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The Impact and Cleanup of Oil Spills on Canadian Shorelines: A Summary

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THE IMPACT AND CLEANUP OF OIL SPILLS ON CANADIAN SHORELINES: A SUMMARY

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ABSTRACT

The structure of Canadian shorelines is described in terms of 10 basic types: rock surfaces, cliffs, coarse sediment beaches, sand beaches, intertidal coarse sediments, intertidal sand, intertidal mud, marshes, backshore areas and man-made structures. The expected impact of oil and cleanup strategies for each type of shoreline are presented.

RÉSUMÉ

Les formes des rivages du Canada sont décrites à l'aide de 10 types de base: rochers, falaises, plages à sédiments grossiers, plages de sable, sédiments grossiers intertidaux, sable intertidal, boue intertidale, marais, hautes plages et ouvrages édifiés par l'homme. Les répercussions de la marée noire et les stratégies de nettoyage s'appliquant à chaque type sont exposées.

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1 SHORELINE TYPES

1.1 Introduction

The coastal geomorphology of Canada's shorelines can be discussed in terms of 10 basic shoreline types such as cliffs, beaches, marshes, etc. The objective of this shoreline-type approach is to provide a basic outline of the variations in Canada's coastal geomorphology. This information must then be related to the littoral processes in order to assess the impact and persistence of oil on a particular section of coast.

The 10 shoreline types are as follows:

1. Rock Surfaces
2. Unresistant or Unconsolidated Cliffs
3. Coarse Sediment Beaches
4. Sand Beaches
5. Intertidal Coarse Sediments
6. Intertidal Sand
7. Intertidal Mud
8. Marshes
9. Backshore Areas
10. Man-made Structures

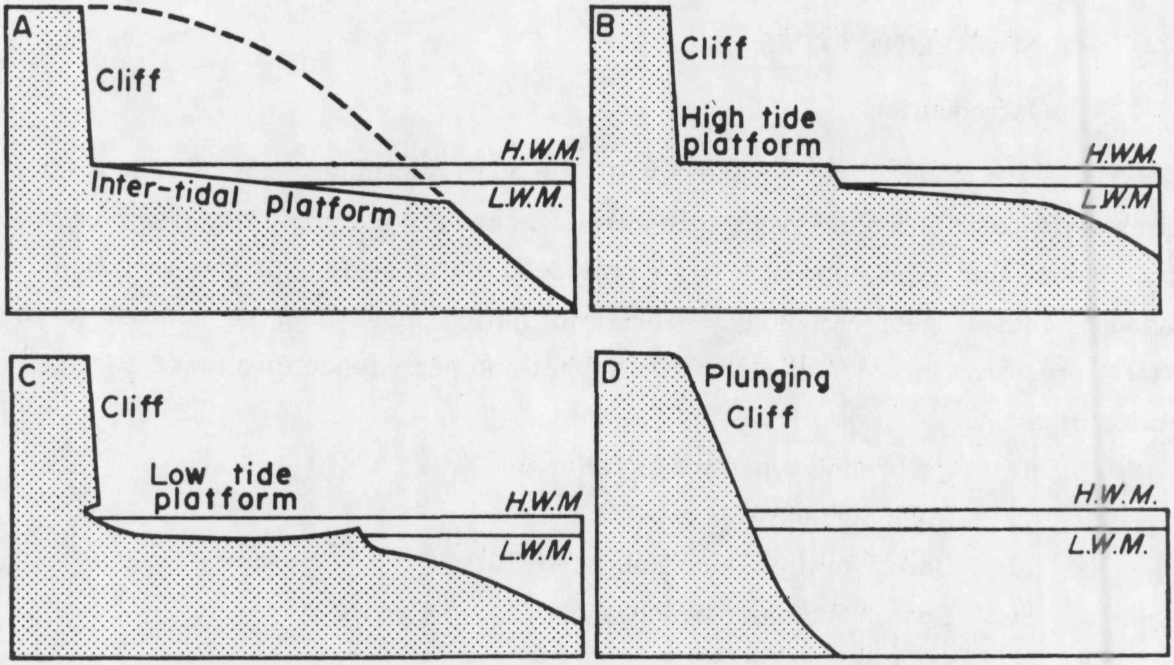
The information in this report is summarized from the publications:

- "Coastal Environments of Canada: The Impact and Cleanup of Oil Spills", Department of Fisheries and the Environment, EPS 3-EC-77-13.
- "Coast Environments, Oil Spills and Cleanup Programs in the Bay of Fundy", Department of Fisheries and the Environment, EPS 3-EC-77-9.

1.2 Rock Surfaces

This category includes rocky cliffs and rock platforms that are resistant to wave force and weathering. Although these coasts are subject to erosion, the rates of shoreline retreat are barely perceptible over decades or even centuries.

Where rocky coasts have no beach or intertidal wave-cut platform (Figure 1) the morphology of the shoreline is controlled by the nature of the rock and the overall gradient across the coast (Plate 1).



HWM - High Water Mark
LWM - Low Water Mark

Fig.1 - Cliff erosion results in the formation of a platform in the littoral zone (A,B,C) unless the rates of erosion are extremely low due to the resistant nature of the rock (D)

Plate 1
A Rocky Coast

Backshore erosion results in the formation of a platform unless the nearshore zone is deep (Figure 1). The width and nature of the platform depend on the rock or sediment type and the internal structure of the material.

Intertidal platforms generally vary in width from a few metres to as much as 15 km.

The main characteristic to be noted about intertidal rock shorelines is that *sediments do not provide a protective cover*; wave and tide-induced processes act directly on the rock surfaces. Frequently, flora (algae or "seaweed") and fauna cover the intertidal rock surfaces; and there are many biologically rich tidal pools that do not drain completely at low tide.

1.3 Unresistant or Unconsolidated Cliffs

This type of shoreline is made up of sedimentary rocks or unconsolidated glacial deposits with relatively high erosion rates (to a maximum of 2 m/year) (Plate 2). The retreat of unresistant rock coasts, such as the sandstone cliff illustrated in Plate 3, can result from erosion of a notch at the high-water level; a rockfall will ensue once an unstable situation is created.

Erosion can also result from weathering such as frost action. Water expands when frozen and contracts when thawed; numerous freeze-thaw cycles lead to fragmentation and rockfalls from cliff faces. Vertical cliffs are uncommon in areas where unresistant rocks or unconsolidated deposits are predominant. Cliff retreat results primarily from landslips (slumping or sliding), particularly after heavy rains or storms. Wide intertidal wave-cut platforms are common on unresistant coasts and are usually covered with sediment supplied by local erosion. If cliffs are located in a sheltered environment, their rates of retreat are much slower and intertidal platforms are much narrower. As sheltered areas are usually drowned lowlands, backshore relief is not high; consequently, cliff heights are low.

1.4 Coarse Sediment Beaches

According to the size of the sediment, beaches can be classified as consisting of coarse sediment (e.g. pebble-cobble) or sand. A beach consisting of unconsolidated sediments in the coastal zones exists between the low-water mark and the landward limit of storm-wave activity. Figure 2 shows a typical beach profile.

Plate 2

An Unresistant Cliff

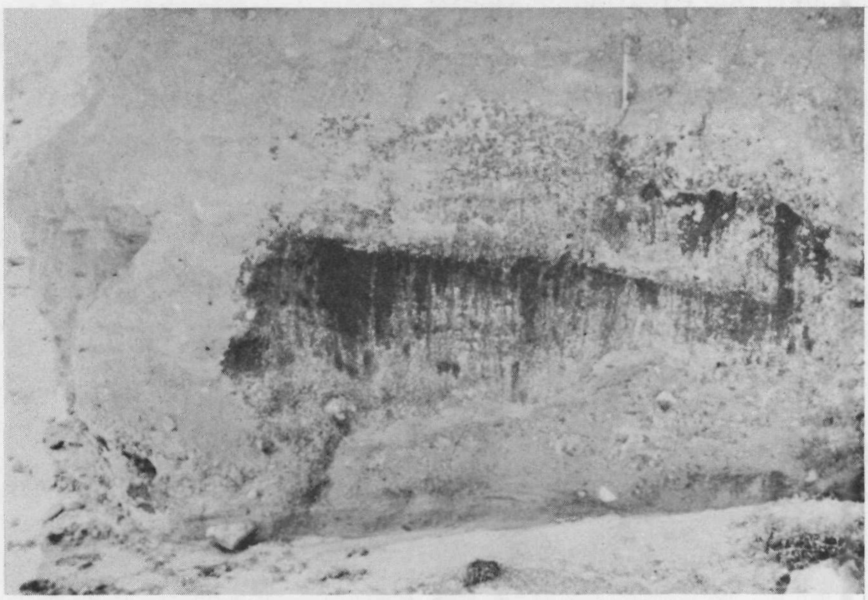


Plate 3

An Unconsolidated Sandstone Cliff

The following is a glossary of common terminology used in describing beaches:

BACKWASH - the movement of water down the beachface slope after a wave has broken and surged up the beach;

BEACHFACE - the upper part of the foreshore that is between the low and high-water marks and is exposed to swash action; usually the beachface has the steepest slopes (to 40°) in the beach zone;

BERM - a zone above the beachface; it is nearly horizontal and is above the limit of normal wave action;

BERM CREST - the seaward limit of the berm;

STORM RIDGE - a ridge formed in the backshore above the high-water mark by wave action during storms; this ridge is changed only by subsequent storm waves;

SWASH - the rush of water up a beachface that follows breaking of the wave.

Coarse sediment beaches have a narrower and steeper beachface slope than sand beaches. A second effect of sediment size and the predominance of swash over backwash may be the construction of a ridge landward of the berm (Figure 3). This ridge, built by swash action during periods of storm waves, pushes material up the beach. It is a natural dyke that is breached or overwashed only during major storms.

If there is a net loss of material from the intertidal zone due to low rates of sediment input from alongshore, a slow, net-landward movement of the beach system results.

1.5 Sand Beaches

Sand beaches are governed by the same processes as, and are similar in form to, mixed-sediment beaches. The exception is the development of storm ridges: waves wash sand over the berm during storms, producing a flat backshore berm.

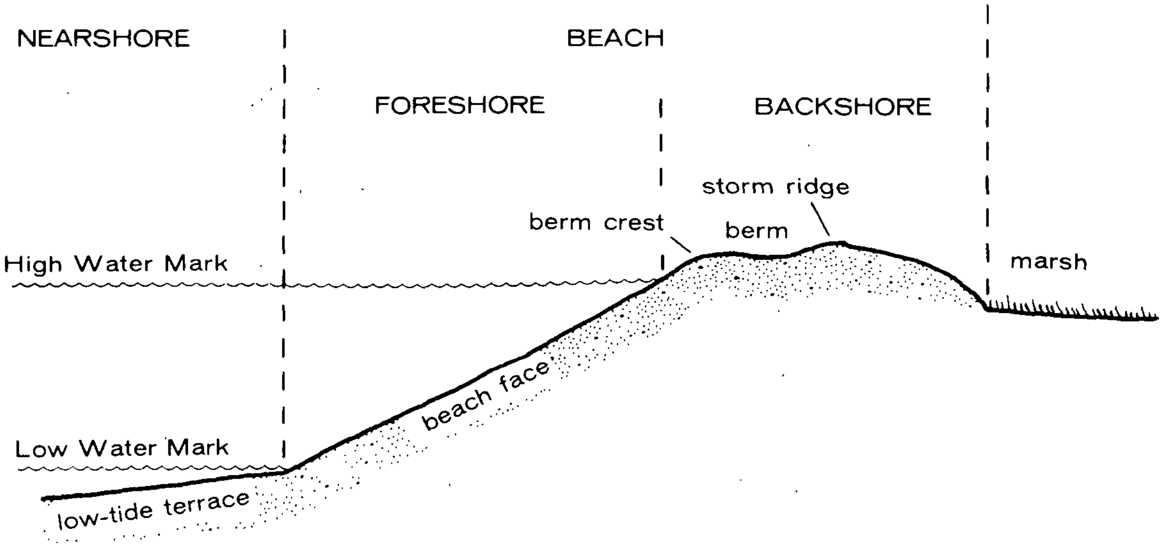


Fig.2 - A Beach Profile

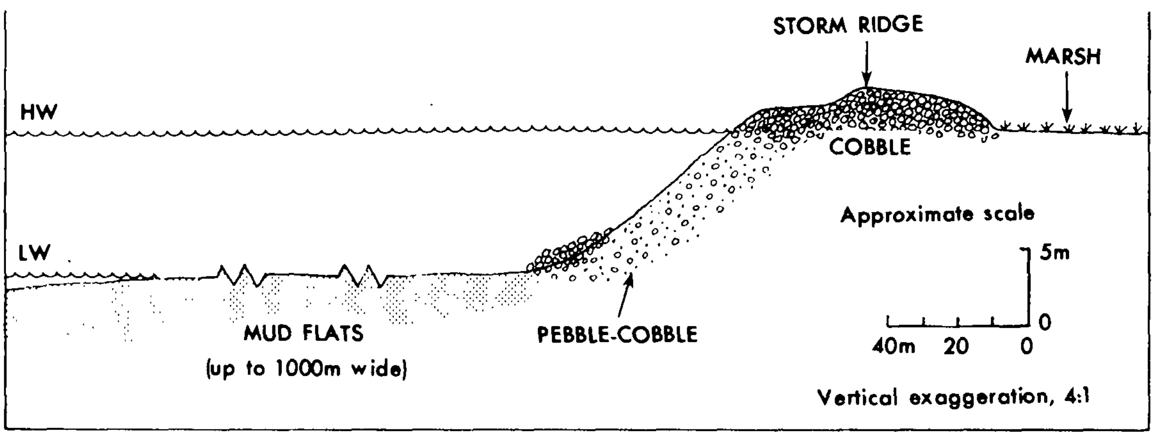


Fig.3 - Cross-section of a Pebble-Cobble Beach

Plate 4

Oil Deposit Above High-Water Mark Level of Sand Beach

Plate 5

A Pocket Beach

Due to the fact that the swash cannot percolate into the beach rapidly, the swash continues its uprush farther and usually moves right across the berm.

The berm may become colonized by salt-tolerant plants that initiate small dune systems by trapping wind-blown sand. If the vegetation withstands subsequent storm wave activity, a dune system will develop slowly.

1.5.1 Pocket Beaches. Pocket beaches are isolated beaches along coastlines of rock or cliffs. For cleanup purposes they may be treated as special types of beaches (either coarse sediment or sand). It should be noted that pocket beaches are collectors of sediment and oil. Material removed from this type of beach during cleanup should be replaced to prevent retreat of the beachface. Plate 5 illustrates a typical pocket beach.

1.6 Intertidal Coarse Sediments

Sediments on a platform (Plate 6) protect the rock surfaces from abrasion and erosion unless the layer of material is thin, in which case the sediments become an abrasive tool. As rates of wave energy decrease and sediment size increases, the ability of littoral processes to move sediment decreases and results in lower rates of abrasion.

1.7 Intertidal Sand

Shorelines of intertidal sand are characterized by migrating sand waves of different sizes that result in local erosion and deposition of surface sediments. Frequently, at low tide, the troughs between the sand waves are wet or contain standing water. Sand waves are typical in areas where wide intertidal flats are exposed and where there is an abundant supply of sediment.

On beaches where a variety of sediment sizes are supplied to the littoral zone and where sufficient wave energy is available to sort this material, sand is usually deposited on the low-tide terrace. Coarser material is transferred to the beachface slope and the upper parts of the beach. The sandy, low-tide terraces are usually flat and have high water content (Plate 7).

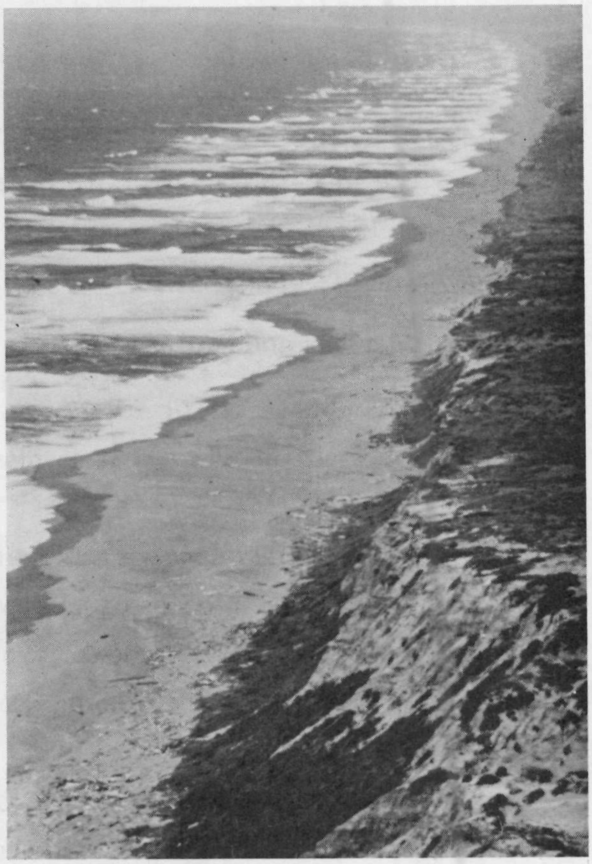


Plate 6
Intertidal Wave-cut Platform

Plate 7
Intertidal Sand Flats

1.8 Intertidal Mud

Deposits of this kind occur primarily in areas sheltered from wave activity. The mud flats, which are often characterized by a network of creeks and channels (Plate 8), are either extensive features or are restricted to the lower intertidal zone of pocket beaches.

1.9 Marshes and Deltas

The characteristic form of marsh is one of a flat, vegetated surface above the normal high-water level that is dissected by muddy, non-vegetated creeks and channels.

Marshes develop when vegetation encroaches on the sediments of the upper intertidal zone. In cases of relatively new marsh development, the edges are a zone in which this encroachment is slow, whereas old marsh edges are scarps (resistant formations usually standing above normal terrain) eroded by waves at the limit of normal high tides.

In areas of high tidal range, creeks are frequently deep, have strong tidal currents at the turn of the tide, and dissect the marsh; this makes access to some areas very difficult. On their margins, these creeks or channels often have levées that are slightly above the general level of the marsh surface.

Deltas are similar to marshes in many respects: they are subject to inundation by storm surges, tides, and high river levels. Low-lying areas between river channels are usually marshes (Plate 9).

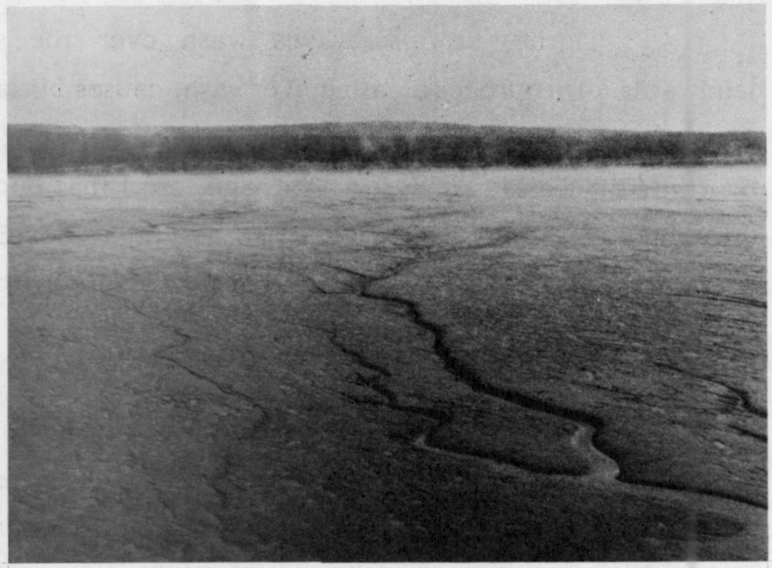


Plate 8
Wide Intertidal Mud Flats

Plate 9
A Delta

1.10 Backshore Areas (overwash, debris, inlets and lagoons)

During storms, waves wash over the storm ridge, pushing material landwards. This process, called overwash, causes burial of the land or marsh landward of the backshore zone (Plate 10). The upper limit of storm-wave activity is marked by a line of debris (wood, logs, garbage, etc.) that normally accumulates at the high-water line and is subsequently carried to a higher level by the storm waves.

Inlets develop primarily where rivers or streams exit from adjacent land areas. The morphology of inlets constantly changes due to the ebb and flood tidal currents.

Lagoons drained by inlets have muddy intertidal zones. Where a closed lagoon or pond is present behind a beach, overwash deposition leads to gradual infilling. Water level changes that result from the adjacent land areas' runoff develop debris lines; these mark the upper limit of the water level. Lagoons or ponds are usually too small to generate significant waves; essentially, these are areas of low energy and little change.

Plate 10
View of Extensive Backshore Area with Marsh

1.11 Man-Made Structures

Piers, docks, breakwalls, etc. are considered as special shoreline types, and are divided into three categories for cleanup purposes: concrete structures, rock or broken concrete structures, and wooden piling structures. Concrete structures are treated in the same manner as rock surfaces. Rock or broken concrete structures such as breakwaters are treated as coarse sediment beaches. Structures on piles such as piers are special cases and must be treated accordingly.

1.12 Effect of Ice on Shorelines

The formation of ice on the water or on the shoreline modifies littoral processes. Waves are not generated in areas where ice cover is continuous; ice on water will generally damp wave action. Furthermore, ice forming on shorelines acts as a defense against waves and oil reaching shorelines. Onshore ice, usually referred to as ice foot, typically forms prior to and persists longer than sea ice. Sea ice, grounding on the beach, can push sediments landward to form a ridge. This ridge, if formed before oil impacts the coastline, could prevent contamination above the ridge; however, should ridge formation take place after oil has been deposited on the beach, the oil would be buried under or mixed with beach sediments.

2 SHORELINE CHARACTERISTICS OF CANADIAN REGIONS

With a few exceptions, the majority of the detailed scientific studies conducted during the last 20 years on Canadian coastlines have involved the lower Great Lakes, the southern portion of the Gulf of St. Lawrence, and the Mackenzie and Fraser Deltas.

Although there is a wide range of geologic, oceanographic, climatic and biologic environments, the coasts of Canada are predominantly low-wave energy environments with rock shorelines or coarse-sediment beaches.

Approximately 90 percent of Canada's total coastline is affected by the presence of ice on the beaches or in adjacent waters. British Columbia is the only ice-free region. Arctic shorelines are affected by ice for more than six months of each year, and the most northern areas may remain ice locked for several successive years.

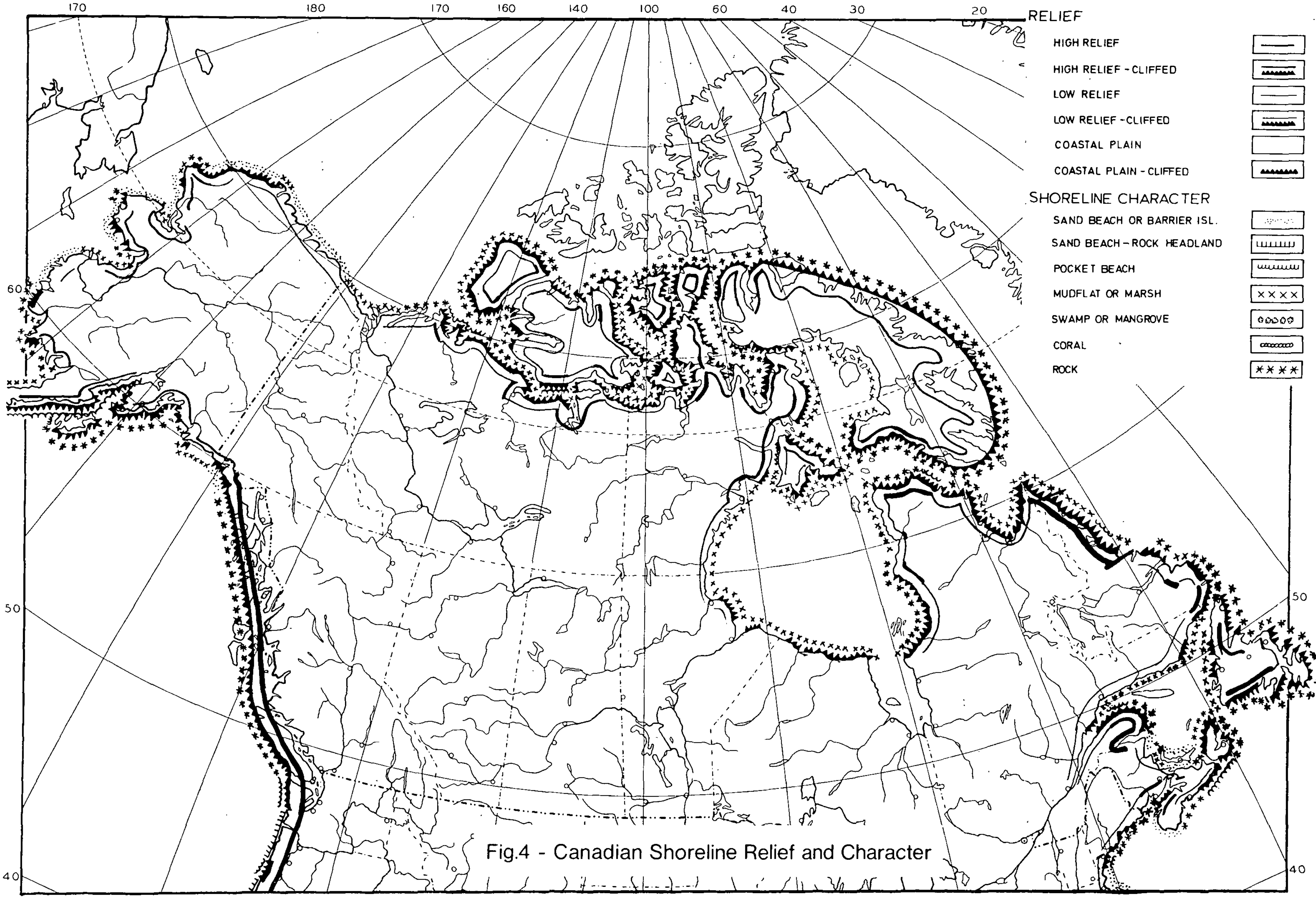


Fig.4 - Canadian Shoreline Relief and Character

2.1 Atlantic Coast

The Atlantic coast of Canada is a predominantly exposed, rocky environment that extends from the United States border to Cape Chidley in northern Labrador. This unit is 45,369 km in length and represents 18.6 percent of Canada's ocean coastline; it includes the large marginal sea of the Gulf of St. Lawrence (a coastline of 7,500 km) and the smaller Bay of Fundy (1,400 km). Within this region there are large variations in tidal ranges and levels of wave energy. The unifying characteristics of the region are the rocky shorelines, the predominance of storm-generated waves and the general scarcity of littoral sediments.

The exposed outer coasts of Labrador, Newfoundland and Nova Scotia are primarily rocky and contrast with the sections of depositional shorelines in the more sheltered Gulf of St. Lawrence and Bay of Fundy. Ice plays an important role in all but the most southerly areas of the Atlantic Coast environment.

2.2 Pacific Coast

The Pacific coast of Canada accounts for 10.5 percent of Canada's total ocean coastline. The dominant characteristic of this region is a structurally controlled coastline of mountains and fjords. Elevations to 4,000 m in the coastal mountain ranges and a complex shoreline of islands, inlets and fjords give the coast an irregular, rugged character. This is a west-facing coast in a mid-latitude location. It is exposed to waves generated in the north Pacific Ocean by the prevailing westerly winds. The exposed coast has a swell-wave environment rather than one dominated by locally generated storm waves. Usually, swell waves are long-period, very regular and lower in height than waves within the area of open water over which they are generated. This coast has high wave-energy levels throughout the year. In contrast to the exposed shorelines, wave-energy levels are very low in sheltered coastal areas.

2.3 Arctic Coasts

This coastal environment includes almost three-quarters of the ocean coastline of Canada. It borders on both the Arctic Ocean and the Baffin Bay-Davis Strait extension of the northwest Atlantic and includes the coasts of Hudson Bay, a large inland sea. Ice plays an important role in modifying shoreline processes and morphology here. These shorelines are affected by ice for more than six months each year.

There is a great variety in the shoreline characteristics, which range from the large delta of the Mackenzie River to the cliffed fjord coasts of Baffin Bay. Sea ice and shore ice determine the length of time during which littoral processes can operate.

2.4 Great Lakes Coast

The Great Lakes system has the largest surface area of freshwater in the world (245,000 km^2). Canada borders the northern shores of Lakes Superior, Erie and Ontario and the eastern and northern shores of Lake Huron; Lake Michigan is entirely within the United States. No measurements are available on the length of Canada's Great Lakes coastline, but it is estimated to be 15,000 km. The lakes form a step-like sequence from Lake Superior (184 m above mean sea level) through Lake Huron (117 m) and Lake Erie (174 m) to Lake Ontario (75 m) that drains into the north Atlantic Ocean through the St. Lawrence River. The coastal processes that affect the shorelines of the Great Lakes are essentially the same as those that operate on open-ocean coasts. The primary differences are the lack of astronomical tides and the relatively small bodies of water, making these sheltered wave-energy environments.

3 EFFECTS OF AN OIL SPILL

3.1 Introduction

The effects of an oil spill on a coast depend on the volume of oil in the spill, the type of oil involved, the climatic and meteorologic conditions at the time of the spill, the shoreline energy conditions (waves and tides), and the morphology and sediments of the shore zone. These factors can be predetermined with some confidence and may be used as the basis for regional and local contingency plans by providing estimates regarding:

- how and where the oil would be deposited;
- the persistence of the oil;
- the suitability of available cleanup techniques to a particular area and the effectiveness of these techniques; and
- guidelines for the cleanup operations.

3.2 Persistence of Oil

The following are the major factors which determine the persistence of oil in various areas:

- the physical and chemical characteristics of crude oil vary considerably from those of refined oil;
- "light" oils have volatile components that readily evaporate on exposure;
- "heavy" oils have a high viscosity and degrade more slowly;
- rates of degradation depend on (a) the physical and chemical composition of the oil and (b) the available energy (thermal or wave);
- shoreline movement of waves, tides, ice and wind all affect oil degradation;
- buried oil degrades very slowly;
- rates of degradation are usually high immediately following a spill;
- the physical and chemical characteristics of spilled oil change constantly.

3.3 Persistence of Oil in Different Coastal Regions

3.3.1 The Atlantic Coast and Oil. Rates of weathering are relatively low during the winter months. Contamination of recreational sand beaches requires a cleanup response. Restoration of these shorelines could be effective. Fog can hamper slick surveillance and shoreline protection during the summer months.

3.3.2 The Pacific Coast and Oil. The relatively warm climate and water temperatures encourage biochemical degradation of stranded oil. Fog can hamper surveillance of slicks and onshore protection. Log debris may protect backshore areas, but could be difficult to remove or burn. Oil trapped by kelp beds and subsequently released may be stranded on adjacent shorelines.

3.3.3 The Arctic Coast and Oil. Natural degradation rates and littoral zone energy levels are very low throughout the year. Ice on the sea or on the beach is present in all areas for at least six months each year. Water sprayed on a surface with ambient temperatures below freezing could form a layer of ice that would protect surfaces from contamination and assist with removal of the oil.

3.3.4 The Great Lakes Coast and Oil. Water level variability is an important factor in predicting the impact of spilled oil. Natural weathering of oil is relatively rapid during the summer months. Dispersion by waves is limited by low wave-energy levels, but available wave energy is usually restricted to a narrow band.

3.4 Shoreline Sensitivity

The sensitivity of a coastal environment is the reaction that results from the alteration of normal processes caused by stranded oil or by restoration programs. Table 1 shows the sensitivity of different shoreline types to oil. The impact of oil spills is generally great in biologically productive environments such as lagoons and marshes. These shoreline types should be given the highest priority for protection and restoration. Conversely, rock or cliff shorelines in high-energy environments have less sensitive ecosystems. Due to high rates of natural dispersion and degradation of the oil, they do not generally require cleanup or protection.

Between these two extremes are a great variety of environments having varying levels of ecological and geological sensitivity.

TABLE 1 SHORELINE SENSITIVITY

DECREASING SENSITIVITY ↓		
	I	Marshes Lagoons
	II	Sheltered Environments Pocket Beaches
	III	Exposed Beaches Mud Flats Sand Flats
	IV	Exposed Rock or Cliff Environments

4 SHORELINE CLEANUP

Decisions to implement either a protection or a cleanup operation are based on a wide range of criteria that include the following: economic or recreational use of a shoreline, rates of natural cleaning, biological sensitivity, shoreline stability, possibilities of recontamination, effectiveness of available techniques, and accessibility.

The factors that influence the choice of method(s) include amount and type of oil; shoreline type; depth of oil penetration into the sediments; aereal extent of the oil; equipment availability and logistics; accessibility and trafficability of the shoreline; potential damage of method(s) to the coastal environment; and the effectiveness of the method(s) - i.e., cleaning rates and percentage of oil removed.

Table 2 summarizes the recommended cleanup techniques for different shoreline types. Brief descriptions of the impact of spilled oil and the necessary cleanup techniques for the shoreline types follow.

4.1 Rock Surfaces and Oil

4.1.1 **Impact of Oil.** This shoreline type occurs in areas of high wave-energy levels. Slicks are usually dispersed or broken up before reaching the shoreline.

Oil coats rocky coasts if the rock surface is dry and wave conditions are calm. Waves are reflected from steep rock coasts and tend to keep oil away from the shoreline in all but calm conditions. The ready adherence of oil to dry surfaces can affect the nature of the contamination, particularly in the intertidal zone.

Oil deposits are more common in upper intertidal zones and at high-water levels because these areas have more drying-out time during low tide than the lower section of the intertidal zone.

Rocky intertidal zones are often covered with algae which adsorb or physically trap oil. Generally, as the steepness of the rock coast increases, the amount of oil deposited decreases.

4.1.2 **Cleanup Techniques.** Hydraulic steam-cleaning or sandblasting techniques can disperse the oil from the rock surfaces where accessibility allows. However, there is a danger that intertidal flora and fauna could be damaged by these techniques.

TABLE 2 SHORELINE CLEANUP TECHNIQUES

	Chemical Dispersants	Hydraulic High Pressure	Hydraulic Low Pressure	Steam Cleaning	Sandblasting	Mixing	Mechanical Removal	Manual Removal	Sorbents	Burning	Cropping
Rock Surfaces	+	+	✓	+	+	-	-	✓	+	-	+
Unresistant or Unconsolidated Cliffs	-	x	x	x	x	-	x	x	x	-	-
Coarse Sediment Beaches	+	+	+	x	x	+	+	✓	+	x	-
Sand Beaches	+	x	x	x	x	+	✓	✓	✓	x	-
Intertidal Coarse Sediments	+	+	+	+	x	+	+	✓	+	x	-
Intertidal Sand	+	x	x	x	x	x	+	+	+	x	-
Intertidal Mud	+	x	x	x	x	x	x	+	+	x	-
Marshes and Deltas	x	x	✓	x	x	-	x	✓	+	+	+
Backshore Areas	+	+	+	-	-	✓	+	✓	+	x	+
Man-made Structures	+	✓	✓	✓	✓	-	-	✓	+	-	-

✓ Recommended
\+ Applicable and Possibly Useful
x Not Recommended
\- Not Applicable

If oil collects in rock crevices or hollows, manual cleanup techniques can be employed using such items as pumps, buckets or cans. These are recommended if cleanup is required to prevent redistribution of the oil to adjacent areas.

4.2 Unresistant or Unconsolidated Cliffs and Oil

4.2.1 **Impact of Oil.** As cliffs of this type are usually protected by a platform and/or beach, oil is deposited above the beach by storm waves only.

These cliffs are eroded by weathering, rockfalls, or landslips at rates that may reach 2 m/year. As they recede, any oil on the cliff face erodes as well and becomes deposited in the littoral zone or as talus. If deposited above the active beach zone or buried, the oil degrades slowly; if moved into the intertidal zone, oil degradation is relatively rapid.

4.2.2 **Cleanup Techniques.** No action is recommended as this shoreline type will clean itself naturally within a relatively short period of time (one to two years, depending on the type and volume of oil).

Collection of oil from rock pools, crevices or hollows by manual techniques removes oil that might otherwise be redistributed to adjacent shorelines. On cliffs of unconsolidated material, shovels or rakes may be used to remove oil from the cliff face.

4.3 Coarse Sediment Beaches and Oil

4.3.1 **Impact of Oil.** In an oil spill the oil is usually deposited on the upper beach or the low-tide terrace, and penetrates into beaches that have large open spaces between beach particles.

Where energy levels are low or where large volumes of oil are washed ashore, oil can contaminate the entire intertidal zone.

The degradation process is slow when oil is buried or is deposited either on the berm or on the storm ridge.

4.3.2 **Cleanup Techniques.** Sorbents can be used to reduce penetration of the oil and to facilitate cleanup. Dykes along the high-water mark can prevent or reduce oil deposition on the backshore. Manual removal of oil is recommended for small spills; mechanical removal by front-end loaders is recommended for large spills.

4.4 Sand Beaches and Oil

4.4.1 Impact of Oil. Only light-grade oil penetrates sand beaches. Oil is usually deposited on the upper parts of the beach; however, in low wave-energy environments or where large volumes of oil are washed ashore, the oil can coat the entire intertidal zone.

Normal cycles of beach erosion or deposition cause removal or burial of stranded oil; buried oil degrades very slowly. Dispersion and degradation rates in the intertidal zone are controlled by wave-energy levels. Onshore protection using sorbents or construction of wet-sand dykes near the high-water level can be effective.

4.4.2 Cleanup Techniques. Manual removal is recommended for small spills; the use of graders and elevating scrapers are recommended for large spills. Pits or ditches can be dug near the high-water line to act as collectors. Evaporation of light-grade oils can be accelerated by mixing the surface sediments.

If cleanup is not required, the oil can be pushed into the intertidal zone for reworking by waves. Alternatively, the oil cover can be broken up by machinery, thereby increasing the rate of degradation.

If large volumes of sediment are removed, these should be replaced. Berms can be rebuilt using backshore sediments.

4.5 Beaches in Sheltered Environments and Oil

4.5.1 Impact of Oil. Oil tends to collect in sheltered beaches and will coat the intertidal zone except during heavy storms. An "asphalt pavement" will form if large volumes of oil are involved. The dispersion and degradation of oil in a sheltered beach is very slow and may take several years.

4.5.2 Cleanup Techniques. Manual cleanup is effective if large amounts of oil are not washed ashore. If contamination is extensive and oil deposits are thick, the use of mechanical equipment is necessary.

If major cleanup is unnecessary, dispersion and increasing rates of weathering can be achieved by the use of equipment such as rakes and hoes to break up the oil cover. Since there is usually limited sediment replenishment, any material removed should be replaced.

4.6 Intertidal Coarse Sediments and Oil

4.6.1 Impact of Oil. Coarse sediments are moved only in high-energy environments and the rates of sediment movement are usually low. Oil penetrates spaces between particles and heavy oils can lead to the formation of "asphalt pavement", which is very persistent.

4.6.2 Cleanup Techniques. There are no ideal and effective cleanup methods that can be recommended, although machinery can be used to break up the "pavements" and oil can be removed manually. Cleanup can only be carried out during low tide.

4.7 Intertidal Sand and Oil

4.7.1 Impact of Oil. Light-grade oils penetrate sands, while heavy oils collect in depressions during ebb tide. Oil is refloated by flooding tides if the sand is wet. If oil deposition occurs, the sand can be subject to movement by wave and tidal activity, resulting in burial of the oil. Buried oil does not degrade.

4.7.2 Cleanup Techniques. Large amounts of heavier oils can be removed by machinery if sand surfaces are flat and traction is adequate.

Although wide, intertidal sand flats are very difficult to clean, oil can be removed from low-tide terraces by mechanical or manual techniques. Care should be exercised to prevent personnel and machinery from becoming stuck in soft sand patches, or trapped by rapidly rising tides.

4.8 Intertidal Mud and Oil

4.8.1 Impact of Oil. Except for heavy and residual oils, oils are refloated by flooding tides. Buried oil does not degrade until re-exposed.

4.8.2 Cleanup Techniques. Access and travel in muddy environments is difficult and may be dangerous. Cleanup is difficult and is not advisable unless necessary. There are no practical or effective techniques except in the case of small spills, at which time either manual or mechanical techniques can be employed.

4.9 Marshes and Deltas and Oil

4.9.1 Impact of Oil. Marshes and deltas are flooded only during exceptionally high tides, storm surges or at periods of maximum river discharge; otherwise, oil remains stranded on marsh or delta edges or in tidal creeks and channels.

Generally, marshes recover naturally since degradation by biochemical processes is somewhat rapid except in cold climates. Marshes should be protected; the use of dykes at marsh edges can effectively provide such protection.

4.9.2 **Cleanup Techniques.** Manual removal of oil, flushing with low-pressure hoses, use of sorbents, controlled burning, or cropping of contaminated vegetation can all be effective cleanup techniques. However, the use of low-pressure hoses is preferable. Machinery, except for floating aquatic weed-cutters, should not be used. Burning of oil should be carried out only during the fall and winter seasons.

4.10 Backshore Areas and Oil

4.10.1 **Impact of Oil.** Oil stranded or deposited in backshore areas is degraded and dispersed slowly since energy levels are low. Damage to backshore vegetation can lead to erosion by wind action and possibly to subsequent overwash and flooding of backshore areas.

Backshore areas should be protected and dyking is often the means by which this can be effected. Where an inlet connects a lagoon to the open sea, oil often enters the sheltered backshore areas through the inlet during the flooding tide. If it is possible to boom the inlet, protection is achieved.

4.10.2 **Cleanup Techniques.** If the spill is small, manual removal can be effective. Further, if an "asphalt pavement" is created by oil mixing with coarse sediments, machinery can be used to break up and push the pavement into the intertidal zone, thereby increasing rates of dispersion and degradation.

Vehicular traffic on vegetated backshore areas or dunes should be restricted and limited to the use of existing access routes. Damage to these areas can also be reduced by the use of mats.

4.11 Man-made Structures and Oil

4.11.1 **Impact of Oil.** If oil reaches the surface of a structure, it tends to coat the exposed surface areas. Degradation and dispersion of the oil depend on the energy levels present. Above the level of wave activity, the oil would be dispersed and degraded very slowly.

4.11.2 Cleanup Techniques. No effective protection method can be recommended except spreading sorbents on low-angle slopes or spraying water over contaminated surfaces. Man-made structures can be steam cleaned, sandblasted, or cleaned with hoses. Low-pressure hosing can disperse oil from man-made structures onto adjacent water surfaces for collection.