CHAPTER 148

NATURAL CLEANING OF OIL POLLUTED SEASHORES

by

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ABSTRACT

Field observations were carried out for a period of 20 months on the seashores of Chedabucto Bay, following the spillage of 108,000 barrels of bunker C oil in the bay by the tanker Arrow in February 1970. The main factors that control the natural cleaning of seashores are as follows:

1) Physico-chemical characteristics of oil: The bunker C-type fuel oil carried by the tanker Arrow forms, when spilled at sea, a very stable emulsion containing some 40 percent sea water. The emulsion formed is 40 times as viscous as pure bunker C (30,000 poises at 32°F).

2) Nature of polluted seashore: The natural cleaning of seashores is essentially mechanical. Abrasion of oil is most rapid on sand beaches because sand-size sediments are moved more vigourously by wave action. Such beaches clean within six months. Cobble and boulder beaches take one year to clean in Chedabucto Bay. Bedrock outcrops are still covered with a veneer of "dried" oil after 20 months of exposure to the surf.

3) Hydrodynamics of the environment: Wave action is the dominant source of energy that reaches the seashores of Chedabucto Bay and the cleaning of beaches is directly related to the amount of wave energy reaching different areas of the seashore.

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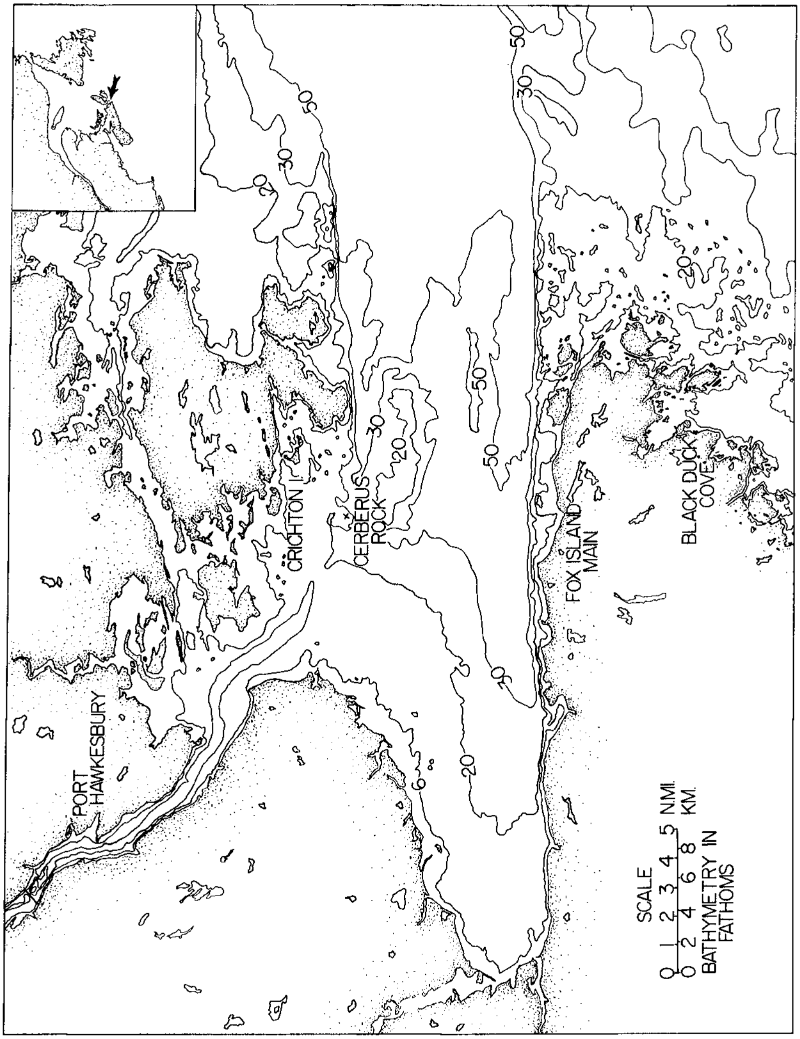

FIG. 1 Bathymetric map of Chedabucto Bay. Location of the map-area is shown in the upper right corner.

4) Climatic conditions prevailing when oil reached the seashore: The spillage of oil from the tanker Arrow took place during a period of wintry weather. High waves and high tides prevailed at that time. Much oil was then pushed very high on the beaches and remained unreached during the following summer season. Had the oil spill occured during the summer in calm weather, the pollution of seashores would have been much less extensive.

INTRODUCTION

The Liberian tanker Arrow grounded on Cerberus Rock in Chedabucto Bay, Nova Scotia (fig. 1). Chedabucto Bay, located on the Atlantic Coast of Canada between mainland Nova Scotia and Cape Breton Island, is a triangular bay 20 miles deep and some 10 miles wide. The south coast of the bay is developed along a fault zone and is consequently rectilinear and steep. By contrast, the north coast is characterized by a submerging, low-lying topography. The coast of Chedabucto Bay comprises a variety of rock outcrops, eroding till cliffs, gravel and mixed sand-gravel beaches (Owens, 1972 a). The Arrow lost 108, 000 barrels of bunker C oil and approximately one third of that cargo reached the shore and polluted 190 of the 375 miles of seashore surrounding the bay. A task force was formed by the Canadian Government to contend with that accident and also to gain as much understanding as possible of oil spills in a wintry environment. A program of field observations of oil pollution on seashores was initiated as part of the Canadian Government Task Force (Drapeau, 1970). It is possible, after 20 months of field observations, to outline the main factors that control the natural cleaning of oil polluted seashores. These factors are: 1) Physico-chemical characteristics of oil, 2) nature of polluted seashore, 3) hydrodynamics of the environment, and 4) climatic conditions during the oil spill.

1) Physico-chemical characteristics of oil:

The oil spilled by the tanker Arrow is a bunker C-type fuel oil which is much heavier than the Kuwait crude spilled by the Torrey Canyon in the English Channel, or the crude oil released by the offshore well blowout and natural seepages in the Santa Barbara Channel.

The most significant characteristic of bunker C oil, as far as oil pollution of seashores is concerned, is that it forms a stable emulsion of sea-water-in-oil. A similar phenomenon has been observed for crude oils (Great Britain Cabinet Office, 1967; Benyon, 1969; Batelle Memorial Institute, 1969). Experiments carried out by the Canadian Government Task Force indicate that the exposure time in thc sea necessary to increase the water content in bunker C by 30 percent is in the order of three days (Task Force - Operation Oil, 1970). Samples of

FIG. 2 Bunker C emulsion deposited on sand. The emulsion is so viscous that it does not permeate deeply into the sand. The "asphalt pavement" formed is approximately four inches thick (April 9, 1970).

FIG. 3 Indian Cove, south shore of Chedabucto Bay. Photograph taken one month after the oil spill, on March 25, 1970. The sandy portion of the beach is already clean, while the boulders are still heavily polluted.

FIG. 4 Same area as above photographed 14 months after the oil spill, in May 1971. The boulders are clean and oil has disappeared completely from that beach.

FIG. 5 Sand beach in a protected inlet (Black Duck Cove, see location in figure 1). That beach is "frozen" under a heavy coat of oil. Shallow channels developed in response to action of tides on the beach (March 25, 1970).

oil emulsion collected in different areas at different times contained between 33 and 53 percent water. The physico-chemical properties of the bunker C-sea water emulsion are substantially different from those of pure bunker C. As compared with pure bunker C, the viscosity of the emulsion is increased from 700 to 30,000 poises at 32°F (McKay, 1970; Richards, 1970). Time-lapse photography has shown that bunker C creeps slowly on bedrock surfaces, the rate of flow depending on the thickness of the slick, the ambient temperature, and the intensity of sunshine. Field observations indicate that the bunker C-sea water emulsion is very stable. Eighteen months after the spill, particularly on warm days (70°F, 21°C), heavy accumulations of bunker C emulsion appeared as fresh as at the time of the oil spill.

2) Nature of polluted seashore:

As the bunker C-sea water emulsion is chemically inert, the natural cleaning of seashores results from the mechanical abrasion of oil. Surfing waves are the main source of mechanical energy on the seashore, but wave energy is effective in cleaning the seashore in as much as it induces the movement of sediments on the beach. Sand beaches are easily stirred up by wave action and, as the bunker C emulsion is so viscous that it does not permeate deeply into the sand (fig. 2) sand beaches clean rapidly. Oil slicks one half inch thick that strand on moderately exposed sand beaches take only one to two months to disappear (fig. 3). The situation is different however if the oil cover is too thick; the beach is then completely "frozen" under the oil slick and the waves run on and off without cleaning the oil (fig. 5). Gravel beaches take longer than sand beaches to clean because gravel is not moved as easily by waves and also because the bunker C emulsion penetrates more deeply into a gravel bed (Owens, 1972 b). Boulder and bedrock seashores are not easily cleaned because they are immobile. The exposed boulder beaches in Chedabucto Bay cleaned within one year (fig. 4). Heavily polluted bedrock outcrops exposed to wave attack were still covered with a veneer of "dried" oil 20 months after the spill.

3) Hydrodynamics of the environment:

Wavc energy is the main source of mechanical energy prevailing on the seashores of Chedabucto Bay. The wave climate in the bay is moderate as compared with that of the open ocean. The fetch in Chedabucto Bay does not allow for the formation of waves exceeding a period of eight seconds, according to Bretschneider's (1952) diagram of maximum wave period versus fetch length. However, the bay is open to the Atlantic Ocean and long period waves coming from the east and southeast can penetrate deeply into the bay, which is 300 feet deep and eight miles across at the entrance. Because of its orientation, Cheda-

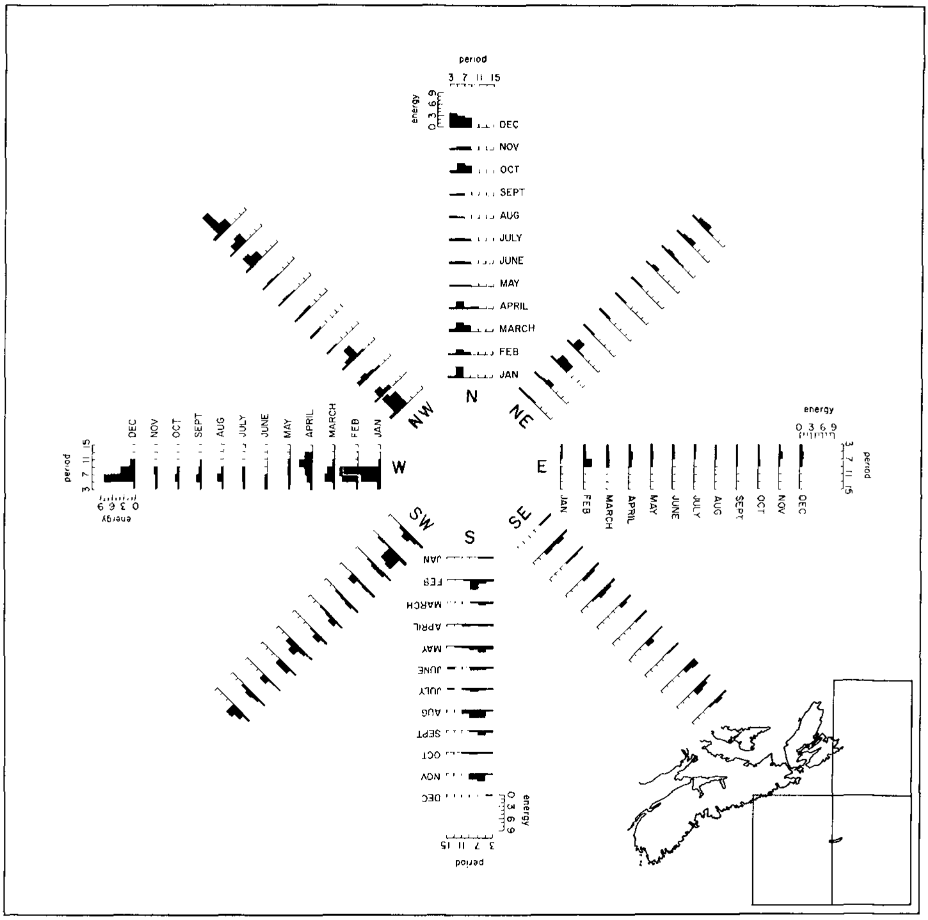

FIG. 6 Wave climate compiled from Wave Climate of the Canadian Atlantic Coast and Continental Shelf - 1970 (Neu, 1971). The areas used for compilation are outlined in the lower right corner.

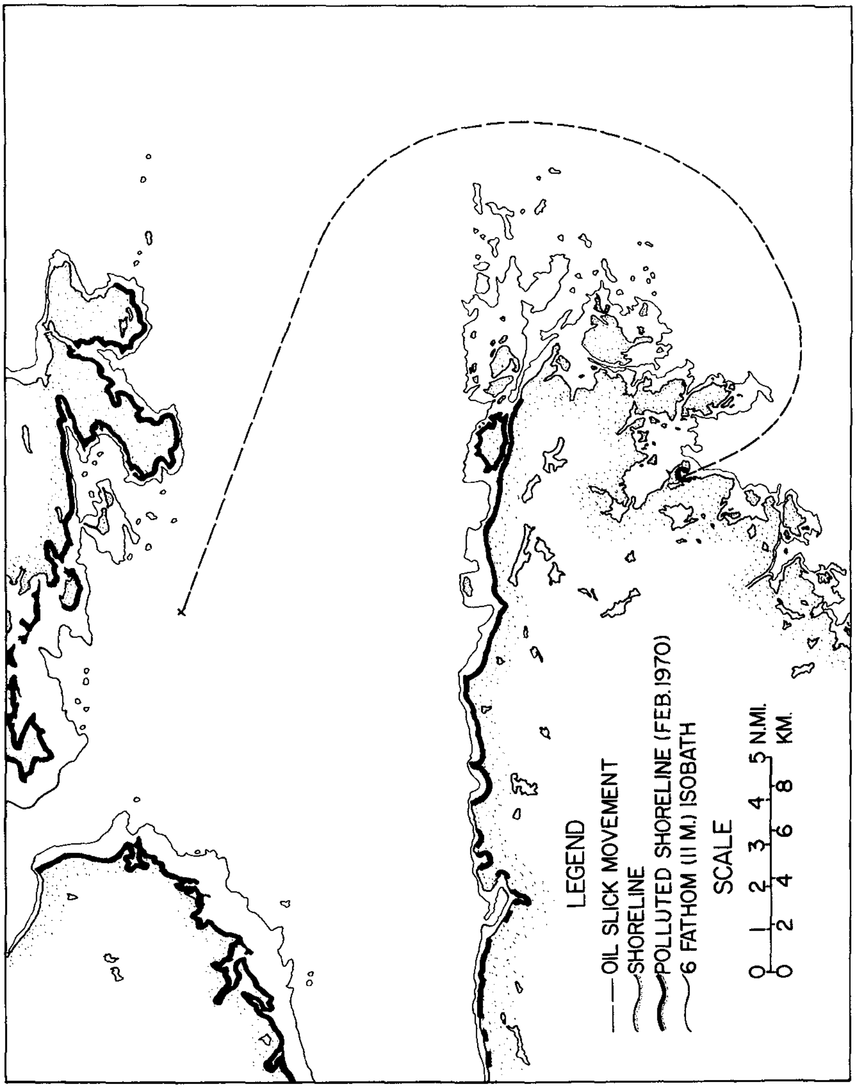

FIG. 7 Assumed track of a large oil slick that reached Black Duck Cove. Oil slicks can be brought into presumably protected areas by the combined action of winds and tides.

bucto Bay is protected from the strongest waves developing in that area of the Atlantic Ocean. The strongest ocean waves come from the north-west as outlined by the rose diagram (Neu, 1971) shown in figure 6. Direct wave measurements were taken near Cerberus Rock by Neu (1970) during the salvage operations. A maximum of 11 seconds was recorded for wave period and a maximum of 9.5 feet for wave height.

Tides in Chedabucto Bay are semi-diurnal and range between 4.4 and 6.9 feet (Canadian Hydrographic Service, 1971). Longshore currents in Chedabucto Bay result from the combined action of tides and winds and are in the order of 0.4 to 0.6 ft/sec. (Neu, 1970).

4) Climatic conditions during the oil spill:

Oil slicks are moved by the combined action of winds and tides. The wind was blowing from the south at the time of the grounding of the Arrow so that the first oil slicks were pushed on the shores of Isle Madame. The wind eventually turned and the oil escaping from the wreck was pushed onto the south shore of Chedabucto Bay and into the open ocean. The trajectory of oil slicks can be very intricate. A particularly striking case in Chedabucto Bay is the heavy pollution of Black Duck Cove, which can only be described as a "caprice de la nature" (fig. 7).

The stranding of oil on seashores bears many similarities with that of other floating debris. On seashores exposed to surf action, oil accumulates at the high-water level with driftwood and plastic containers (fig. 8). In areas protected from the surf, oil slicks are pushed slowly by the wind, and blanket large portions of the intertidal zone instead of accumulating at the high-tide level (fig. 5).

The heavy polluted south shore of Crichton Island (fig. 1) located 2.5 miles north of the ship wreck, was monitored in greater detail in order to understand more precisely the mechanisms of deposition and removal of oil from beaches. The section of beach studied is particularly interesting because it is in a delicate state of equilibrium with the environment (fig. 9). Part of the shore is protected by a sublittoral rock platform which modifies the wave approach (fig. 10) thus inducing the formation of a convex barrier as seen in figure 9. The height and the slope of the beach, as well as the texture of its sediments, are controlled by the hydrodynamics of the environment (fig. 11). Where the beach is not directly protected by the subtidal rock platform, the crest is higher, the slope is steeper, and the texture of sediments coarser, as compared with the crescentic portion of the beach

FIG. 8 Helicopter view of Crichton Island beach showing that oil accumulated at high-tide level, and above, in areas exposed to wave action (April 9, 1970).

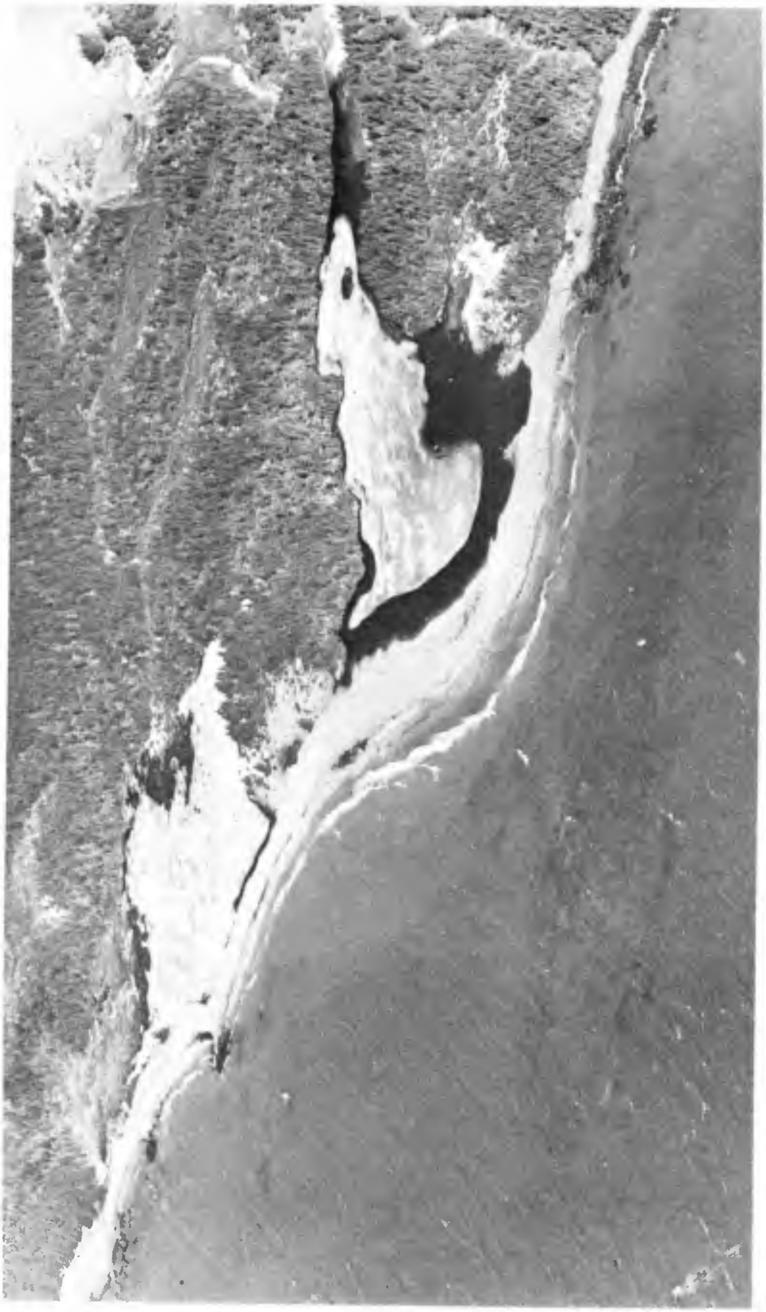

FIG. 9 Crescentic beach on Crichton Island. Concentrations of oil are apparent at high-tide level and on bedrock (April 9, 1970).

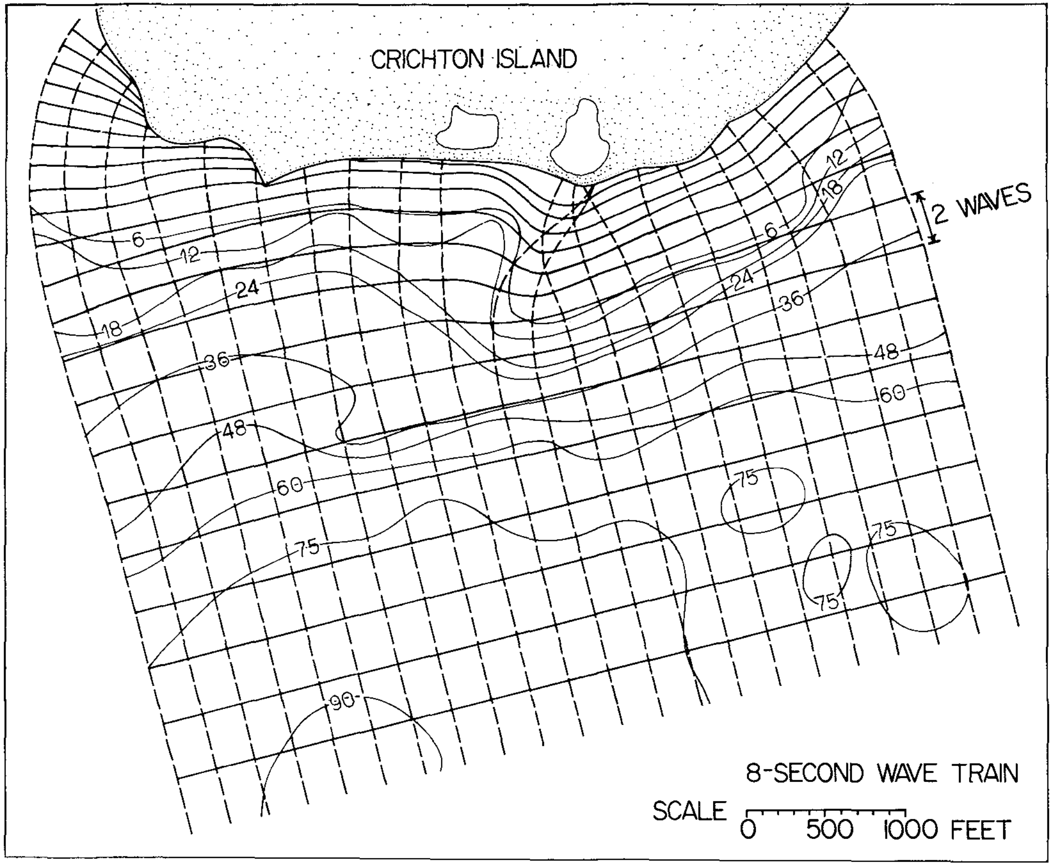

FIG. 10 Computer plotted (Vandall, 1972) wave refraction diagram for the beach shown in figure 9. The two ponds appearing behind the beach on the photograph are outlined under the words "Crichton Island" on the diagram.

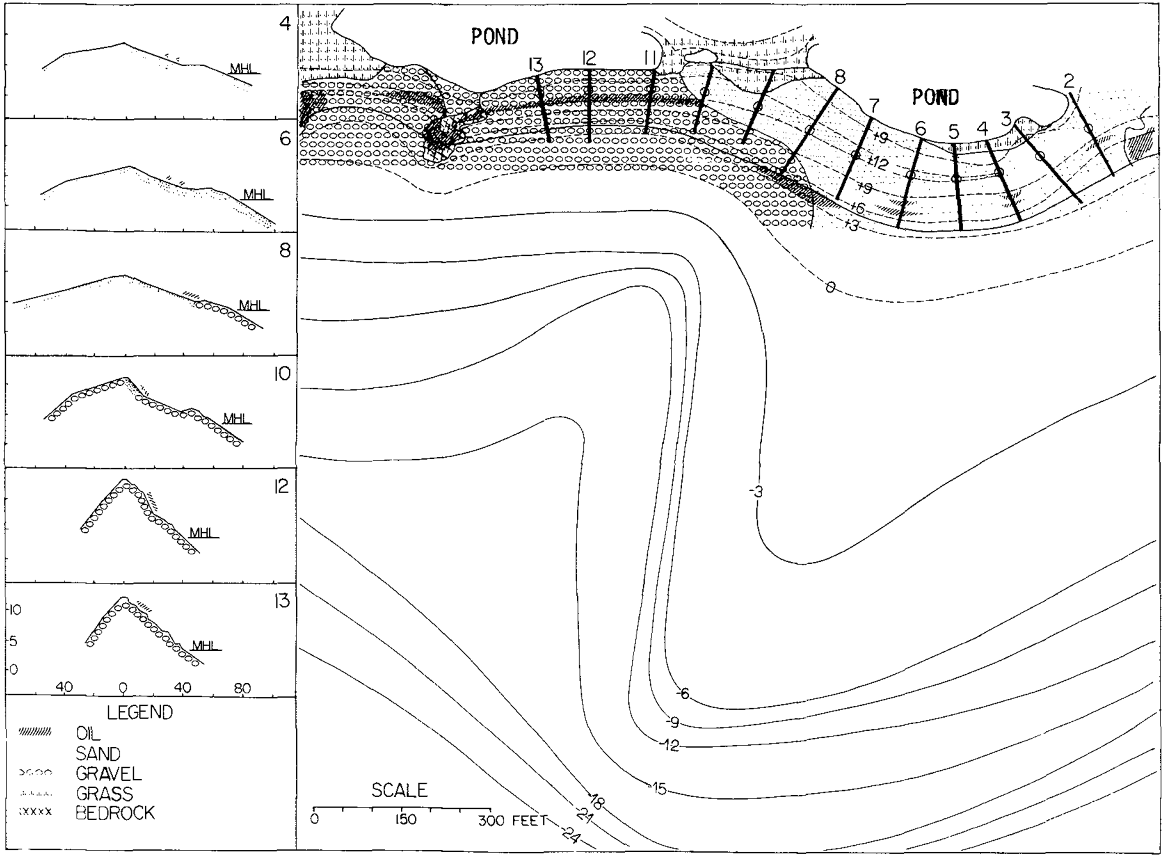

FIG. 11 Geological map and profiles of the beach shown in figures 9 and 10. The two ponds seen in figures 9 and 10 are identified on the map. The topography is contoured in feet with reference to the Canadian Hydrographic Service datum.

FIG. 12 Photograph taken in April 1970 facing profile 12 outlined in figure 11. Oil was pushed above higher high tide level which normally reaches the lower post seen on the photograph.

FIG. 13 Same area as figure 12 photographed in March 1971. This gravel beach is essentially clean. The profile of the beach has changed as indicated by the reference poles, but the gravel is clean underneath.

FIG. 14 Crichton Island beach. The lower edge of the photograph is parallel to profile 8 outlined in figure 11, and the portion of beach between profiles 8 and 13 appears on the photograph. Oil stranded at a lower level on the protected portion of the beach in the foreground, and was pushed higher along the more exposed section of the beach in the background.

directly protected by the offshore platform, where the profile is lower and the sediments are composed of sand instead of gravel. The deposition of oil on that beach follows a similar pattern. The oil was pushed higher on the gravelly, more exposed portion of the beach than on the less exposed sandy crescentic section, as shown in figure 11.

The grounding of the Arrow occured in a period of wintry weather during which waves in Chedabucto Bay presumably reached a height of 15 feet and the tides departed by more than 1.5 foot from predicted levels (Neu, 1970). Oil was then pushed very high on exposed seashores (Owens and Drapeau, 1972). On the most exposed portion of the beach monitored on Crichton Island, (profiles 12 and 13, fig. 11, and fig. 12 and 13) the oil was pushed sufficiently high to remain out of reach throughout the following summer season, so that portions of the beach were only cleaned during the storms of the following winter. Naturally oil was not pushed as high on the portion of the beach partly protected by the sublittoral platform (profiles 4, 6 and 8 in figure 11 and figure 14); therefore that oil was reached by summer waves and cleaned within six months.

The detailed monitoring carried out on Crichton Island shows then that the climatic conditions prevailing during an oil spill determine the extent of pollution on the seashore. Had the oil spill in Chedabucto Bay occured during a period of calm weather, the oil pollution on the shore would have been confined to the high water-level and would have been easily reached by the waves afterward.

CONCLUSIONS

In the eventuality of a major oil spill threatening a seashore, three points should be taken into consideration. Firstly, all efforts should be concentrated to prevent oil from entering inlets even if such areas do not seem as important as the exposed beaches used for recreation. Natural cleaning of exposed sand beaches is relatively rapid, but inlets remain polluted for a very long time and become a continuous source of contamination for the clean beaches. The experience of Chedabucto Bay has shown that sand beaches in the vicinity of polluted areas can be recontaminated to a greater or a lesser extent many times during one season. It takes very little oil to make a beach unsuitable for recreational purposes. Secondly, attention should be given to the fact that no detergents were used in Chedabucto Bay. The bedrock on exposed seashores that had been heavily polluted, was as clean eighteen months after the spill as if large quantities of detergents had been used immediately after the pollution occured. A slower but nonetheless efficient natural cleaning of bedrock surfaces is a better compromise than using large quantities of detergents that would jeopardize the biological equilibrium of the environment. Thirdly, salvage operations or any type of operation involving a risk of oil spillage should be attempted only in calm weather and during periods of neap tides. Should then an oil spill occur, oil slicks would strand lower on the seashore. Detailed monitoring on Crichton Island has shown that the natural cleaning of exposed beaches is relatively rapid when oil does not extend above normal high tide level. By contrast, oil pushed by storm waves beyond the high-water mark stagnates on the berm until the next period of prolonged wintry weather. Furthermore, it takes considerably more wave energy to clean a beach than to pollute it. It is an important point to consider when assessments are made of the rate of natural cleaning.

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