gear while loading.
3. Position bucket flat on beach for loading loose material.
4. Position bucket at slight downward tilt for digging and skimming.
5. Load bucket most easily by moving tractor forward.
6. Fill bucket only 1/2 to 2/3 full to minimize spillage while loading.
7. Minimize traffic over oil-contaminated area when using crawler loader to avoid oil being ground into substrate.

Figure 805-4 depicts the operational sequence.

Cleaning Rate

The rate of shoreline cleanup when using only a front-end loader depends primarily on three factors: 1) whether a rubber-tired or crawler type tractor is used, 2) the haul distance to the truck loading area, and, to a lesser extent, 3) the capacity of the bucket. The rate of operation of a front-end loader removing contaminated beach material over a one-way haul distance of 30 m (100 ft) is 16.5 hr/hectare (6.6 hr/acre) for a rubber-tired loader and 22 hr/hectare (8.8 hr/acre) for a crawler type loader.

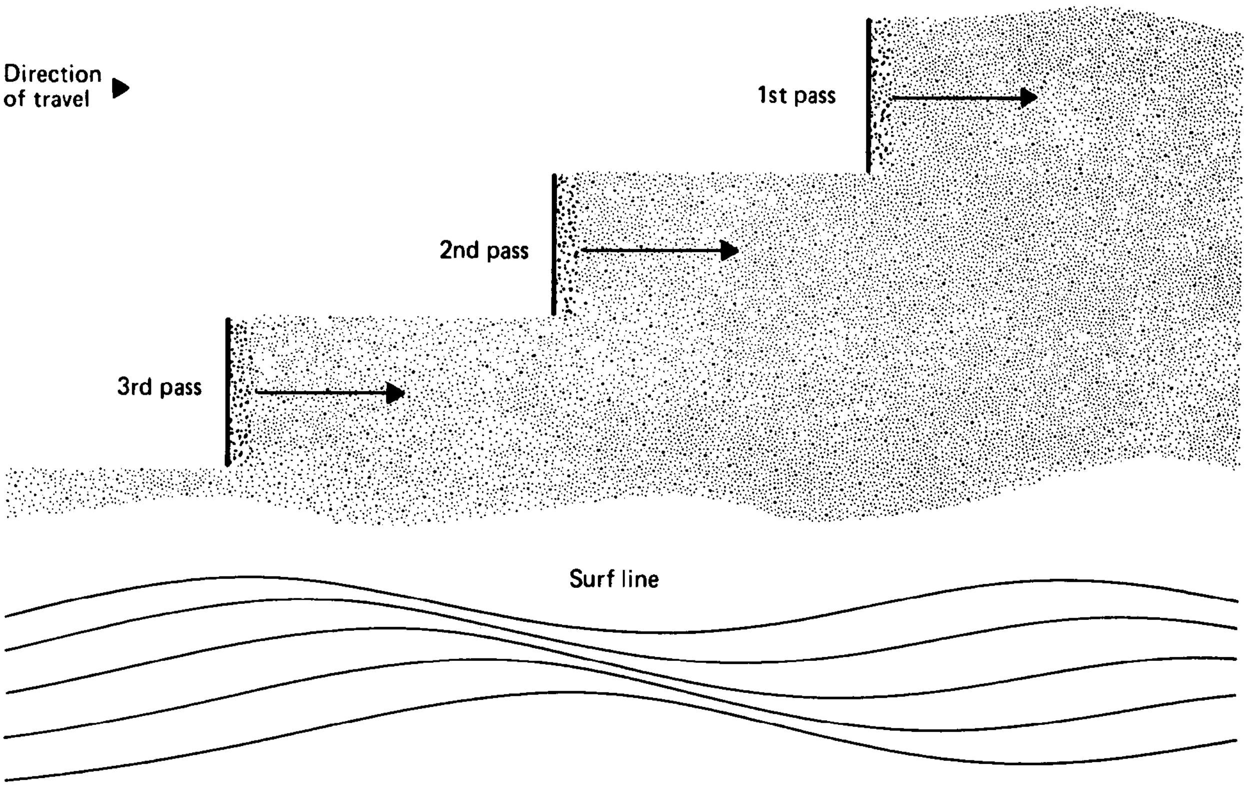


Figure 805-4. Front-end loader operational sequence.

Logistic Requirements

The logistical requirements for using the front-end loader technique will vary with those factors affecting cleaning rate. Table 805-5 gives the logistical requirements for operation of a front-end loader only.

TABLE 805-5. LOGISTICAL REQUIREMENTS FOR FRONT-END LOADER

Item	30-m (100-ft) Haul Distance	150-m (500-ft) Haul Distance	Combined Cleaning Rate (hr/hectare)
Equipment			
• Front-end loader (rubber-tired)	2	4	8-8.5
• Front-end loader (crawler)	2	6	11-11.5
	No. of 10 yd^3 Loads/hr		No. of 20 yd^3 Loads/hr
• Dump Trucks	23[a]		12[a]

Personnel - 1 operator for each piece of equipment and 1 uupervisor

Support	Diesel Fuel Requirements (gal/hr)	Bucket Capacity (yd^3)
• Front-end loader (rubber-tired)	5-5.1	2
	13.5-14.5	5
• Front-end loader (crawler)	4.5-5	1.7
	11-12	4
• Dump truck	6-12	

Access requirements - heavy equipment, barge, or landing craft

NOTE: Cleaning rates based on bucket capacity of 2 yd^3 2/3 full.

[a]Based on a cleaning rate of 9 hr/hectare (3.6 hr/acre) and 1521 m^3/hectare (850 yd^3/acre) of material removed.

Bulldozer/Front-End Loader (Rubber-Tired)

Used primarily on coarse sand, gravel, or cobble beaches where oil penetration is deep, contamination extensive, and trafficability poor. Can also be used to remove heavily oil-contaminated vegetation.

Description of Technique

For those situations described above when no other techniques are applicable, the bulldozer/front-end loader combination is an acceptable method. The bulldozer is utilized to push the contaminated material into piles for pickup by the front-end loader. (Because the bulldozer will have to operate in the upper edge of the surf zone, an old or expendable piece of machinery should be used.) The sequence of operational procedures for a bulldozer follows:

1. Begin at low tide line of the beach using a universal or straight type blade. If there is a longshore current the bulldozer should be at the up-current end of the contaminated area.

2. Dozer is operated in first gear.

3. Contaminated material is pushed up the beach perpendicular to the tideline and onto an area with suitable trafficability to operate a front-end loader.

4. The cut depth should not exceed the depth of oil penetration.

5. Material should not be pushed beyond the contaminated area to avoid spoiling uncontaminated areas. A road may have to be constructed for the front-end loader to gain access to the stockpiled material.

6. Dozer is returned to starting point by backtracking on cleaned area and repositioned so that the second cut will overlap the first cut slightly.

7. The procedure is repeated along the beach. (Figure 805-5).

8. Rubber-tired front-end loaders operate at the backshore side of the contaminated area to pick up the stockpiled sediments and transfer them to dump trucks for disposal.

9. The loaders are operated by placing the bucket flat on the ground or tilted slightly forward. The bucket is filled by the forward movement of the loader.

Cleaning Rate

The shoreline area that can be cleaned by a bulldozer/front-end loader combination is primarily dependent on the haul distance of the loader and the width of the contaminated area. For a 30-m (100-ft) one-way haul

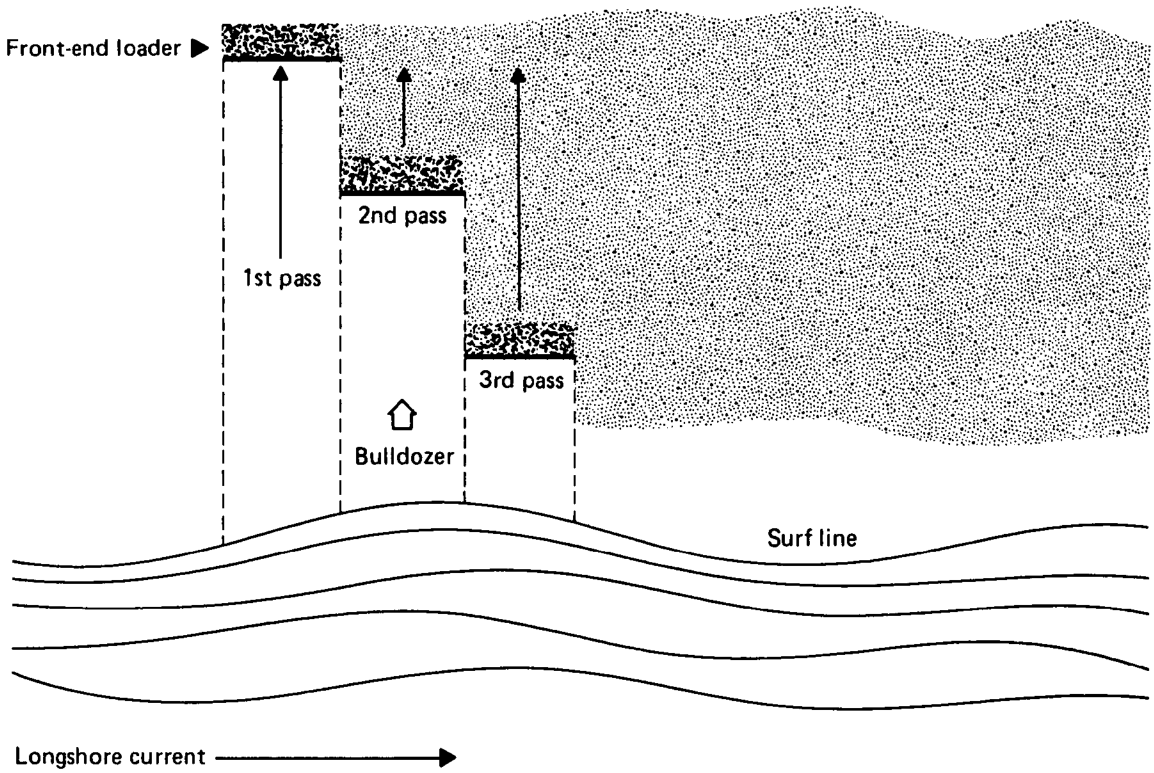


Figure 805-5. Bulldozer/front-end loader operational sequence.

distance the cleaning rate for the combination is approximately 25 hr/hectare (10 hr/acre).

Logistic Requirements

The logistical requirements for using the bulldozer/front-end loader combination will vary with the haul distance between the pickup point and truck-loading area; as the haul distance increases more front-end loaders will be needed to maintain a reasonable cleaning rate. Table 805-6 gives logistical requirements for a 2-km (1.2 mi) length of beach.

TABLE 805-6. LOGISTICAL REQUIREMENTS FOR BULLDOZER/FRONT-END LOADER (Rubber-Tired) COMBINATION

Item	30-m (100-ft) Haul Distance	150-m (500-ft) Haul Distance	Combined Cleaning Rate (hr/hectare)
Equipment			
• Bulldozer	1	1	
• Front-end loader (rubber-tired)	2	4	12 1/2-13
	No. of 10 yd^3 Truck-Loads/hr	No. of 20 yd^3 Truck-Loads/hr	
• Dump trucks	23[a]	12[a]	
Personnel - 1 operator for each piece of equipment			
Support	Diesel Fuel Requirements (gal/hr)	Bucket Capacity (yd^3)	
• Front-end loader (rubber-tired)	5-5.1	2	
	13.5-14.5	5	
• Bulldozer	4-14		
• Dump truck	6-12		
Access requirements - heavy equipment, barge, or landing craft			

NOTE: Cleaning rates based on bucket capacity of 3 yd^3 2/3 full.

[a]Based on a cleaning rate of 13 hr/hectare (5.26 hr/acre) and 2281 m^3/hectare (1207 yd^3/acre) of material removed.

Backhoe

Use

Used to remove oil-contaminated sediment (primarily mud or silt) on steep banks where other types of equipment are unable to operate.

Description of Technique

The oiled sediment is removed by positioning the backhoe at the edge of the bank, extending the boom down the bank, and scraping the surface layer into the bucket as the boom is retracted. The contaminated material is stockpiled or loaded directly into dump trucks and hauled away for disposal. The sequence of operational procedures for the backhoe is as follows:

1. Backhoe is positioned at the top of the bank facing downhill.

2. The boom is extended to the lower edge of the contaminated area or as far downhill as possible.

3. The edge of the bucket is placed in the sediment about 25 to 50 cm deep and moved up the bank, scraping the sediment into the bucket.

4. When the bucket reaches the top of the bank or becomes 2/3 full it is leveled and the material is stockpiled or placed directly into a dump truck.

5. Several slightly overlapping cuts should be made to clear a path approximately 3 to 6 m (10 to 20 ft) wide.

6. Backhoe is then repositioned to begin clearing a path adjacent to the previous path.

Figure 805-6 graphically depicts this operational sequence.

Cleaning Rate

The area that can be cleaned using a backhoe is largely dependent on the size of the bucket and to a lesser extent, the swing angle from the pickup point to the unloading point. For a 12-ft^3 bucket loaded 2/3 full and a 90° swing, the cleaning rate for the backhoe is approximately 66 hr/hectare (27 hr/acre).

Logistic Requirements

The logistical requirements for using the backhoe technique will vary with the amount of contaminated area. Since their cleaning rate is low, a larger contaminated area will require more backhoes to maintain a reasonable cleaning rate. Table 805-7 gives logistical requirements for a 3-km (1.2-mi) length of shoreline.

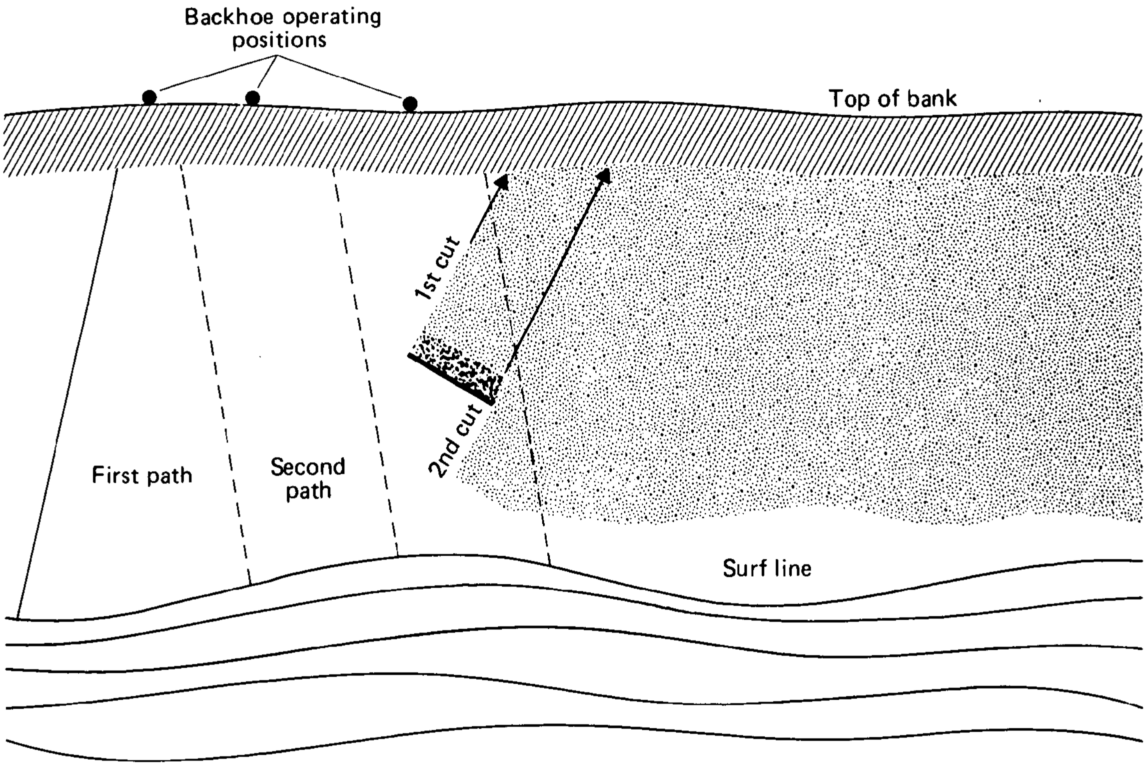


Figure 805-6. Backhoe operational sequence.

TABLE 805-7. LOGISTICAL REQUIREMENTS FOR BACKHOE

Item	For 12-ft^3 Bucket	For 16-ft^3 Bucket	Combined Cleaning Rate (hr/hectare)
<u>Equipment</u>			
• Backhoe	4	3	16-17
	<u>No. of 10 yd^3 Truck-Loads/hr</u>		<u>No. of 20 yd^3 Truck-Loads/hr</u>
• Dump trucks	23[a]		12[a]
<u>Personnel</u> - 1 operator for each piece of equipment			
<u>Support</u>	<u>Diesel Fuel Requirements</u> (gal/hr)	<u>Bucket Capacity</u> (yd^3)	
• Backhoe	7-8 18-19	1.5 3.8	
• Dump truck	6-12		
<u>Access requirements</u> - heavy equipment, barge, or landing craft			

[a]Based on a cleaning rate of 17 hr/hectare (7 hr/acre) and a cut depth of 30 cm (1 ft).

Dragline or Clamshell

Use

Used on sand, gravel, or cobble beaches where trafficability is very poor and oil contamination and penetration is extensive. Although this method is quite slow and inefficient, it can be used on shorelines where trafficability excludes the use of tracked equipment.

Description of Technique

The dragline or clamshell is operated along the upper edge of the contaminated area or as close to it as trafficability of the sediments will permit. It may be necessary to construct an access road from which equipment can operate. The specific operating procedures for a dragline are:

1. If a longshore current is present, begin at the up-current end of the contaminated area.
2. Operate from backshore edge of contaminated area.
3. Position boom* for maximum reach or enough reach to cover the contaminated area.
4. Drop the bucket to the beach and pull back toward the crane to scoop up the sediment.
5. Tilt bucket back when 2/3 full**, swing around, and load the collected sediments into a dump truck, or deposit in a stockpile.
6. Swing the bucket back and continue the cut or start a new cut adjacent to, and slightly overlapping, the previous cut.

If a clamshell is used, then the following procedures are followed:

1. The crane and boom are positioned as before and the open clamshell is dropped onto the beach surface.
2. The clamshell jaws are shut, scooping oiled material into the bucket portion.
3. The clamshell is raised and swung around to a dump truck or stockpile where the clamshell is opened, spilling its contents.
4. The clamshell is returned to a spot on the backshore side of, and just barely overlapping, the previous cut.

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*The boom may have to be of considerable length should the contaminated area be of excessive width.

**The bucket is only filled to 2/3 capacity to avoid spillage.

The procedure is repeated until a pass is completed across the contaminated area where by the crane is moved slightly and a new pass is started adjacent to the previous one. Figure 805-7 graphically displays the cleaning pattern for both types of equipment.

Cleaning Rate

Shorelines which can be cleaned using a dragline or clamshell depends primarily on the width of the contaminated area and the bucket capacity. The cleaning rate for a 2/3 full 12 yd^3 bucket dragline is approximately 28 hr/hectare (11.3 hr/acre). For a 1 yd^3 capacity clamshell 2/3 full, the rate is approximately 50 hr/hectare (20 hr/acre).

Logistic Requirements

The logistical requirements for the technique utilizing a dragline or clamshell will vary with the size of the area contaminated and the capacity of the bucket or clamshell. Because the acre-per-hour that can be cleaned by a dragline or clamshell is small, several units are required to maintain a reasonable cleaning rate. Table 805-8 gives the logistical requirements for using a dragline or clamshell to clean a 3-km (1.2 mi) length of beach.

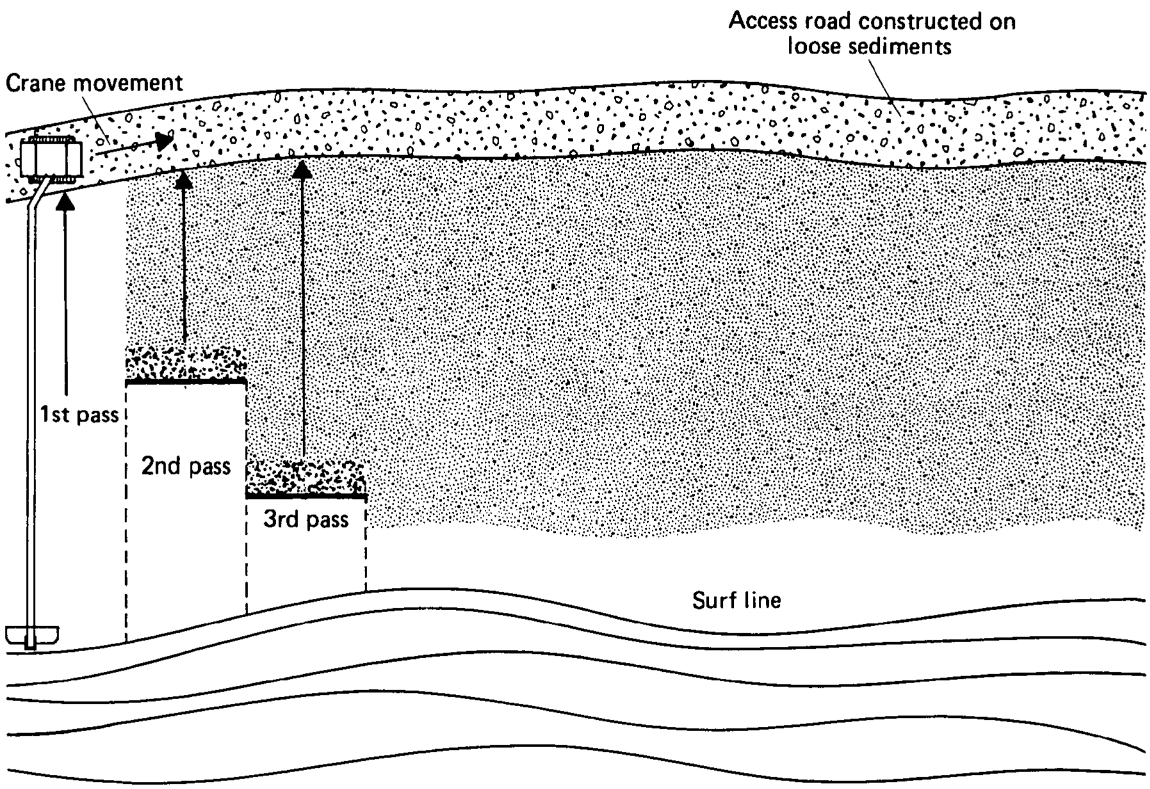

Figure 805-7. Cleaning pattern for dragline or clamshell technique.

TABLE 805-8. LOGISTICAL REQUIREMENTS FOR DRAGLINE OR CLAMSHELL

Item	For 2 yd^3 Bucket	For 5 yd^3 Bucket	Combined Cleaning Rate (hr/hectare)
Equipment			
• Dragline	4	2	6-7
	1 yd^3 Bucket		
• Clamshell	4		13-14
	No. of 10 yd^3 Truck-Loads/hr		No. of 20 yd^3 Truck-Loads/hr
• Dump trucks	57[a]		29[a]
• Personnel - 1 operator for each piece of equipment			

Support	Diesel Fuel Requirements (gal/hr)	Bucket Capacity (yd^3)
• Dragline	7-8	1.5
	18-19	3.8
• Clamshell	No data available	
• Dump truck	6-12	

Access requirements - heavy equipment, barge, or landing craft

[a]Based on a cleaning rate of 7 hr/hectare (3 hr/acre) and a cut depth of 30 cm (1 ft).

High-Pressure Flushing (Hydroblasting)

Use

Hydroblasting has proved to be the most efficient method of removing oil coatings from boulders, rock, and man-made structures. Hydroblasting is safest within a boomed area next to the waterline, but it can be used effectively in the upper intertidal zone if proper steps are taken to contain the runoff water and oil.

Descriptions of Technique

Hydroblasting uses a high-pressure water jet that removes oil from almost any surface. The water is often heated close to boiling for increased effectiveness. The water jet should be used only by trained personnel. A properly controlled jet can remove oil from mussel shells without harming the mussels; but too strong a jet will remove all plant and animal life and may also damage man-made surfaces.

When the hydroblast jet drives oil from a surface the oil then adheres to another surface or forms a slick on top of the water. The oil must be prevented from contaminating other rocks, gravel, silt, or sand, and this is best achieved by letting the water and oil form a pool or letting the oil re-enter the water. Specific operating procedures for hydroblasting are:

1. If the oil is to be channeled into the water or there is a possibility of it reentering the water, containment booms should be anchored beyond the surf zone, or close to the shore when used on inland waterways.

2. Flushing should begin at the highest point, working downslope. It should be conducted at high tide or timed so the lowest point is cleaned at low tide and the oil recovered before the tide rises and recontaminates the area.

3. Plastic sheets should be placed over adjacent surfaces to prevent further contamination and to direct the flow of water and removed oil to the desired area.

4. Berms or ditches can be constructed or booms used to further channel the oil and water into collecting pools or, in some cases, back into the surf or waterway.

5. Pumps, vacuum trucks, or shoreline skimmers can be used to transfer the collected oil to suitable containers for disposal.

6. Shoreline characteristics, winds, and currents should be used to an advantage.

Cleaning Rates

The rate at which a shoreline can be cleaned using the hydroblasting technique mainly depends on the type and condition of oil and the pressure at which the flushing is conducted, but is affected by a variety of factors. Hydroblasters range in pressure from 1,000 to 10,000 psi. For a unit producing 3,000 to 4,000 psi pressure, used on freshly deposited oil, the cleaning rate is approximately 0.75 to 1.5 m^2 (7 to 15 ft^2) min.

Logistic Requirements

The logistical requirements will vary with the amount of the contaminated area to be hydroblasted. The larger the area the more hydroblasting units and support equipment will be needed. Table 805-9 gives the logistic requirements for a 2-km (1.2-mi) length of shoreline with a limited amount of contaminated area to be hydroblasted.

TABLE 805-9. LOGISTICAL REQUIREMENTS FOR HIGH-PRESSURE FLUSHING (HYDROBLASTING)

Item	Type	Number Required
Equipment		
• Hydroblasting unit	Self-contained - 10gpm @ 4,000 lbs. psi	2-3
Support		
• Vacuum truck	60-80 barrel capacity	1
• Trash pump and	25-50 gpm	1
tank truck	60-80 barrel capacity	1

Personnel - 1-2 operators per hydroblasting unit and 1-2 per recovery equipment and 1 supervisor

Access requirements - heavy equipment for trucks and light vehicular, shallow craft, or helicopter

Steam Cleaning

Use

Used as a means for removing oil coatings from boulders, rock, and man-made structures. The steam raises the temperature of the adhered oil, thereby lowering its viscosity and allowing it to flow off a surface. However, since living plants or animals attached to a surface would be unlikely to survive the high temperatures of steam cleaning, this process is not usually recommended for surfaces that support living plants or animals.

Description of Technique

Steam cleaning equipment uses a high-pressure steam jet that will remove oil from almost any surface. It drives oil off one surface onto another, requiring that precautions be taken to avoid recontamination of previously unaffected areas. Specific operating procedures for steam cleaning are:

1. When used on shorelines the oil should be prevented from reentering the water by surrounding the working area with containment booms, which concentrate the removed oil for pickup by skimmers or vacuum equipment.

2. Cleaning should begin at the highest point of contamination working downslope and be done at high tide or timed so the lowest point is cleaned at low tide and the oil recovered before the tide rises and recontaminates the area.

3. Plastic sheets should be placed over adjacent surfaces to prevent further contamination and to direct the flow of removed oil to a collection point.

4. Berms or ditches can be constructed to further channel the oil into collecting pools or back into the water.

Cleaning Rates

The rate of cleaning is dependent on the equipment used and the degree of contamination. A unit producing 280 psi at 325°F can generally clean at a rate of approximately 0.5 to 1 m^2 (5 to 10 ft^2)/min.

Logistic Requirements

The logistical requirements for using the steam cleaning technique will vary with the size of the contaminated area and the capacity of the cleaning. In general, the larger the steam cleaner, the faster it can clean an area; thus, fewer units are needed. The size of the contaminated area is directly related to the number of units required in order to maintain a reasonable cleaning rate. Table 805-10 gives the logistical requirements for a 2-km (1.2 mi) length of beach having a moderate amount of rocks, boulders, and man-made structures.

TABLE 805-10. LOGISTICAL REQUIREMENTS FOR A STEAM CLEANER

Item	Size of Unit	Number Required
Equipment		
• Steam cleaner	280 psi @ 325°F	4-6
• Vacuum truck or	80-100 barrel capacity	1-2
• Skimmer	Small	1-2
Personnel - 2 operators for each cleaning unit and 1 supervisor		
Support	Water Consumption/Unit	Fuel Consumption/Unit
• Steam cleaner	225-260 gal/hr fresh water	1.5-2.5 gal #2 diesel fuel oil/hr
Access Requirements - Heavy equipment for trucks, light vehicular, shallow craft, or helicopter for steam cleaning units		

Sandblasting

Use

Used primarily to remove thin accumulations of oil residues from man-made structures. Sandblasting also removes any vegetation or animals inhabiting the surface and should not be used where repopulation may take considerable time, or where other techniques are available.

Description of Technique

Sand is applied to the structure surface at high velocity using sand-blasting equipment. The oil is removed from the substrate by the abrasive action of the sand. The result is an accumulation of sand, oil, and surface material in the area near the operation. This should be removed and transported to a disposal area. In most cases the sand used cannot be taken from a nearby shoreline as it must be screened to obtain the proper size and cleaned to meet air quality regulations. Specific operating procedures for sandblasting are:

1. Blasting should begin at the highest point of contamination and work down to the base of the structure.

2. Operations should be done at low tide to clean as much of the structure as possible.

3. Removal of the accumulation of spent sand, oil residues, and surface material is generally performed manually with shovels and wheelbarrows. Should the quantity become large, front-end loaders may be used.

Cleaning Rates

The cleaning rate of the sandblasting technique depends heavily on the type and degree of contamination of the oil, the type of equipment and abrasive used, and the accessibility to the substrate being cleaned. The rates can vary from 2.3 m^2 (25 ft^2)/hr to 28 m^2 (300 ft^2)/hr depending on the variables. Under normal circumstances, a medium size compressor and equipment can clean 14 m^2 (150 ft^2)/hr.

Logistic Requirements

To maintain a reasonable cleaning rate, several sandblasting units may be required. Table 805-11 gives the logistical requirements for a relatively small area lightly contaminated and easily accessible.

TABLE 805-11. LOGISTICAL REQUIREMENTS FOR SANDBLASTING

Item	Number Required
<u>Equipment</u>	
• Sandblasting unit (compressor incl.)	1
• Sand supply truck	1
• Front-end loader (if used)	1
<u>Materials</u>	
• Sand	Approx. 455 kg (1,000 lb)/hr[a]
<u>Personnel</u>	
• Sandblasting	2-4
• Cleanup	2-3
• Supervisor	1
<u>Access requirements</u> - light vehicular, shallow craft, or helicopter	

[a]Based on cleaning rate of 14 m^4 (150 ft^2)/hr.

Manual Scraping

Use

Used to remove oil from lightly contaminated boulders, rocks, and man-made structures or heavy oil accumulations when other techniques cannot be used. It is effective for situations requiring selective removal of material but is very labor-intensive.

Description of Technique

Manual scraping can be achieved through the use of a variety of tools such as scrapers, putty knives, flat-bladed shovels, etc. Since this technique can be selective, non-oiled animals or vegetation attached to substrates will not be disturbed. There are no specific operational procedures for this technique other than that scraping should begin at the highest point of the contaminated surface and continue down toward the base. The removed oil and substrate material can be scooped up with shovels and placed in buckets or drums for disposal.

Cleaning Rate

Not applicable.

Logistic Requirements

Not applicable.

Sump and Pump/Vacuum

Use

This technique is used primarily on firm sand or mud beaches in the event of continuing oil contamination where sufficient along-shore currents exist, and on streams and rivers in conjunction with diversion booming.

Description of Technique

For a coastal shoreline with an longshore current, a sump is dug in the intertidal zone with a berm built from the excavated material extending from the back of the sump into the surf on the lowest side of the sump. The current moves the oil down the beach where it is intercepted by the berm and channeled into the sump. A vacuum truck or trash pump is used to remove the oil and water from the pit or sump. The specific procedures for constructing and operating the sump and pump are:

1. Dig a rectangular sump at some point down-current from the contaminated area approximately 1 to 2 m (3 to 6 ft) deep at the back end sloping upward toward the surf.

2. It should be constructed at low tide and situated so the back end is located just above the high water mark extending 1/2 to 2/3 the distance across the intertidal zone.

3. The berm should be of sufficient height to be above the water level at high tide and run from the back end of the sump, alongside, and down to the lower intertidal area angling slightly up-current.

4. A suction hose from a vacuum truck or trash pump is operated manually to collect oil from the surface of the sump.

5. Boards or large squeegees are operated manually to further direct oil into the sump and concentrate it in a back corner for pickup.

Figure 805-8 shows the sump and pump method on a coastal shoreline.

For an inland waterway, such as a stream or river construction and operation are basically the same except for the following:

1. The sump is dug into the river bank with the shallow end meeting the river just above the water line.

2. A diversion boom is used to channel the oil to the sump with one end anchored to the shore at the downstream corner of the sump and the other end somewhat upstream and midway across the river.

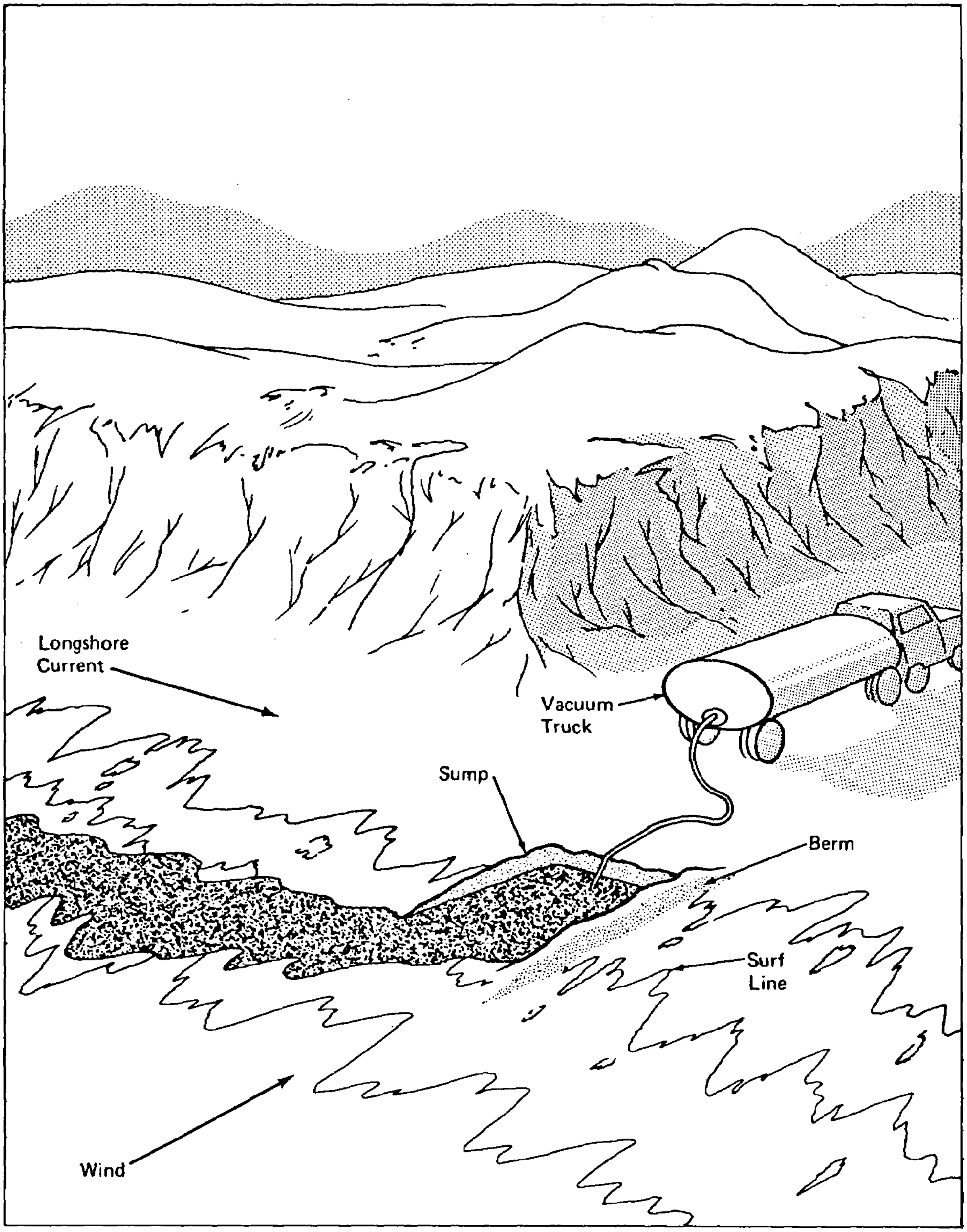

Figure 805-8. Collection of oil on beaches with sumps.

3. The boom should concentrate enough oil and water at the sump opening to allow the oil to spill over the edge into the sump without collecting too much water.

4. The sump should be located on the outside bank of a bend in the waterway where the oil would naturally be concentrated.

5. If the waterway is relatively straight, a sump should be constructed on either side with one slightly downstream of the other and the diversion booms extending past midstream to ensure all the oil is collected.

Figure 805-9 illustrates the sump pump/vacuum technique for an inland waterway.

Cleaning Rate

Not Applicable.

Logistic Requirements

The logistical requirements for using the sump pump/vacuum technique will vary with the amount of oil channeled into the sump. The more oil collected the greater the number of vacuum or tank trucks needed to transport the oil away. Since large amounts of water can be collected with the oil, the total volume of liquid is often large, requiring several disposal vehicles. Table 805-12 gives logistical requirements for a 2-km (1.2-mi) length of beach.

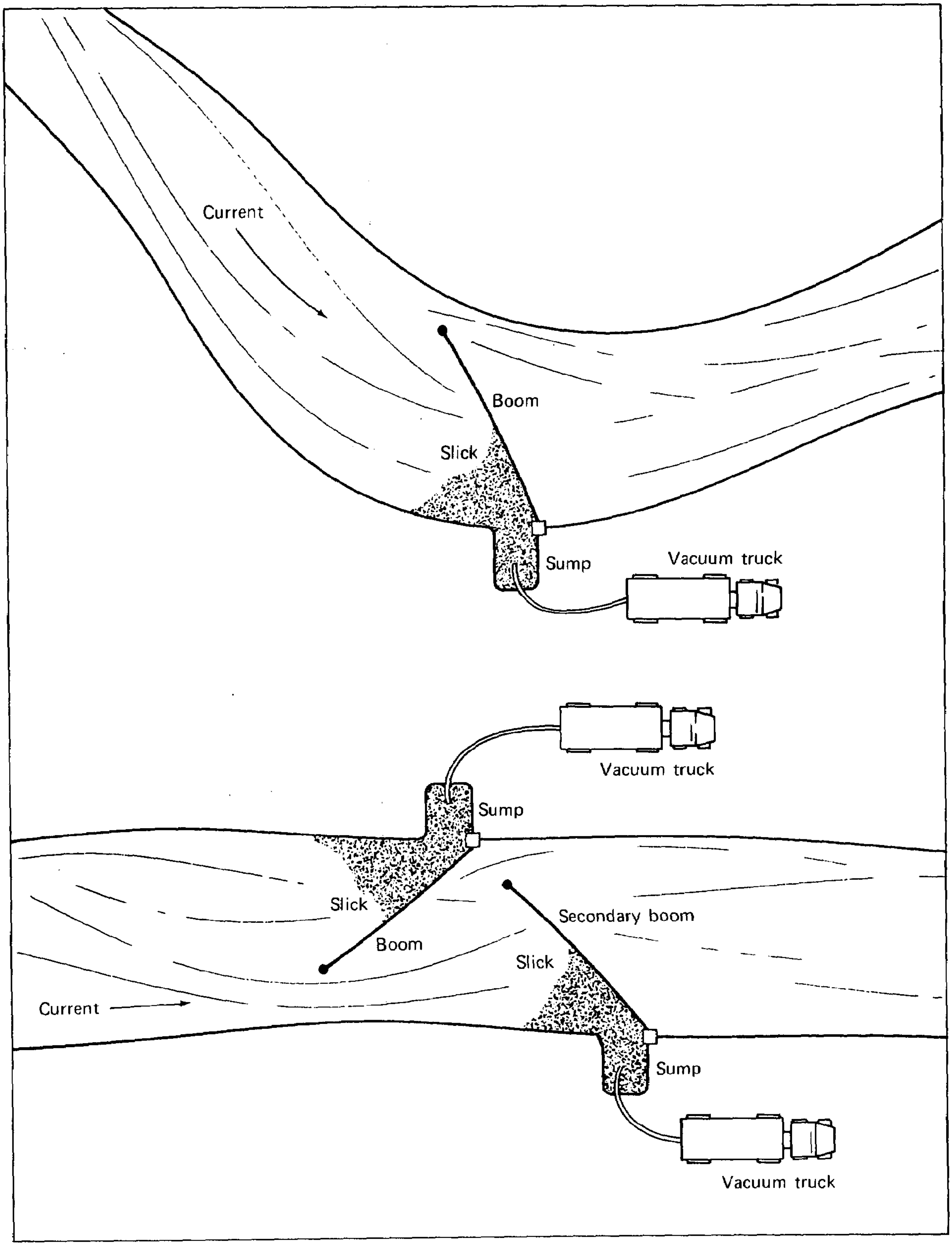

Figure 805-9. Collection of oil on river shorelines with sumps.

TABLE 805-12. LOGISTICAL REQUIREMENTS FOR SUMP PUMP/VACUUM

Item	Typical Suction Rate for Thick Oil (2 mm)	Typical Suction Rate for Thin Oil (0.1 mm)	Fill Time for 110 Barrel Tank
<u>Equipment</u>			
• Vacuum truck or	75 gpm (50% oil)	50 gpm (5% oil)	1 hr @ 75 gpm
high capacity trash pump w/ 3 in suction hose			1 1/2 hr @ 50 gpm
• Number of vacuum trucks or pumps required	Dependent on quantity and rate of collection of oil in sump		

<u>Personnel</u> - 1 person per suction hose, 1 to 2 persons for manual skimming and concentrating of oil, and 1 supervisor

<u>Support</u>	<u>Range of Capacities</u>
• Vacuum truck	6 to 140 barrel @ 42 gal/barrel
• Tank truck	20 to 160 barrel
• 6 in suction hose	700 to 800 or 900 gpm max.[a]
• 4 in suction hose	500 to 600 gpm max.[a]
• 3 in suction hose	300 to 400 gpm max.[a]

<u>Access requirements</u> - heavy equipment, barge, or landing craft

[a]Intake completely submerged drawing water with little or no suction lift.

Manual Removal of Oiled Materials

Use

Used on mud, sand, gravel, and cobble beaches when oil contamination is light or sporadic and penetration is slight, or where heavy equipment access is not possible. Manual removal may also be used when heavy equipment use is deemed harmful to the environment.

Description of Technique

The equipment required for this work includes rakes, shovels, hand scrapers, plastic and burlap bags, buckets, and barrels. Oiled vegetation, debris, and sediments are collected by manual laborers and placed in bags for removal and disposal. Supervisors should be placed in charge of groups of workers with a foreman for each group. The procedures for manual removal are:

1. Wear protective gloves, boots, and hand cream.
2. Cut and/or collect contaminated material into small piles.
3. Do not rake vegetation.
4. Fill plastic or burlap bags half full with material from piles.
5. Place filled bags on plastic sheets above high-water line.
6. Bags may be removed manually, by vehicle, airlifted by helicopter, or loaded onto small boats or barges from shoreline or makeshift docks.

Cleaning Rate

The rate for manually cleaning a shoreline area depends on the number of workers used, their productivity, the method of removal of contaminated materials, and the degree of contamination. If a shoreline area has sporadic contamination it can be cleaned much faster than if heavily contaminated. The more workers used, the faster an area can be cleaned. Helicopter, vessel, or vehicle removal of collected materials is fast and effective whereas manual removal is very slow and labor-intensive. Due to the numerous variables involved, a rate for manually cleaning a beach can not be accurately estimated.

Logistic Requirements

The logistical requirements for manually cleaning a shoreline will vary with the degree of contamination. A heavily contaminated area will obviously require a larger cleanup crew and more supplies and tools than an area with light or sporadic contamination. Table 805-13 gives the logistical requirements for a 2-km (1.2 mi) length of beach.

TABLE 805-13. LOGISTICAL REQUIREMENTS FOR MANUAL REMOVAL OF OILED MATERIAL

Item	For Light or Sporadically Oiled Shoreline	For Heavily Oiled Shoreline
Equipment		
• Debris box	2	3-4
• Helicopter (if used)	1	1-2
• Boat or barge (if used)	1	2-3
• Truck (if used)	1	2-3
Personnel		
• Workers	10-20	50-100
• Supervisors	1	2-3
Access requirements - light vehicular, shallow craft, or helicopter		

Low-Pressure Flushing

Use

Used to remove light, non-sticky oils from lightly contaminated mud substrates, cobbles, boulders, rocks, man-made structures, and vegetation. Low-pressure flushing will not disturb the substrate to any great extent but does present the threat of recontamination of unaffected areas if runoff from the flushing operation is not properly channeled and collected.

Description of Technique

Test flushing should be done in each situation to determine the suitability of this technique. Flushing systems of any size may be assembled, although small portable units are generally most useful. Direct application of the water stream to the oiled substrate is not necessarily desired as erosion or damage to the flora and fauna may result. Bathing the substrate will generally float oil off the suface without any adverse effects. It can then be channeled into collection areas for removal. Procedures for low-pressure flushing are:

1. Containment booms should be anchored just past the surf zone or near the shore on inland waters if there is a possibility of the oil re-entering the water.

2. Flushing should be completed and oil recovered at low tide to avoid recontamination of the intertidal zone by the rising tide.

3. Begin flushing at the highest contaminated point and work down-slope toward the water.

4. The runoff is channeled by berms, ditches, or booms into contained areas or sumps where it can be removed by vacuum trucks, pumps, or sorbents. If used on inland waters with little or no current, it may be washed back into the water within the confines of a containment boom and herded toward a collecting point with water jets.

5. Shoreline characteristics, winds, and currents should be used to advantage.

Figure 805-10 shows general flushing tactics.

Cleaning Rate

Not applicable - the rate of cleaning is too heavily dependent on the degree of contamination, type of oil, and substrate, and therefore cannot realistically be quantified.

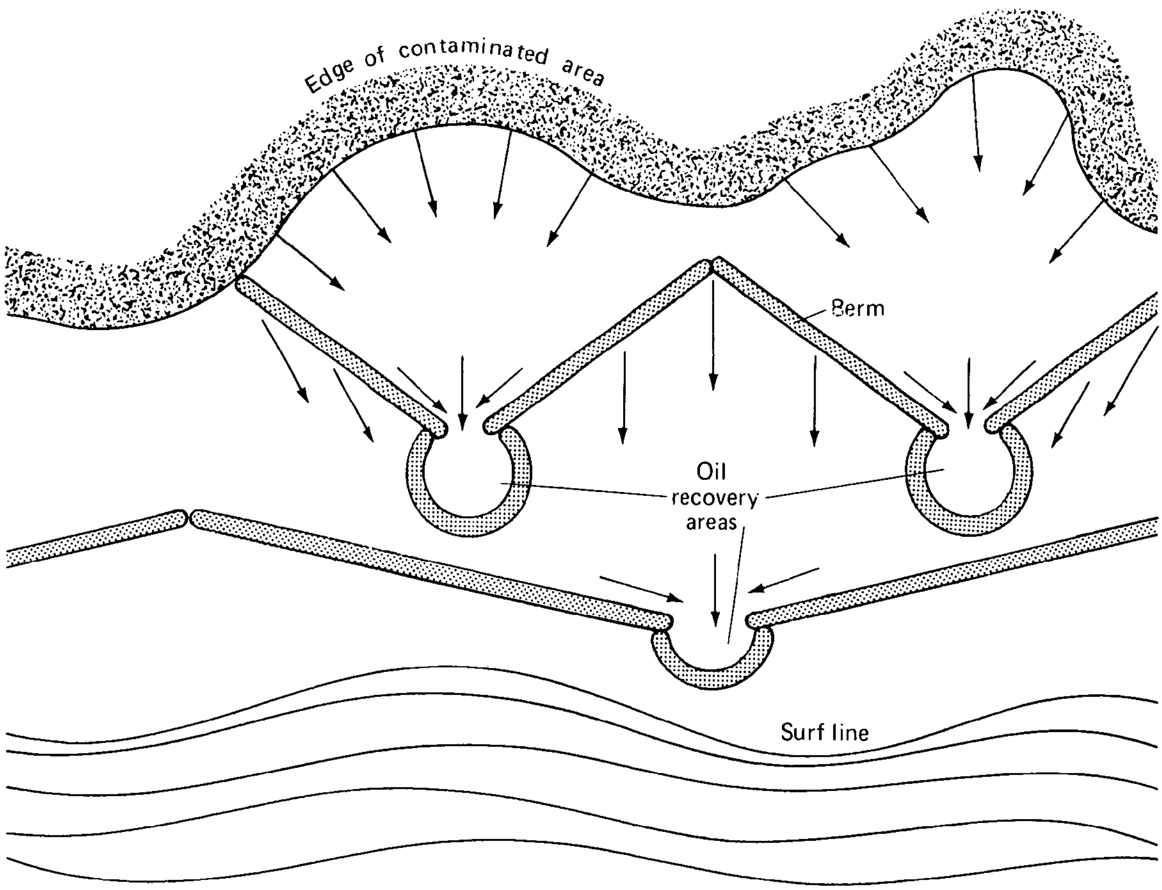

Figure 805-10. Low pressure flushing tactics.

Logistic Requirements

The logistical requirements for using low pressure flushing will vary with the degree and type of oil contamination, the shoreline configuration, and size of oiled area. The larger the area, the higher the degree of contamination; the more severe the shoreline relief, the greater the number of flushing units needed. Table 805-14 gives the logistic requirements for a 2-km (1.2-mi) length of lightly contaminated shoreline with low relief.

TABLE 805-14. LOGISTICAL REQUIREMENTS FOR LOW PRESSURE FLUSHING

Item	Type	Number Required
Equipment		
• Flushing unit (pump & hoses)	10-20 psi pressure @ 50-100 gal/min	3-5
vacuum truck	110 barrel capacity	1-2
or		
• Trash pump and	50-75 gal/min	1-2
tank truck	125 barrel capacity	1-2

Personnel - 1 to 2 per flushing or recovery unit and 1 supervisor

Access requirements - heavy equipment, barge or landing craft for trucks and light vehiclular, shallow craft, or helicopter for flushing unit

Beach Cleaner

Use

The use of a beach cleaner is a rapid method of cleaning sand or gravel beaches lightly contaminated with oil in the form of hard patties or tar balls.

Description of Technique

The majority of beach cleaners operate by being towed behind a tractor or front-end loader. A blade or rotating drum fitted with blades scoops up the top layer of sand, debris, and tar balls and places it on an inclined wire mesh conveyor belt which moves the contaminated material up the belt while allowing the clean sand to fall through. The remaining tar balls, patties, and debris are dumped into a refuse container mounted at the rear of the conveyor belt. The conveyor may be one of several types including:

1. A wire mesh screen which carries the material from the pickup point, up the incline to the refuse container. A vibrating screen is sometimes mounted between the conveyor and refuse bin to further separate the material.

2. A bar conveyor which transports the material up a vibrating bar screen and dumps it into the refuse container.

3. A rotating conical screen with two internal auger scrolls which move the material up and back through a hole at the tip of the conical screen and into the refuse container.

Normally, the cutting blade is adjustable to regulate the depth at which the material is removed. The units are equipped with a gasoline engine to power the conveyor and vibrating screen. It may be advantageous to tow the unit with a front-end loader that can also be used to transfer the collected material from the refuse container to a dump truck for disposal.

The specific operating procedure for the beach cleaner is as follows:

1. Cleaning is begun along the backshore edge of the contaminated area.

2. Tractor is operated in second and third gears at 3 to 10 km/hr (2 to 6 mph) depending on the beach sediment and cut depth.

3. A path is cleaned along the entire length of the contaminated area.

4. The tractor is turned around and a new path is cleaned adjacent to, and slightly overlapping, the previous path.

Figure 805-11 displays the cleaning pattern for a beach cleaner.

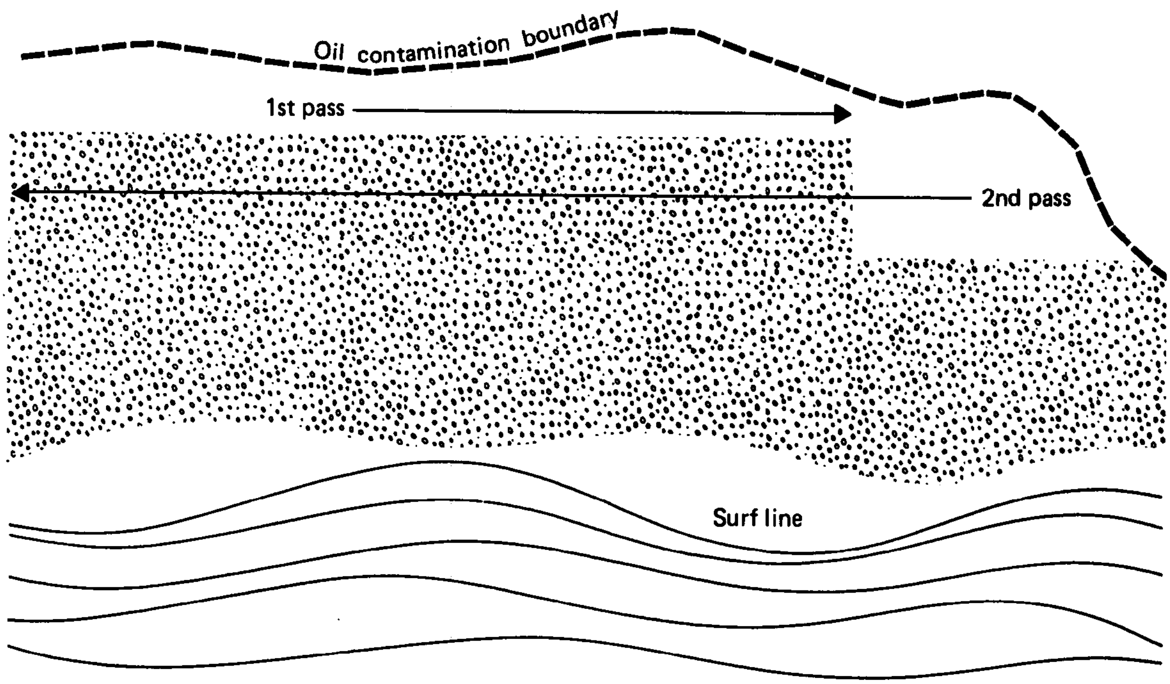

Figure 805-11. Cleaning pattern for use of beach cleaner.

Cleaning Rate

The shoreline area that can be cleaned within a specified time using a beach cleaner is dependent primarily on the width of the cleaner and the speed at which it is towed. The cleaning rate for a 6 ft wide beach cleaner towed at 6.4 km/hr (4 mph) is 3/4 to 1 hr/hectare (approximately 1/2 hr/acre).

Logistic Requirements

The logistical requirements for using a beach cleaner are dependent on the size of the contaminated area. Since the cleaning rate of the beach cleaner is high, most shoreline areas require only one tractor and cleaner to effectively remove tar balls or patties under normal circumstances. Table 805-15 gives the logistical requirements for a 2-km (1.2 mi) length of beach.

TABLE 805-15. LOGISTICAL REQUIREMENTS FOR USE OF A BEACH CLEANER

Item	No. of Pieces	Cleaning Rate
Equipment		
• Beach cleaner operated at 6.4 km/hr (4 mph) taking a skim cut	1	1 hr/hectare
• operated at 1.6 km/hr (1 mph) taking a deep cut	1	3 1/2 hr/hectare
Personnel - 1 operator for each piece of equipment		
Support	Diesel Fuel Requirements	
• Rubber-tired tractor	8-14 gal/hr	
Access requirements - heavy equipment, barge, or landing craft		

Manual Sorbent Application

Use

Given current methods of cleanup, recovery, and disposal, sorbents are not recommended for use in the initial phases of oil spill cleanup on shorelines. However, they can be used to remove small pools of light, non-sticky oil from mud, boulders, rock, and man-made structures. Sorbents can also be used to remove thin films or iridescence occurring during final cleanup phases and to prevent oil contamination of facilities such as walkways and work areas during the cleanup operation.

Description of Technique

Sorbent materials are presently available in four forms:

1. squares and strips (pads)
2. rolls and sweeps
3. sorbent booms and pillows
4. loose material

Each form of sorbent is usually associated with a slightly different method of application and situation for which it is used. The specific procedures for the use of each sorbent are given in Table 805-16.

Cleaning Rate

Not applicable.

Logistic Requirements

Not applicable.

TABLE 805-16. SORBENT MATERIALS APPLICATION TECHNIQUES

Form of Sorbent	Description of Technique
1. Squares and Strips (Pads)	• Placed in confined areas to pick up small quantities of oil; they should be left for a period of time for greater effectiveness.
2. Rolls	• Used in the same manner as squares and strips but usually more convenient since they can be torn or cut off at the optimum length.
	• Very effective in protecting walkways, boat decks, working areas, previously uncontaminated or cleaned areas; can be used to cover areas used as temporary storage sites for oily materials.
	• Disposal is facilitated by rolling up sorbent and placing in suitable container.
3. Booms	• Can serve a dual function by absorbing oil and acting as a boom but is only effective in very quiet waters.
	• The tightly compacted sorbent material encased in mesh restricts oil penetration thus requiring the boom to be rotated and moved around in the oil to work efficiently. It is usually better to drive the oil into the boom.
	• Can be used effectively to protect sheltered areas against oil contamination. Also can be deployed behind skimmers to pick up excess or missed oil.
	• Disposal is accomplished by folding, rolling, and/or stuffing the boom into plastic or burlap bags for removal.
4. Loose Materials	Loose sorbent materials are not recommended for use in oil spills on water for the following reasons:
	• Without efficient means of recovering loose sorbent materials, tidal action, wind, and currents will disperse oil-soaked sorbents over a large area, thus complicating the cleanup effort.

TABLE 805-16 (Continued). SORBENT MATERIALS APPLICATION TECHNIQUE

Form of Sorbent	Description of Technique
	• Large-scale recovery of loose sorbents such as straw, polyurethane foam, and peat moss is not considered practical in open water, and at the present time no effective equipment is available for this purpose. • Loose sorbent materials tend to clog vacuum equipment when they are used for oil pickup. Loose sorbent materials may have limited applicability in the cleanup of oil from land areas where pools of oil have formed in depressions.

Manual Cutting

Use

Used on oil-contaminated vegetation whose removal is necessary to avoid leaching and recontamination. This method is labor-intensive and can cause severe erosion, particularly if root systems are damaged.

Description of Technique

Manual cutting requires moderate to large crews equipped with shears, power brush cutters, scythes or other devices. The crews should be split into cutters, debris handlers, and baggers for an efficient operation.

1. Before cutting, the areas to be cleared should be boomed so that oil freed during the procedure can be contained. Likewise, cleared areas should be protected from recontamination until that threat is eliminated.

2. Cutting should begin at the upstream end of the area and should work downstream, thus limiting the possibility of recontamination.

3. The bulk of the cutting must be done at low tide, beginning at the water line and working ahead of the tide.

4. The debris handlers should follow the cutters, collecting the oiled vegetation in small piles to be placed in plastic or burlap bags and removed by the bagger group. Debris may be piled directly onto barges or small flat-bottom boats for disposal if cutting is adjacent to a waterway.

5. Cut vegetation that is stockpiled on the site for a period of time should be stored above the high-water line on plastic sheets, tarps, sorbents, or burlap.

6. Oil lost during cutting can be recovered later by flushing or skimming.

Cleaning Rates

Cleaning rates depend primarily on the size of the crew, how heavily vegetated the area is, and the equipment used. Power cutters can obviously cut faster than shears or scythes. The cleaning rate for a ten-man crew consisting of one foreman, two cutters using scythes, three debris handlers, and four baggers operating on a heavily vegetated shoreline is approximately 65 m^2 (77 yd^2)/hr.

Logistic Requirements

The logistical requirements for manual cutting will vary with the size of the contaminated area, the number of workers, and the amount of vegetation. Table 805-17 gives the logistical requirements cleaning for a moderately vegetated 2-km (1.2-mi) length of shoreline.

Table 805-17. LOGISTIC REQUIREMENTS FOR MANUAL CUTTING

Item	Number Per Crew
Equipment	
• Cutting tools - (scythes, power cutters, shears, etc.)	3 - 4[a]
• Collecting tools - (pitch forks, rakes, etc.)	4 - 6
• Plastic or burlap bags	75 - 100
• Rolls of ground cover - (plastic film, burlap, sorbents, etc.)	1 - 3
Personnel - 5 crews of 10 workers each and 1 supervisor	
Access Requirements - foot, shallow craft, or helicopter	

[a]Should have one or two extra in case of breakage or dull blades.

Burning

Use

Used on coastal or inland substrates and vegetation where sufficient oil of a proper type has collected to sustain ignition. Consideration must also be given to the potential environmental damages resulting from burning.

Description of Technique

The feasibility of burning should be determined by test ignition of an oiled area away from the actual site. Relatively high temperatures may be required for ignition, but once ignited the fire must be self-sustaining to be effective. Once "burnability" has been demonstrated, permits must be obtained from appropriate regulatory agencies such as the EPA, state fish and wildlife agencies, and local air pollution agencies. Public and wildlife safety and potential air pollution strongly affect the granting of permits.

Specific operational procedures for burning are:

1. A plan that provides for safe, controlled burning should be prepared.

2. If the area is very large, it may be necessary to section it off with fire breaks to ensure controlled burning.

3. The fire is started on the upwind side of the contamination area or section. A combustion promoter or flame thrower may be required initially to sustain ignition until sufficient heat is generated to maintain the burning.

4. The fire would be allowed to burn until exhausted or until it reaches a barrier.

Figure 805-12 displays burning tactics.

Cleaning Rate

Not applicable.

Logistic Requirements

The logistical requirements for using the burning technique are concerned primarily with maintaining combustion and controlling the fire. The amount of heat required is dependent on the ambient temperature and flamability of the oil. The number of flame throwers or amount of combustion promoters is dependent on the variables previously mentioned in addition to the size of the initial area to be ignited. Table 805-18 gives the logistical requirements for burning an oiled area.

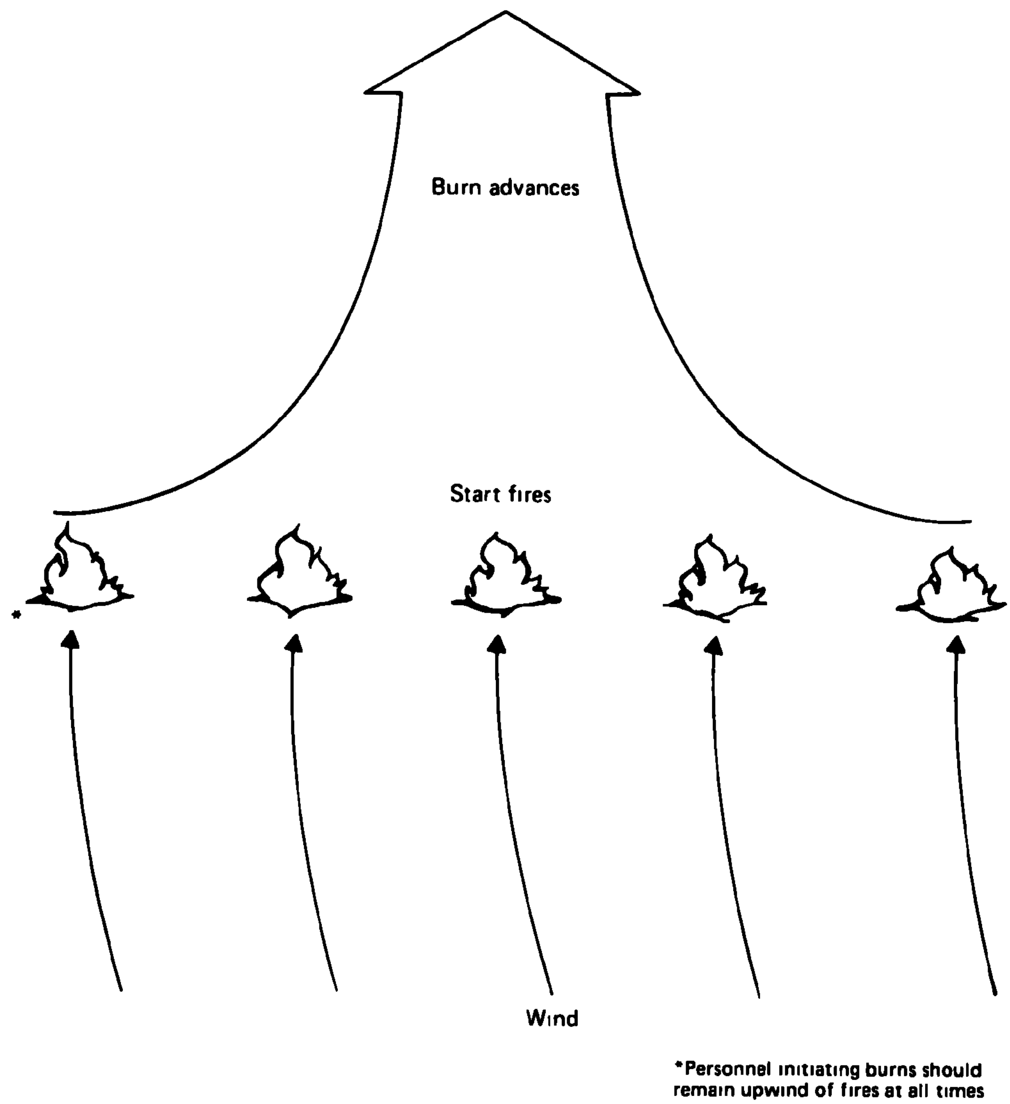

Figure 805-12. Method of initiating burn of oil contaminated areas.

TABLE 805-18. LOGISTICAL REQUIREMENTS FOR BURNING

Item	Type
Equipment	
• Flame thrower	Propane, kerosene, gasoline, etc.
• Fire fighting equipment	Small fire trucks or portable fire pumps with nozzles
Materials	
• Burning agents	Chemicals, gasoline, diesel fuel, napalm, or flammable materials (rags soaked in diesel fuel, wood chips, dried brush, etc.)
Personnel - 2 to 3 to ignite and control fire and 1 supervisor	
Access requirements - Foot, shallow craft, or helicopter	

Vacuum Trucks

Use

It is best used to pick up oil which has collected in pools on the shoreline, but can also be used to skim relatively thick layers of oil off the surface of the water. The latter use is somewhat inefficient, as rather large quantities of water are usually collected along with the oil. This technique is, however, invaluable in the absence of skimming equipment.

Description of Technique

When vacuum trucks are used to pick up oil which has formed pools in shoreline depressions the procedure is as follows:

1. Truck is backed up to pool of oil.
2. Suction hoses are placed in the oil, maneuvered manually until all oil is removed.
3. A screen should be placed over the suction nozzle to prohibit any debris that can cause serious and expensive damage from entering the vacuum truck system. Finer-mesh screens should be used for light oils, such as kerosene, while coarse screens are needed for heavy oils.

If used to collect oil from a water's surface, the same procedure is used with the addition of booms or some means of concentrating the oil to increase the ratio of oil to water collected.

Cleaning Rate

Not applicable.

Logistical Requirements

The logistical requirements for using the vacuum truck technique will vary with the amount of oil to be picked up and whether it is on land or water. The larger the quantity of oil to be collected, the more vacuum trucks required. Oil recovery from water also requires more trucks due to the large amount of water collected in conjunction with the oil. Table 805-19 gives the logistical requirements for using vacuum trucks to pick up oil.

TABLE 805-19. LOGISTICAL REQUIREMENTS FOR THE VACUUM TRUCK TECHNIQUE

Item	Typical Suction Rate for Pooled Oil	Typical Suction Rate for Oil on Water	Fill Time for 110-Barrel Truck
Equipment			
• Vacuum truck w/ 3 in suction Hose	100 gpm (75% oil)	50 gpm (5% oil)	3/4 hr @ 100 gpm 1 1/2 hr @ 50 gpm
• Number of vacuum trucks required	Dependent on quantity of oil and number of pools present	Dependent on quantity of oil and number of recovery sites. Also on oil/water ratio	

Personnel - 1 person per suction hose and 1 to 2 persons for manual skimming and concentrating of oil, and 1 supervisor

Support	Range of Capacities
• Vacuum truck	• 6 to 140 barrel @ 42 gal/barrel
6 in suction hose	700 to 800-900 gpm max.[a]
4 in suction hose	500 to 600 gpm max.[a]
3 in suction hose	300 to 400 gpm max.[a]
• Devices for concentrating oil on water	• Booms, skimming boards, low-pressure water hoses

Access requirements - heavy equipment, barge, or landing craft

[a]Intake completely submerged, drawing water with little or no suction lift.

Push Contaminated Substrate into Surf

Use

This technique is used primarily on lightly contaminated cobble and gravel beaches where removal of sediments may cause erosion of beach or backshore area.

Description of Technique

Bulldozers are used to push the contaminated layer of sediments into the lower intertidal area where wave action and increased cobble or gravel movement will remove the majority of the oil from the sediments and accelerate degradation rates. The sediments are returned to the beach within a relatively short period of time through natural wave and tidal action. Specifically, the sequence of operational procedures is as follows:

1. Preferably this operation is carried out at low tide to avoid the equipment operating in the water.

2. If a longshore current is present, cleaning should begin at the up-current end of the contaminated area.

3. The bulldozer is operated in first gear, cutting to a depth not exceeding that of oil penetration.

4. Starting from the backshore side, the oiled sediment is pushed straight into the lower intertidal area.

5. The dozer is returned to starting point by backtracking on cleaned area.

6. Dozer is repositioned for second pass which should run adjacent to, and slightly overlapping, the previous pass.

7. Figure 805-13 displays the cleaning pattern for pushing contaminated substrate into the surface.

Cleaning Rates

How much shoreline area can be cleaned within a specified time is dependent on the size of the bulldozer and width of the blade used. For a medium-size dozer with a 3-m (10-ft) blade, the cleaning rate is approximately 4-1/2 to 5 hr/hectare (1-3/4 to 2 hr/acre).

Logistic Requirements

The logistical requirements for using a tracked bulldozer to push the contaminated substrate into the surf will vary with the length and width of the oiled area. If the area is very large, several bulldozers may be needed to maintain a reasonable cleaning rate.

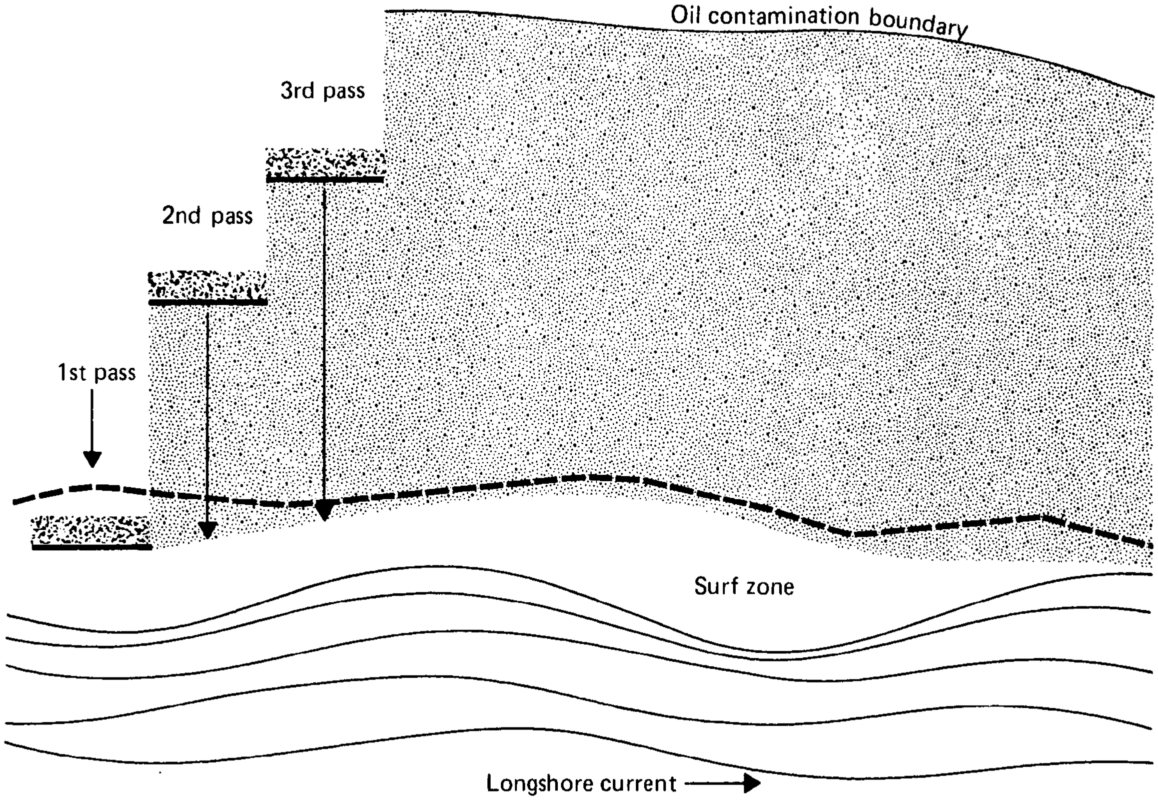

Figure 805-13. Cleaning pattern for pushing contaminated substrate into surf.

Table 805-20 gives the logistical requirements for a 2-km (1.2 mi) length of beach.

TABLE 805-20. LOGISTICAL REQUIREMENTS FOR BULLDOZING CONTAMINATED SUBSTRATE INTO SURF

Item	For 20-m (66-ft) Wide Area	For 50-m (165-ft) Wide Area	Combined Cleaning Rate
Equipment			
• Bulldozer	2	5	Approx. 2-1/2
Personnel - 1 operator for each piece of equipment and 1 supervisor			
Support	Diesel Fuel Requirements		
• Tracked-type • Bulldozer	4-14 gal/hr		
Access requirements - heavy equipment, light vehicular, barge, or landing craft			

Breaking up Pavement

Use

This method can be used on high-energy, low-amenity cobble, and on gravel or sand beaches where thick layers of oil have created a pavement on the beach surface and substrate removal will cause erosion. Because this technique leaves the oil on the beach to degrade naturally, it should be used only on remote, non-recreational or low-priority beaches.

Description of Technique

Pavement is broken up by a tracked bulldozer or front-end loader fitted with a ripping apparatus on the rear of the tractor. The ripper consists of two or three large, curved teeth which are dragged through the pavement by the forward movement of the tractor. The specific sequence of operating procedures are:

1. Operate the tractor in first gear at 1.6 to 3.2 km/hr (1 to 2 mph).
2. Set the rippers to a depth slightly below the pavement thickness.
3. Begin ripping along the backshore edge of the pavement-covered area, operating parallel to the surf line.
4. Continue to end of contaminated area or approximately 200 to 300 m in distance.
5. Tractor is turned around and repositioned to rip a path in the opposite direction adjacent to the previous one.

Figure 805-14 displays the cleaning pattern for breaking up pavement with a tractor/ripper.

Cleaning Rate

The rate of cleaning a shoreline area using this technique is dependent on the operating speed of the tractor. Although pavement will probably rip easily with little resistance, the ripping speed should be kept under 3.2 km/hr (2 mph) to facilitate the formation of smaller pieces and extend the service life of the ripping teeth. For an operating speed of 2.4 km/hr (1-1/2 mph) on a 300- by 3-m pass, the cleaning rate is 20 min/hectare (9 min/acre).

Logistic Requirements

The logistical requirements for using the ripping technique for breaking up pavement will vary with the size of the pavement-covered area. If the contaminated area is exceptionally large, several tractor rippers may be required to maintain a reasonable cleaning rate. Table 805-21 gives the logistical requirements for a 2-km (1.2-mi) length of beach.

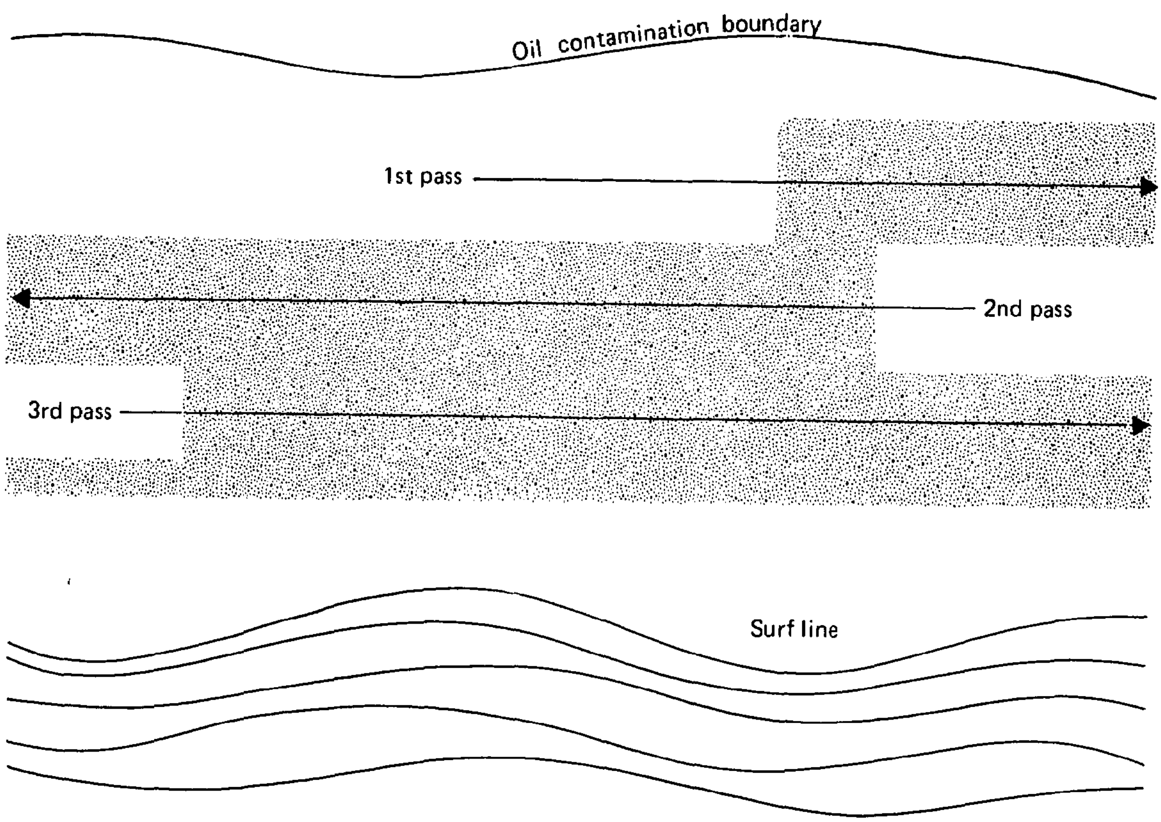

Figure 805-14. Cleaning pattern for breaking up pavement.

TABLE 805-21. LOGISTICAL REQUIREMENTS FOR USING A TRACTOR/RIPPER FOR BREAKING UP PAVEMENT

Item	For 20-m (66-ft) Wide Area	For 50-m (165-ft) Wide Area
Equipment		
• Tractor/ripper	1	2
Personnel - 1 operator for each piece of equipment and 1 supervisor		
Support		
• Tracked-type • Tractor/ripper	4-14 gal/hr	
Access requirements - heavy equipment, light vehicular, barge, or landing craft		

Disc into Substrate

Use

Used on nonrecreational sand or gravel beaches which are lightly contaminated and of moderate to good trafficability. Although this technique is very fast and efficient, the oil is not removed but buried into the top layer of sediments and left to degrade naturally.

Description of Technique

The oil is disced into the substrate using a tracked loader or tractor towing a discer. Thus discing equipment is the same as that used for tilling agricultural fields. The specific operating procedure for discing into the substrate is:

1. Begin along the backshore edge of the contaminated area.

2. Operate the tractor in second gear and continue to the end of the contaminated area or approximately 200 to 300 m in distance.

3. The tractor is turned around and a new path is started adjacent to, and slightly overlapping, the previous one. Figure 805-15 displays the cleaning pattern for discing.

Cleaning Rate

The shoreline area that can be cleaned within a specified time by discing the oil into the substrate is governed by the speed of the tractor and the width of the discing equipment. The cleaning rate for a 2.5-m (8-ft) wide discing machine towed at approximately 6.4 km/hr (4 mph) is 3/4 to 1 hr/hectare (1/4 to 1/2 hr/acre).

Logistic Requirements

The logistical requirements for discing into the substrate are primarily dependent on the size of the contaminated area. Under normal circumstances, unless the area is very large, one tractor and discing machine can usually maintain a sufficient cleaning rate. Table 805-22 gives the logistical requirements for a 3-km (1.2-mi) length of beach.

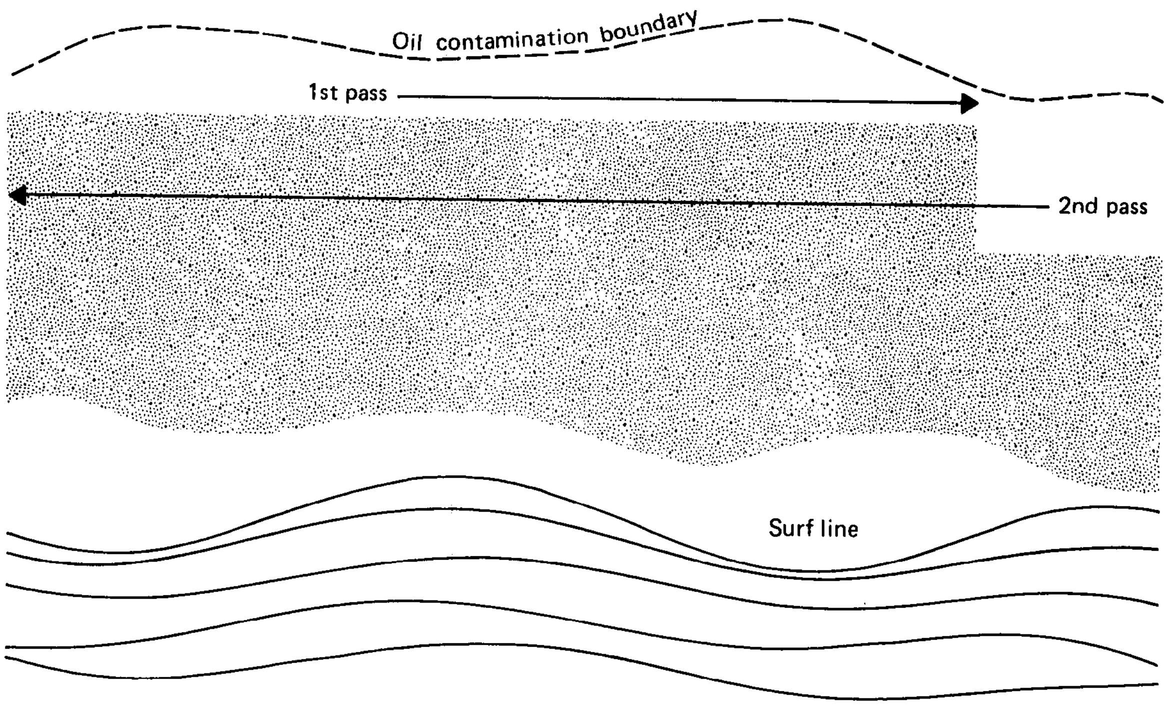

Figure 805-15. Cleaning pattern for discing
into substrate technique.

TABLE 805-22. LOGISTICAL REQUIREMENTS FOR DISCING INTO SUBSTRATE

	No. of Pieces	Cleaning Rate (hr/hectare)
Equipment		
• Track-type tractor and 8-ft wide discer	1	3/4 to 1
• w/ 12-ft wide discer	1	1/2 to 3/4

Personnel - 1 operator for each piece of equipment and 1 supervisor

Support	Diesel Fuel Requirements
• Track-type tractor	2 1/2 to 9 gal/hr

Access requirements - heavy equipment, barge, or landing craft

Natural Recovery

Use

Used on oil-contaminated high energy beaches (primarily cobble, boulder, and rock) where wave action will remove most of the oil in a relatively short period of time. This method sometimes becomes a necessity for shorelines with no access or where cleanup operations would be environmentally hazardous.

Description of Technique

No action is taken, shoreline should be monitored periodically to determine if natural cleaning is sufficient.

Cleaning Rate

Varies with amount of wave energy on shoreline.

Logistic Requirement

Not applicable.

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(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The purpose of this manual is to provide the on scene field user 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.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
MANUALS	Oil Spills	43
OILS	Clean-up	68C
SHORES	Restoration	68D
BEACHES	Protection	85
		91

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