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# A Review of Countermeasures for a Major Oil Spill from a Vessel in Arctic Waters



Canada

Economic and Technical Review
Report EPS 3-EC-83-2

Environmental Impact Control Directorate

March 1983

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# A REVIEW OF COUNTERMEASURES FOR A MAJOR OIL SPILL FROM A VESSEL IN ARCTIC WATERS

by

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for

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

EPS 3-EC-83-2
March 1983

**Disponible en français**

s'adresser au:

Coordonnateur des publications
Direction générale du contrôle des incidences environnementales
Service de la protection de l'environnement
Environnement Canada
Ottawa (Ontario)
K1A 1C8

et demander:

Vue d'ensemble des mesures d'intervention
en cas de déversement majeur d'hydrocarbures
dû à un accident de navire dans les
eaux arctiques


Cat. No.: En46-3/83-2E
ISBN: 0-662-12566-5

## ABSTRACT

The existing capability to deal with a major tanker oil spill in the Arctic is presented. A particular emphasis is placed on the government's role and state of preparedness.

First, a review of the countermeasures utilized at past major tanker spills throughout the world is performed. This is followed by summaries of the northern environmental setting and the oil shipment operations that are proposed for the Arctic. A comparison between historical southern spills and those which could occur in the Arctic is then made.

Best-practicable oil spill control technologies for the North are identified through a group of hypothesized accident scenarios and response strategies. The government's present organizational structure, contingency plans and major equipment supplies for a northern oil spill response are reviewed, and the likely success of a government response to the hypothesized spills is discussed. Research and development of new equipment, equipment acquisitions and the planning activity needed to improve this capability are then recommended.

In general, it is felt that the government's ability to deal with an oil spill on open water in the Arctic is not too different from its capability in the south. However, a review of international responses to oil spills in offshore waters has revealed that these techniques are generally not very successful even in southern climates. The complete ice cover setting which exists in the Arctic for much of the year provides the best opportunity for a successful countermeasures operation. Oil spilled under these conditions would be contained and preserved by the ice. If adequate incendiary devices were available in the spring thaw, a high percentage of the released oil could be removed by burning. At present, methods are not available which can deal effectively with spills that occur in a partial ice cover situation.

Countermeasures operations in general could be improved if the damaged tanker were to be used as a work platform. Studies are required to determine the feasibility of this concept.

## RÉSUMÉ

Ce rapport fait état des moyens dont nous disposons à l'heure actuelle pour faire face à un gros accident de pétrolier dans l'Arctique, et traite particulièrement du rôle des autorités gouvernementales et du potentiel d'intervention.

Dans une première partie, l'auteur fait le point sur les mesures d'intervention qui ont été utilisées dans le monde, par le passé, au cours de gros déversements. En deuxième lieu, il donne un aperçu des conditions ambiantes dans le Grand Nord et des opérations de transport d'hydrocarbures prévues dans l'Arctique, puis il compare les grands déversements ayant eu lieu dans les régions méridionales à ceux qui pourraient survenir dans l'Arctique.

Après avoir déterminé les meilleures techniques de lutte contre les déversements d'hydrocarbures dans le Grand Nord à partir d'un ensemble de scénarios d'accidents et de stratégies d'intervention hypothétiques, l'auteur examine la structure organisationnelle actuelle du gouvernement, les plans d'urgence et l'arsenal anti-pollution utilisable en cas de déversement dans le Grand Nord, et analyse les chances de succès d'une stratégie d'intervention gouvernementale en fonction de déversements hypothétiques. Il formule enfin certaines recommendations portant sur la recherche et le développement en matière d'équipement, sur l'acquisition d'équipement et sur la planification nécessaire à l'amélioration de ce potentiel d'intervention.

En général, nous croyons que les moyens d'intervention du gouvernement en cas de déversement d'hydrocarbures en eau libre dans l'Arctique ne diffèrent pas tellement de ceux qui sont applicables dans le sud. Toutefois, l'examen des stratégies d'intervention internationale mises en oeuvre pour maîtriser des déversements en haute mer, révèle que ces techniques sont généralement peu efficaces, même dans les régions méridionales. La présence, dans l'Arctique, d'une couverture de glace totale pendant une grande partie de l'année favorise grandement le succès des opérations d'intervention. En effet, les hydrocarbures déversés dans ces conditions sont endigués et conservés par la glace. L'emploi de dispositifs incendiaires appropriés au moment du dégel printanier permettrait d'éliminer par combustion un pourcentage élevé des hydrocarbures déversés. À l'heure actuelle, il n'existe aucune méthode de lutte efficace en cas de déversement survenu dans un milieu partiellement couvert de glace.

Les opérations d'intervention pourraient en général être améliorées si le pétrolier accidenté était utilisé comme plate-forme de travail. Des études devront être faites pour déterminer la faisabilité de ce principe.

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# 1 INTRODUCTION

The search in the Arctic for energy reserves, both natural gas and oil, has experienced rapid growth since 1970. This activity has located supplies of both oil and gas which show economic promise, and proposals are being developed to move these resources to market.

Oil has been found in the southern Beaufort Sea; its principal developer, Dome Petroleum, is currently designing large icebreaking tankers to ship the product to the eastern markets via the Northwest Passage.

In addition, gas reserves have been found in the western high Arctic at Melville Island. Plans are well underway by Petro Canada and others to construct large icebreaking liquid natural gas carriers to transport this fuel to the east coast, again through the Northwest Passage.

While other projects in the North are not as advanced in their planning with regard to the use of the Arctic as a shipping zone, such endeavours are expected in the future. The American oil development in Alaska has considered the use of this tanker route to supplement its existing pipeline flow which is presently near capacity. Exploratory drilling for oil in several parts of the Canadian Arctic is also actively underway or being considered. Shipment of commercial resources again will likely be accomplished by large Arctic Class vessels.

The advent of year-round shipping in the North creates the potential for accidents and the release of hydrocarbons into the environment. Of primary concern is the transport of crude oils by tanker.

Prior to past Arctic offshore exploration, extensive reviews of state-of-the-art methods for dealing with exploratory accidents and subsequent oil spillage were undertaken by several government and private agencies. This same type of assessment is needed for the transportation phase of northern petroleum development to minimize the possibility of environmental damage.

This report reviews the potential for Arctic tanker accidents and discusses the present technological capability in dealing with such incidents. The present role and future outlook of various government groups responsible for preventing and fighting spills in the North are also briefly examined and assessed.

## 2 SCOPE

The primary objectives of this study are to identify the deficiencies which exist in available oil spill countermeasures technology when applied to a large northern tanker spill and to identify the problems which would have to be overcome to eliminate these deficiencies.

In order to accomplish this, background information is first developed concerning the causes of historical tanker accidents and oil spills and the effectiveness of the various cleanup operations attempted. This information provides the "standard" by which the relative effectiveness of potential northern responses can be measured.

The environmental and industrial settings and a review of the probable behaviour of oil spills in the Arctic are presented in such a manner as to provide a framework for the countermeasures study. As such, it is neither detailed nor comprehensive.

Similarly, the countermeasures study itself is a state-of-the-art review, and hence concentrates on generic or general information rather than on specific products or step-by-step response details.

The necessary technology to successfully handle a northern spill is identified through hypothesized spill scenarios and responses in the northern setting. These scenarios draw upon the previously mentioned reviews of the environmental and industrial settings, oil behaviour and countermeasures state-of-the-art. Deficiencies in existing methods are identified by these scenario discussions.

Finally, the capability of the responsible government organizations to handle the hypothesized northern tanker spills is assessed on the basis of both equipment availability and present government plans.

# 3 THE MAIN ISSUE: NORTHERN vs SOUTHERN TANKER SPILLS

## 3.1 Historical Tanker Accidents

A sizable data base is available concerning the cause and outcome of tanker accidents which have occurred in the past. Recent studies commissioned by Dome Petroleum and conducted by Det norske Veritas (DnV) (Larsen et al., 1979) and by Bercha (1981) have utilized this information to characterize several aspects of tanker-related oil spills.

The general conclusions of the DnV report indicate that:

a) the probability of an oil spill increases with the vessel's age;
b) large vessels have fewer oil spills, but this is biased by the fact that the larger vessels are also the newer ones;
c) when comparing the oil released by large and small tankers, a higher percentage of the large tanker's spillage is due to groundings;
d) the amount of oil spilled per incident increases with an increase in the vessel size;
e) the highest number of oil spills occur in waters which have been designated as restricted (e.g. entraces to harbours, ports, etc.);
f) most spills have been due to human error, negligence, or ignorance of operation, and thus are largely preventable by the tanker owner through good management practice.

Bercha utilized the data of DnV and others to probabilistically assess the risks involved in Arctic oil transport by large icebreaking carriers. The statistical prediction of tanker risk in the Arctic was not possible since a historical data base is not available. In this work, a well-operated and maintained conventional tanker was taken as the "base case" for comparison with the Arctic tanker. This was done with the intention of setting a demanding standard of comparison for the risks estimated for the Arctic tanker. This conventional tanker was taken to be relatively new, medium-sized (50 000 DWT), and operating in a northwest Atlantic shipping area. Historical information revealed the following with regard to accident causes and oil spillage for such a conventional tanker operating in the south:

a) a spill rate of 120 barrels per million barrels carried can be expected;
b) spills in coastal waters, which comprise only 14% of the tanker's total route, account for 66% of the total oil spilled;

c) the major source of spilled oil is from grounding accidents which account for 37% of the total outflow;

d) structural failures, although uncommon, create large oil losses and are responsible for 28% of all spillage;

e) coastal collisions account for about 13% of the remaining oil spilled in tanker accidents.

The information provided by DnV and Bercha thus summarizes the nature of historical spills with regard to tanker type and operation, the amounts spilled, the location of accidents, and the causes of the oil release. Of more importance to this study, perhaps, are the details concerning the attempts at cleaning up the oil spilled in these mishaps.

### 3.2 Typical Cleanup Operations after Southern Tanker Spills

A review of a dozen documented tanker spills, which occurred between 1974 and 1979, was undertaken to identify the general nature and effectiveness of the cleanup operations implemented after these accidents (Table 1). The level of response for these global spills varied widely. Often very little action was taken. Where some response activity was evident, it involved one or more of the following operations: tanker lightering or cargo off-loading; at-sea oil containment and mechanical recovery; chemical dispersion; oil pool containment and recovery at shorelines; and shoreline cleanup and restoration. The success of each of these is briefly reviewed, as follows.

An effective capability to off-load or lighter damaged tankers was demonstrated in many of the reported accidents. The benefits of this technology, however, were limited to cases where high seas were not prevalent, where alternate storage was available, and where the damaged vessel provided a stable working platform.

In cases where at-sea containment of the oil around the vessel by booms was attempted, the operation was severely limited by the sea-state. Under calm conditions (which generally do not accompany tanker accidents) and with rapid deployment, heavy-duty booms proved to be effective. In most cases, however, rough water, bad weather, and the time required to get the boom to the site did not permit the installation of the booms until large quantities of the oil had already escaped and spread to cover a large area. Even when implemented, impropprer placement and failure due to high currents or structural problems limited the benefits of offshore spill containment operations.

The pursuit, capture and containment of stray oil slicks on the open ocean by mobile boom systems also experienced limited success in past incidents. In many cases,

TABLE 1 TANKER SPILL REVIEWS

| Incident | Reference |
|---|---|
| AMOCO CADIZ | Bellier and Massart (1979)<br>Bocard et al. (1979) |
| KURDISTAN | Duerden and Swiss (1981) |
| BURMAH AGATE | Thebeau and Kana (1981)<br>Kana et al. (1981) |
| LEE WANG ZIN | Bayliss and Spoltman (1981) |
| F/V RYUYO MARU NO. 2 | Reiter (1981) |
| GLOBAL HOPE | Mathews (1979) |
| METULA | Hann (1977) |
| S.S. SANSINENA | Hutchison and Simonsen (1979) |
| ST. PETER | Hayes (1977) |
| URQUIOLA | Robertson et al. (1976) |
| SHOWA MARU | Bennett (1977) |
| BORAG | Bennett (1977) |

the oil spread so rapidly that sufficient quantities of hardware were not available for efficient collection. In cases where thick oil was present, inexperienced operators and sea conditions hampered operations.

The mechanical recovery of the oil once it was contained at sea also proved difficult. One problem was the utilization of skimmers which were not designed for offshore use or for processing viscous oils. Even when an appropriate skimmer was available and used, the presence of high currents and moderate waves or chop reduced the equipment's efficiency drastically. Most devices are designed to handle significant thicknesses of oil; these amounts are often not available due to the rapid spread of the oil. None of the reported spills which were reviewed identified a significant amount of oil being removed by offshore containment and mechanical recovery. This was obviously due to limitations regarding response time, equipment availability and performance, as well as the absence of knowledgeable operators at the site.

The dispersal of oil into the sea by chemical agents was attempted at several tanker spills. These dispersing programs were generally of limited success for several reasons. In some cases, the chemicals were applied after the oil had aged and/or formed heavy emulsions. Currently available dispersants are simply not effective on these oils. The rapid spread of oil and the aging process both dictate that a quick arrival of dispersant on the scene is necessary for the operation to be effective; historically, this had not been the case. In addition, application techniques and dosage control were often inadequate during these operations.

For the spills under study, and for many others, the lack of success of the at-sea countermeasures techniques prompted extensive attempts at shoreline protection, oil recovery and restoration. The protection of small, quiet bays or inlets by booming was very successful where the equipment was available and correctly implemented. Containment of oil which naturally accumulated in shoreline irregularities was also effective. The only drawback to these schemes was the fact that often very long lengths of shoreline were affected by the oil and the resulting need for large amounts of boom, vessels and manpower was not satisfied. In any case, mechanical skimming of the contained oil, when attempted nearshore, was usually successful when the proper match of equipment to oil type was made.

Stretches of the shore, which were directly exposed to the open ocean and not protected by barriers, were ultimately oiled in many spill situations. For the most part, cleanup of these areas was by manual labour. Up to 10 000 people were involved in these cleanup operations, some of which lasted for months. Some success was achieved in accelerating the shoreline cleanup and restoration procedure through the use of heavy machinery. On several occasions, vacuum trucks assisted in the removal of emulsified oil and oiled debris along shorelines. Front-end loaders and scrapers were also useful in removing oiled material from flat beaches. Steam and high-pressure water cleaning was another method commonly used in these operations. However, the use of heavy equipment sometimes created damage of its own when placed into service in sensitive areas.

The ability to clean up oil-contaminated shorelines was restricted only by the time, manpower and money which were devoted to its cause. The ultimate recovery of any affected area was very much a function of the care and effort devoted to the final cleanup/restoration procedure.

Several general reviews on the subject of tanker spill countermeasures have been written (Garnett et al., 1978; White et al., 1978; White et al., 1979). The main point made in all of them concerns the need for a combination of good contingency planning, organization, and control of operations. While much has been said about the effectiveness/ineffectiveness of certain cleanup options under varying environmental and logistical constraints, the underlying fact is that none of them work without the presence of good management. Much of the failure of past cleanup operations must be attributed to a lack of commitment and preplanning and not to the capability of existing equipment and knowledge. The review of past oil spill responses reinforces this concept. While advances in equipment design for mechanical recovery and dispersant application have been made over the years, the lack of preparedness, in terms of contingency planning, equipment acquisitions and personnel training, has prevented the judicious use of these improvements.

### 3.2 The Northern Perspective

As previously mentioned, a historical basis for characterizing large tanker spills in the Canadian Arctic is obviously not available. A brief review of shipping statistics in the south and speculation as to how northern accidents might differ can, however, be made.

The conclusions of DnV are in all likelihood directly applicable to the northern scene. Since all future icebreaking tankers will be ultra-modern in design and construction, the probability of an oil spill will be much below the southern average due to age consideration alone. In the event of a spill, there is a potential for a larger discharge than in the south due to the larger vessels which will be in operation. The greatest potential for spills again lies in the hands of the vessel crew, with human error, negligence, or ignorance of operation the threatening factors. The waters of the more dangerous restricted zones are again the prime area for potential mishaps.

The findings of Bercha for conventional tankers in ice-free waters (Section 3.1) cannot be directly transferred to the northern climate. The presence of thick ice and icebergs poses a threat to the Arctic tanker not encountered in the south. This factor, as well as the different climate, remoteness of the route, and vessel construction, alters the frequency and type of accident expected. For example, coastal routes may again be of primary concern with regard to potential spill sites but the presence of icebergs on the east coast adds an additional threat in these open waters over the southern conditions. Conventional tanker spills have been primarily due to groundings but the likely use of double-hulled vessels in the North reduces the potential for this type of spill. Bercha combined all of these factors of ship construction and safety features, route differences, and past accident statistics for Dome Petroleum Ltd. in order to compare the risk of such northern tanker shipments to a southern counterpart. The results of this study, which apply to the very specific case of the proposed Dome icebreaking tankers, indicate that these ships in northern service would have a spill risk 120 to 160 times less than the conventional tankers operating in the south. Much of this reduction in spill risk is attributed to the double-hull construction, but significant importance also is placed on the sophisticated navigational equipment, ship manoeuvreability, inerting systems, and structural integrity of the proposed vessel. The proposed installation of duplicate independent systems for navigation, propulsion and steering would also reduce spill risk. While this analysis indicates a promising and safe future for northern shipping, the possibility of a major oil spill in the North cannot be discounted entirely. To prepare for this event, an understanding of the northern environment and future industrial plans for the Arctic is of importance.

# 4 ENVIRONMENTAL AND INDUSTRIAL SETTINGS

To simplify discussions in the remainder of this report, the Arctic study area has been divided into five fairly distinct regions based on seasonal ice considerations, geomorphology, natural resources, and present industrial activities. The selected zones, shown in Figure 1, are:

a) Southern Beaufort Sea/Prince of Wales Strait;
b) Viscount Melville Sound/Barrow Strait;
c) Lancaster Sound/Northwest Baffin Bay;
d) Baffin Bay/Davis Strait; and
e) Labrador Sea.

Background environmental and industrial information is presented on the basis of this regional breakdown.

## 4.1 Environmental Setting

To set the stage for hypothesized oil spills in the Arctic and the events following such accidents, it is necessary to briefly describe the environment of the study area. The following information has been condensed from "An Arctic Atlas" (Fenco Consultants, 1978).

### 4.1.1 Climate.

**4.1.1.1 Air temperature.** Regional variation in the air temperature across the Arctic is not significant. July mean offshore temperatures are approximately +5°C throughout the North, with only a slight increase to about +10°C in the more southern Labrador Sea area. Even under summer temperatures, cleanup operations will be uncomfortable. January mean temperatures are approximately -25°C in the Southern Beaufort Sea, -30°C in the Viscount Melville Sound and Lancaster Sound areas, -25°C in the Baffin Bay zone, and -20 to -15°C along the Labrador coast. These average winter temperatures do not reflect the potential for much harsher weather due to wind chills and extreme temperature drops. The mean winter temperatures themselves will severely limit any countermeasures operation in the North; colder temperatures or significant winds would surely eliminate any attempt towards a winter oil cleanup operation.

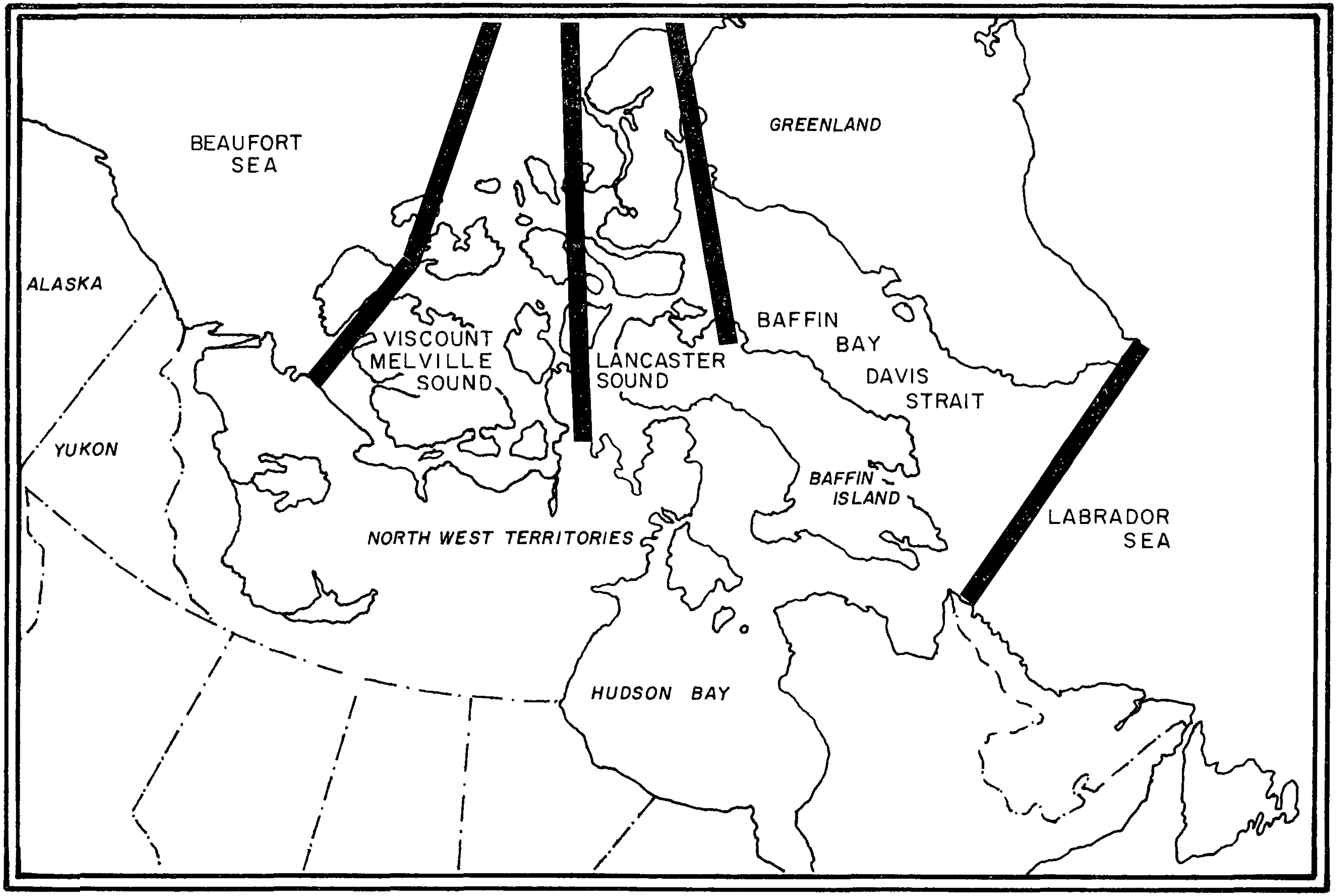


FIGURE 1 ARCTIC STUDY AREA, BY ZONE

**4.1.1.2 Surface water temperature.** The cool summer temperatures and insulating winter ice result in a very small fluctuation in the surface water temperature in the Arctic. From the Southern Beaufort Sea to Baffin Bay, surface temperatures vary from -1 to +3°C throughout the year. Only in the Labrador Sea area, where summer air temperatures are also higher, do the surface water temperatures rise above these values, reaching about 8°C on average.

**4.1.1.3 Storm tracks and winds.** Storms experienced in the Arctic are the result of slow-moving pressure systems. These systems are stronger and more frequent in the winter months. Figure 2 illustrates the favoured position and movement of low-pressure systems for various times of the year. Storm movement from west to east is evident in the northern portion of the study area. The Labrador Sea/Davis Strait area receives its weather off the Labrador and Newfoundland coasts as low-pressure systems make their way to the northwest.

Local winds within the Arctic are greatly influenced by the water and land masses of the area. It is beyond the scope of this work to identify the local winds throughout the Arctic study area. A more detailed discussion of the effects of local winds on oil behaviour is presented in Chapter 7, which deals with specific, hypothesized oil spills.

**4.1.2 Water Currents.** Local surface water currents are dependent upon a number of factors. General circulation patterns of the oceans, such as the Beaufort Gyre in the west, and the West Greenland, the Baffin Land and the Labrador currents in the east, have powerful global significance. Tidal influences can also considerably alter the local currents. These factors combine with wind-induced surface currents to create resulting water movement.

As mentioned above, the Beaufort Sea is influenced by the Beaufort Gyre, a clockwise rotation within this portion of the Arctic Ocean. The local influences of wind and the outflow from the Mackenzie River can, however, direct the local surface currents of the southern reaches of the Beaufort Sea to either the east or the west depending on the wind direction.

The surface currents of Prince of Wales Strait are primarily tidal. The general movement of surface waters in Viscount Melville Sound, Barrow Strait and Lancaster Sound is to the east, with an increasing velocity as the water exists to Baffin Bay.

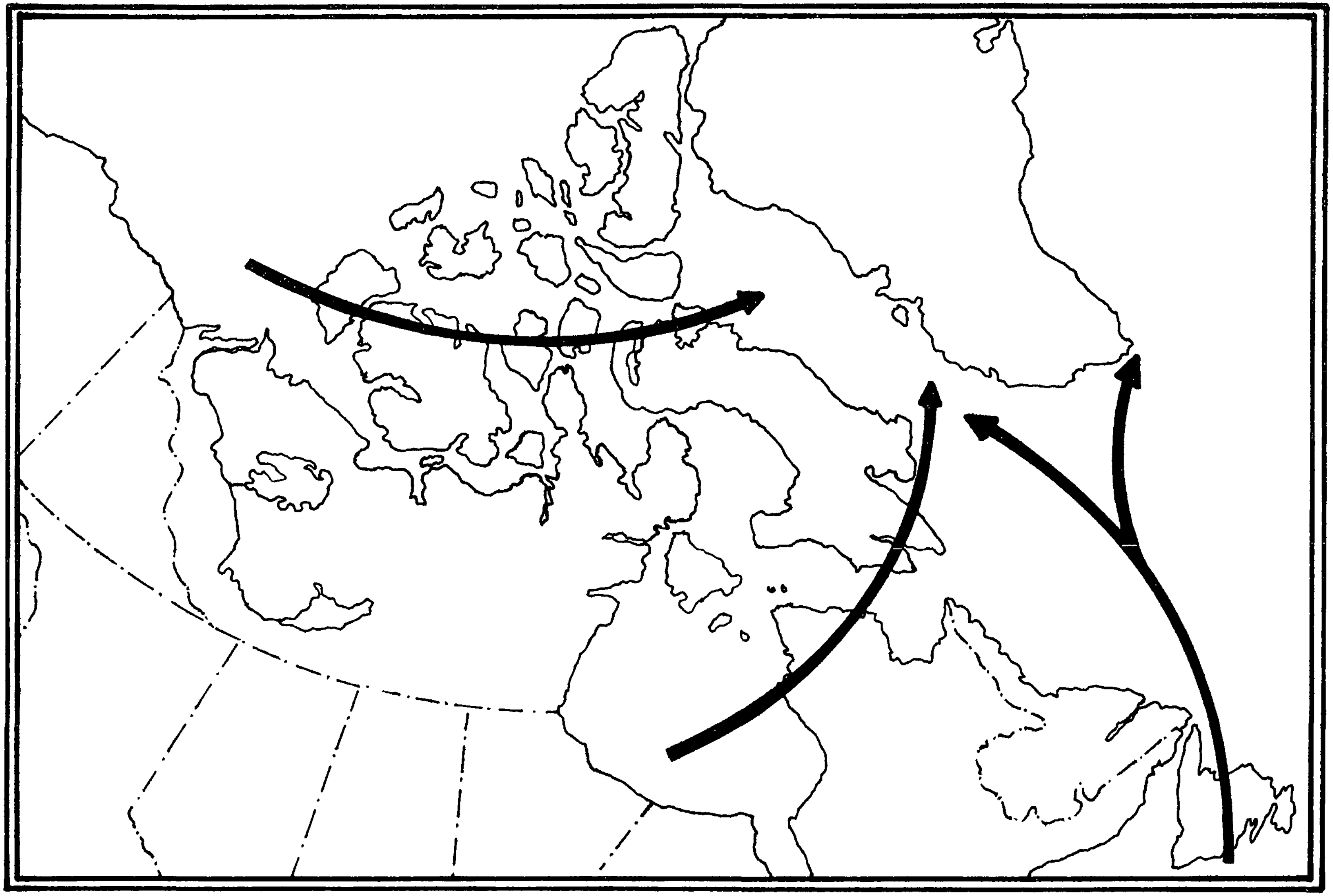

FIGURE 2 PRINCIPAL STORM TRACKS IN THE ARCTIC

Local surface currents of Baffin Bay, Davis Strait and the Labrador Sea are not well documented. The strong ocean circulation and likely wind influence due to the open fetch of this area undoubtedly are the primary factors in determining the general surface currents. In the absence of wind, the general circulation will be that shown in Figure 3 due to the major ocean circulation.

**4.1.3 Ice Conditions.** Ice conditions in the North are governed by the complex interactions of the air and water temperatures, surface currents, and position of multiyear ice and icebergs. Because of this, the ice cover can vary significantly from year to year. The categorization of ice cover for various regions of the Arctic, which is shown in Table 2, is therefore only a rough estimate of what may be expected in any given year.

TABLE 2 ICE COVERAGE

| | Time of Year Under Ice Condition | | |
|---|---|---|---|
| Zone | Open Water | Complete Ice | Partial Ice |
| Southern Beaufort Sea | July/Aug. Sept. | Nov./Dec./Jan. Feb./Mar./April | May/June Oct. |
| Viscount Melville Sound | Never | Nov./Dec./Jan. to July | Aug./Sept. Oct. |
| Lancaster Sound & Baffin Bay | June/July Aug./Sept. | Dec./Jan. to April | May Oct./Nov. |
| Baffin Bay & Davis Strait | Aug./Sept. Oct. | Jan./Feb. March | April/May/June July Nov./Dec. |
| Labrador Sea | All Year | Never | Never |

Multiyear ice concentrations also vary considerably throughout the Arctic. The area of major concern in this regard is Viscount Melville Sound. In typical years, upwards of 50% multiyear ice concentration is possible, year-round. It is this older ice which is thicker and more difficult to navigate. All other segments of the Northwest Passage have multiyear concentrations less than 50%, year-round.

Icebergs are a problem only on the eastern coasts. Calved from the glaciers of Greenland, these massive pieces of ice circulate in the major ocean currents previously identified in Figure 3. A counterclockwise rotation from the Greenland shore

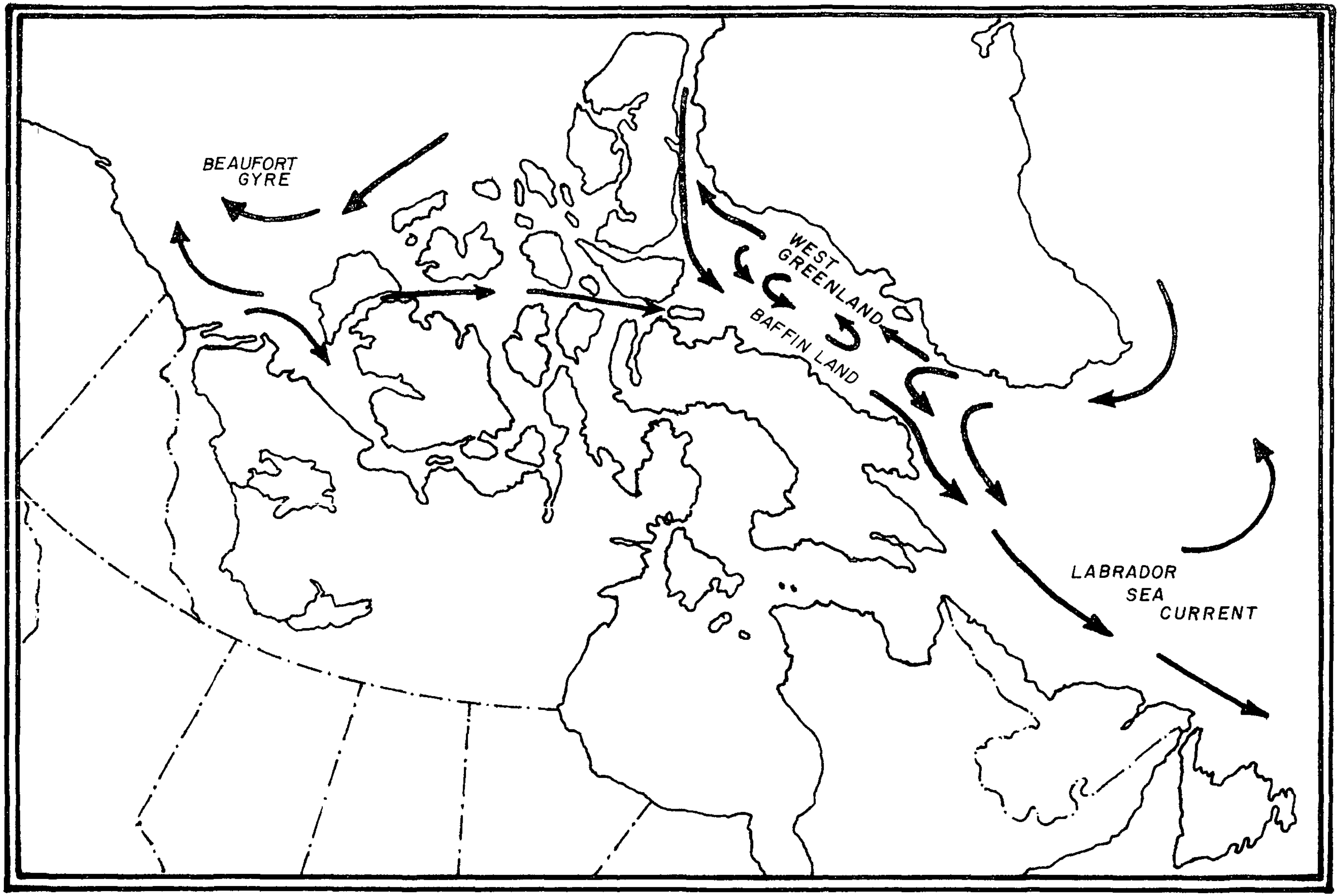


FIGURE 3 MAJOR SURFACE WATER CURRENTS

predominates. The bergs move to the north, cross Baffin Bay, and then travel south along the shore of Baffin Island, with some eventually reaching the Grand Banks south and east of Labrador. The concentration of icebergs varies throughout the season but is never at a level such that safe passage is not possible, provided that their positions can be accurately monitored.

4.1.4 **Coastal Geomorphology.** The shoreline of the five Arctic zones is very briefly described here because offshore countermeasures and not shoreline cleanup are emphasized in this study. The Beaufort Sea/Prince of Wales Strait district has coastline composed of primarily steep beaches with tallus or cliff backshores and ground moraine deposits ranging from fine sand to tallus. A major delta is present at the mouth of the Mackenzie River.

Viscount Melville Sound, Barrow Strait and Lancaster Sound are dominated by erodable cliffs and steep tallus beaches. Areas of gentle beach with a backshore storm ridge are also common in the central portion of the Viscount Melville Sound zone.

The eastern shores of Baffin Island and the Labrador coast are composed of hummocky bedrock foreland or resistant bedrock cliffs.

4.1.5 **Wildlife.** A brief description of the higher-order biological groups throughout the Arctic is presented merely to highlight the visible resources which could be damaged in the event of a major oil spill. No further reference in subsequent chapters is made to biological resources. Fox and polar bear have been included in the discussion since they depend on seals and other marine food for all or part of the year and would therefore be affected by an oil spill in the marine environment. The mammal, bird and fish populations are discussed on a regional basis from information provided in "An Arctic Atlas" (Fenco Consultants, 1978).

#### 4.1.5.1 Southern Beaufort Sea/Prince of Wales Strait.

**Mammals.** The polar bear population in the Southern Beaufort is estimated at between 1 000-1 500, with the largest area of concentration being over 50 kilometres offshore. Many of these bears migrate northeast to Banks Island to den. Fox are plentiful along the entire Beaufort shoreline and are known to feed on seal during the winter.

The most significant occurrence of marine mammals in the Sourthern Beaufort area is the large population of white whales which congregates in the Mackenzie Delta in the summer. Bearded and ringed seals are also common in this area; their distribution is largely dependent on the ice conditions. During the winter, pregnant female ringed seals reside in the shorefast ice zone while the remaining ringed and bearded seals maintain breathing holes in the transition zone. In the summer, the population is spread throughout the area.

**Birds.** The Beaufort region supports few true seabirds in comparison to the eastern Arctic regions. The use of the area as a stopover point and nesting ground for migrating birds is, however, extremely important. Loons, swans, geese, ducks, eiders and old-squaws all concentrate in the area at some time of the year. The Prince of Wales Strait is primarily used as a fall migratory route for the king eider and old-squaw from Viscount Melville Sound to the south.

**Fish.** During the summer, large quantities of whitefish, cisco, char and inconnu immigrate to the Mackenzie Delta in preparation for ascent of the river for spawning. Cod and flounder are present in the more offshore waters, and Pacific herring utilize the Tuktoyaktuk Penninsula as a migratory corridor and feeding ground. Commercial and subsistence fishing is conducted in the summer and fall. Catches of Pacific herring, whitefish, cisco, inconnu and Arctic char are the primary harvest.

#### 4.1.5.2 Viscount Melville Sound.

**Mammals.** Fox and polar bear are common along all of the shorelines of this zone. The polar bear venture away from the shoreline only in areas north of Victoria Island and in Barrow Strait.

The limited information available on marine mammals of this area indicates the presence of ringed and bearded seals, white whales, narwhal and fairly large, but isolated, populations of walrus.

**Birds.** Limited research has indicated that this area has a low use by both waterfowl and seabirds. The presence of a wide range of species in both of these bird types has, however, been recorded throughout the area.

**Fish.** Again, limited data are available on the fisheries of this area. Char and Arctic cod are likely the most important potential commercial resources.

#### 4.1.5.3 Lancaster Sound.

**Mammals.** Polar bear and Arctic fox are present throughout this entire region. This area is also one of the richest in the high Arctic with regard to marine mammals. White whales move into the area as the ice breaks and leave before complete freeze-up. Harp seals are present in large numbers in July and September during migration.

**Birds.** As with the marine mammals, this area is highly productive in terms of seabirds and waterfowl. Large populations of northern fulmars, kittiwakes and murres are known to exist throughout the Sound. Eider ducks, snow geese, loons and gulls are other birds which nest in large numbers in the area. Large numbers of migrating dovekies are also present in ice leads at the exit of the Sound in Baffin Bay in the spring, but do not nest in the area.

**Fish.** While data are limited, the fisheries of this district are considered to be highly productive, with commercial stocks of both char and Arctic cod.

#### 4.1.5.4 Baffin Bay/Davis Strait and Labrador Coast.

**Mammals.** Polar bears and Arctic foxes are common along the entire east shore of Baffin Island. Their ranges extend down the Labrador Coast where they feed on harp seal populations.

Marine mammal populations vary in these regions. The waters off Baffin Island north of Davis Strait support some bowhead whales, but ringed and harp seals predominate. Several species of whales, porpoises and dolphins are known to exist in Davis Strait but whaling operations have greatly reduced these populations. Upwards of one million harp seals migrate through the area twice each year, mostly offshore. A large whelping area for hooded seals is also present on the ice in Southern Davis Strait. Very large populations of harp, hooded and ringed seals migrate off the Labrador coast at various times of the year. The offshore waters of this area also are home to several species of whale and porpoise.

**Birds.** Moderate pelagic concentrations of seabirds exist in the west Baffin Bay area. Further east towards Greenland, moderate to large populations of murres and fulmars are present. The only major bird populations on the west coast of Baffin Island are two northern fulmar colonies. Other species, such as brant, eider, gulls, terns, and loons, are present in low numbers in scattered pairs or in small colonies. The shores of Davis Strait support large colonies of seabirds, and the offshore waters are home to large concentrations of pelagic birds. Murres, dovekies, puffins, and fulmars are the dominant species. The Labrador coast has few major bird colonies but supports a large eider population and low numbers of several other species.

**Fish.** The rivers of the east coast of Baffin Island contain moderate populations of char. The only significant fishery in the Baffin Bay/Davis Strait area is the salmon fishery along the Greenland shore. Quantities of cod and halibut have also been reported in the waters off Greenland.

The waters off Labrador support an increasing quantity of Atlantic salmon and a decreasing number of char as one moves to the south. Extensive fishing for cod, plaice, halibut, redfish and capelin is common in these southern waters.

## 4.2 Industrial Setting

**4.2.1 Present Shipping Activity.** There are currently no industrial operations shipping goods on a year-round basis in the Arctic; the only non-supply movements of goods are the shipment of asbestos from Deception Bay, lead-zinc from the Nanisivik mine, and grain from Churchill. The remaining activity consists of the annual resupply of northern communities and exploration sites from the south. A brief account of this resupply service follows (Transport Canada, 1981a):

> "Historically, resupply provisions have been delivered to Arctic communities by the marine mode because of the bulk nature of the cargoes, the relative costs compared to other means and the general accessibility of communities by water. The communities are spread throughout the Arctic and consist mainly of native populations and government employees. Three main sea routes have been established.
>
> a) Eastern Arctic - The communities of the eastern Arctic, which are those in northern Quebec, Foxe Basin, Baffin Island and the High Arctic Islands east of Resolute, are resupplied by deep sea vessels from Montreal. The Canadian Coast Guard annually administers the sea lift by consolidating cargoes, contracting vessels, supervising loading and unloading and providing icebreaker escort and other marine services. Cargoes delivered under this system are in the order of 55 000 metric tonnes annually.
>
> b) Keewatin - The six communities of the District of Keewatin on the west coast of Hudson Bay and Southampton Island are resupplied by a tug-barge service based at Churchill. The service is operated by the Northern Transportation Company Limited, a Crown Corporation. Cargoes are consolidated at Winnipeg and shipped by rail to Churchill. Cargo on this route has increased to about 25 000 tonnes annually.

c) Western Arctic - The communities in the Mackenzie River Basin and Western Arctic Coast between the Alaskan boundary and Spence Bay are served by a tug-barge transport system comprising the Northern Transportation Company Limited and several smaller operators based at Hay River and having a combined capacity of about 110 000 tonnes. The largest carrier, NTCL, operates three ocean-going ships, 29 towboats and 167 barges and has extensive shore facilities at Hay river and other points. In addition to resupply, mining and oil exploration cargoes are also carried. Historically, traffic has fluctuated in response to northern exploration activity but is now of the order of 350 000 tonnes annually.

All these elements of the resupply service have been well established for many years. They fulfil a vital social need since they are in fact the life line of the northern communities which they serve. It is expected that traffic on these routes will continue to grow at a steady rate in response to increasing populations, larger disposable incomes and the increasing influence of southern tastes. All these routes are limited to the summer navigation season. Improvements in marine facilities are required in all three areas to enhance the service and reduce cargo damage. Adequate dock or landing and fuel discharge facilities are also required at all communities."

In summary, Arctic marine activity has been limited to community resupply (including exploration camps), Churchill grain traffic and some mineral shipment. The potential for oil spills, at this time, lies primarily in the lubricants and bunker fuel on board, and in the shipments of Arctic diesel fuel during these community resupply operations. The relatively small quantities and the dissipative characteristics of this predominantly light oil reduces its threat to the Arctic environment considerably. The further development of oil, gas and mineral reserves in the North will, however, undoubtedly result in an expansion of this bulk transport mode. A substantial portion of this traffic will be the shipment of large quantities of crude oil.

**4.2.2 Proposed Arctic Projects.** The oil and gas finds in the Southern Beaufort Sea, the High Arctic Islands and Alaska have already led to proposals for the shipment of energy reserves to the east coast markets via the Northwest Passage. Commercialization of potential reserves in the Lancaster Sound region would also involve the use of tankers for shipment to southern markets. A brief summary of these activities is included to emphasize the magnitude of these proposals.

**4.2.2.1 Beaufort Sea.** A Dome-Canmar exploration program in the Beaufort has provided indications that this offshore area contains recoverable reserves of oil in the range of billions of barrels. Dome's plans call for the movement of this oil to the east coast via the Northwest Passage by icebreaking supertankers some time in the 1980s. Total production is projected at $10^6$ barrels per day by the end of the century. Figure 4 indicates the possible routes available for these tankers.

**4.2.2.2 High Arctic Islands.** Gas discoveries at Sabine Point, Hecla and off Lougheed Island have prompted industry to develop the "Arctic Pilot Project" proposal for the movement of natural gas to the south in giant liquid natural gas tankers (LNGs). These icebreaking tankers would transport natural gas, which is liquefied in the Arctic, via the Northwest Passage to a gasification centre on the eastern coast of Canada. The initial project is designed to test the economic feasibility of moving gas to the south in this manner at a rate of $7.08 \times 10^6$ $m^3$ per day. Shipments could increase to $10.19 \times 10^6$ $m^3$ per day, future gas reserves permitting.

Oil reserves warranting development have yet to be located in these islands; it is therefore unlikely that any shipments could be made prior to the mid 1990s even if significant quantities were to be found tomorrow.

**4.2.2.3 Lancaster Sound.** Geological structures with promising oil-bearing characteristics have been identified in this section of the eastern Arctic. Proposals for exploratory drilling are being prepared, but estimates of future shipments of oil or gas from the area cannot be made at this time.

**4.2.2.4 Alaska.** At present, the Trans-Alaska Pipeline is shipping $1.2 \times 10^6$ barrels of oil per day to the south, and the known reserves of the area will permit still higher production levels. Proposals for the movement of this additional oil to the east coast via the Northwest Passage by VLCCs have been assessed by both private American interests and the U.S. government. Such shipments could begin by the mid 1990s at a rate of 52 000 barrels per day.

A summary of the potential shipping activity which could be generated by all the above projects is presented in Table 3. While this summary is based on many assumptions concerning exploration success, delivery options, costs, etc., it represents a credible estimate of future sustained shipping in the Arctic (Transport Canada, 1981a). Of significance is the fact that year-round shipping under very severe conditions will be

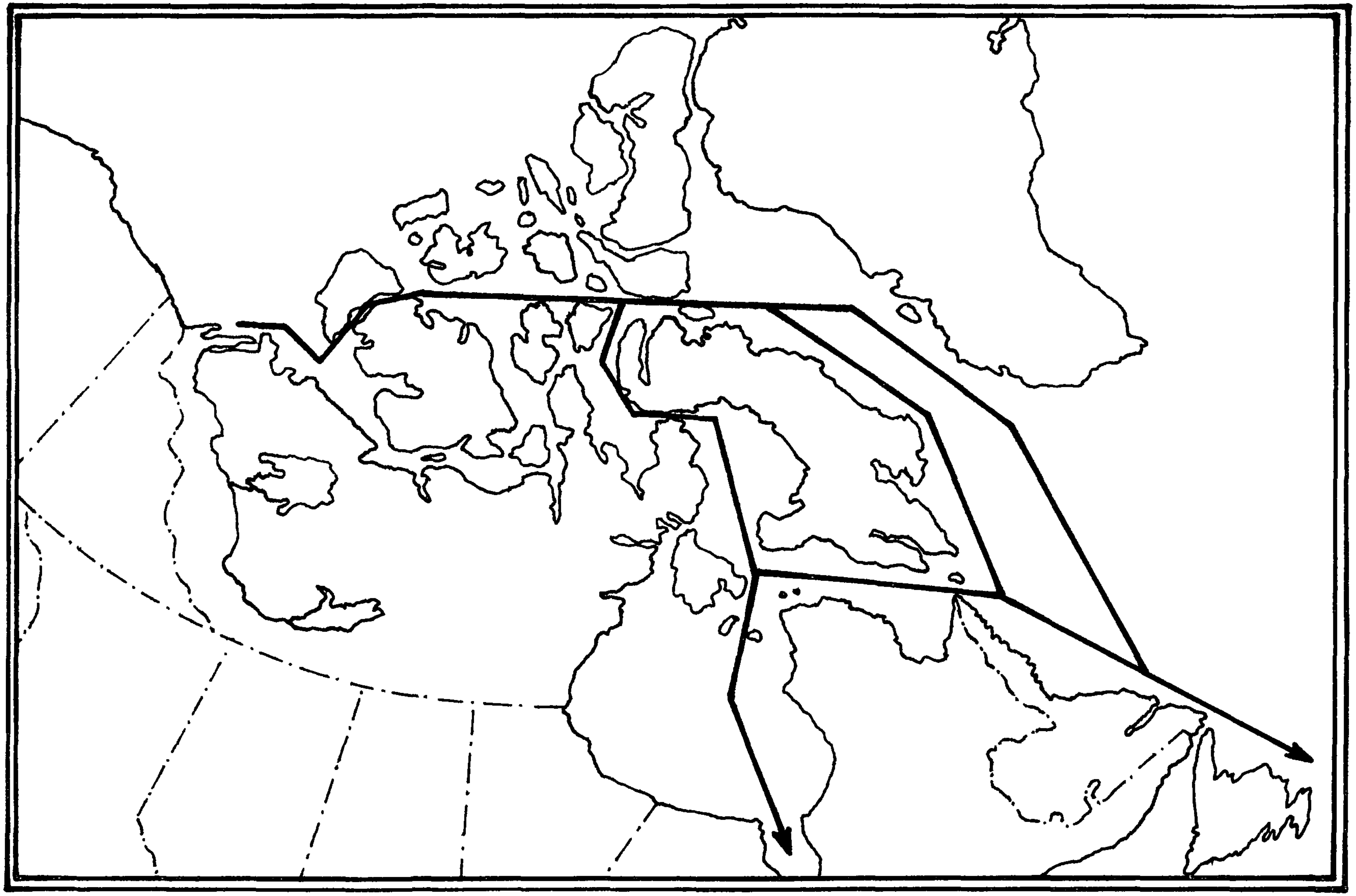

FIGURE 4 POSSIBLE TANKER ROUTES

TABLE 3 FORECAST[a] OF ARCTIC MARINE TRAFFIC LEVELS (Number of one-way ship transits)

| | 1980 | 1985 | 1986 | 1987 | 1988 | 1990 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| <u>Oil/Gas Scenario, Year-round Operation</u> | | | | | | | | | | |
| Beaufort Sea (Oil) | - | - | - | 24 | 48 | 72 | 96 | 120 | 144 | 168 |
| Arctic Islands (Oil) | - | - | - | - | - | - | - | 30 | 60 | 60 |
| Labrador (Oil) | - | - | - | - | - | - | - | - | - | 36 |
| Arctic Islands (Gas) | - | - | 30 | 60 | 60 | 90 | 120 | 150 | 180 | 210 |
| Alaska | - | - | - | - | - | - | - | 24 | 48 | 72 |
| <u>Grain, Minerals, Resupply Scenarios; Seasonal Operation</u> | | | | | | | | | | |
| Grain | | 74 | | | | 74 | | | | 74 |
| Minerals | | 56 | | | | 72 | | | | 69 |
| Resupply | | 176 | | | | 188 | | | | 208 |

[a]Figures assumed as of September 10, 1980 (Transport Canada, 1981a)

necessary to meet these demands. Also, a large percentage of future cargo will be crude oils which pose a potential threat to the Arctic environment if spilled. The Dome-Canmar proposal for the movement of oil through the Arctic is the most advanced of the interested groups and will likely set a precedent which would be followed by future shippers. For this reason, Dome's proposed icebreaking tanker is used as the standard Arctic vessel for the remainder of this document.

Knowledge of the behaviour, under various Arctic conditions, of any oil spilled from vessels of this type is essential in predicting the effects which the oil might have on the local biota and in identifying appropriate countermeasures which could be used to lessen its impact.

# 5 OIL SPILL BEHAVIOUR

The movement and ultimate fate of oil under ice, within ice floes, and on the open water is very much a function of the amount of oil released and the way that it is discharged. Before specific oil behaviour can be addressed, these variables must be considered.

## 5.1 Initial Conditions

**5.1.1 Spill Size.** Considering Dome's proposed Arctic tanker, the maximum conceivable amount of oil which could be discharged in any incident would be the total cargo of 200 000 $m^3$ of crude oil and 20 000 $m^3$ of fuel oil (Johansson and Stubbs, 1980). However, the complete breakup of this ice-strengthened, double-hulled and high-powered vessel, fitted with advanced navigational aids and other safety features, is considered a highly unlikely event. Bercha (1981) determined that the average spill size for a modern standard oil carrier (not of VLCC class) is about 8 200 $m^3$, half of the average tank size of these vessels which is about 16 400 $m^3$. Since the Arctic tanker will have cargo tanks slightly over twice the size of conventional ships, an average spill size of about 18 000 $m^3$ can be extrapolated for the Arctic case. For the purpose of further discussion, a maximum oil discharge of 35 000 $m^3$ will be assumed. This could result from the puncture of two of the vessel's cargo tanks and the loss of half of the oil from each. This volume of oil provides a reasonable "bad case" spill based on conventional averages and differences in Arctic tanker cargo tank sizes.

**5.1.2 Oil Release Conditions.** The rate at which the oil is discharged and the movement of the vessel during the oil release are important factors controlling the ultimate oil spill behaviour and response possibilities.

The characteristics of any future Arctic accident, such as the extent of the ship damage, the effect of the double-hull construction on the oil release rate and the possible presence of ice restricting the oil flow, are not known. The time taken for the proposed 35 000 $m^3$ of oil to leak into the environment could therefore vary from a few hours to days or even weeks. In this study, it will be assumed that all of the oil discharges within the relatively short period of 1 day.

During the period of oil release, the ship's operator has the option of steaming on (if the vessel is able) or remaining on location. His decision on this matter will establish the initial size, shape and thickness of the spilled oil. This may or may not play an important role in the oil's ultimate fate and cleanup. The outcome of the decision, with regard to oil fate and behaviour, will be considered in the discussion of oil behaviour under the three conditions of open water, complete ice cover and partial ice cover. When the vessel steams on, it is assumed that it travels at 20 kmph in complete ice cover conditions and at 35 kmph in partial ice and open water settings. The length of the initial track of oil in these two cases will be 480 km and 840 km, respectively, assuming the 1-day release condition.

## 5.2 Open Water Oil Behaviour

**5.2.1 Spreading.** The rapid release of 35 000 $m^3$ of oil on open water will result in an initially thick slick which spreads primarily by the force of gravity. As the oil thins, the gravity influence is reduced and a balance between surface tension and viscous forces then controls the spreading rate. The approximate area of the slick with time can be estimated from Figure 5. This area is made up of a thick slick portion, which contains about 90% of the oil in approximately 10% of the total slick area, surrounded by a thin sheen of oil (Mackay et al., 1980).

**5.2.2 Drift.** As the slick spreads, it will also be moved by the wind and surface currents. Its final trajectory can be determined by the vector addition of approximately 1 to 4% fo the wind velocity and the whole current vector (Cormack and Nichols, 1977). The coriolis force will also shift the ultimate trajectory somewhat (Fallah and Stark, 1976). An accurate prediction of the slick movement is possible only when the local currents and winds are well documented. For most of the Arctic these variables are not well known.

**5.2.3 Surface Processes.** While the oil spreads and drifts, there are other natural forces which compete to determine its ultimate fate. Evaporation, dispersion and emulsification are the three major governing processes in this regard.

For many crude oils, up to 25% of the oil will evaporate in less than a day even under the cold Arctic temperatures (Nadeau and Mackay, 1978). This rate of loss is controlled primarily by wind, temperature and oil thickness.

Oil which does not evaporate either will be broken up into small droplets which disperse into the water column (oil-in-water dispersion) or will accumulate small droplets of water and remain in a viscous form on the water's surface (water-in-oil emulsions). Which process dominates will depend upon the oil's tendency to form emulsions, it's viscosity and thickness, and the environmental conditions at the time of the spill.

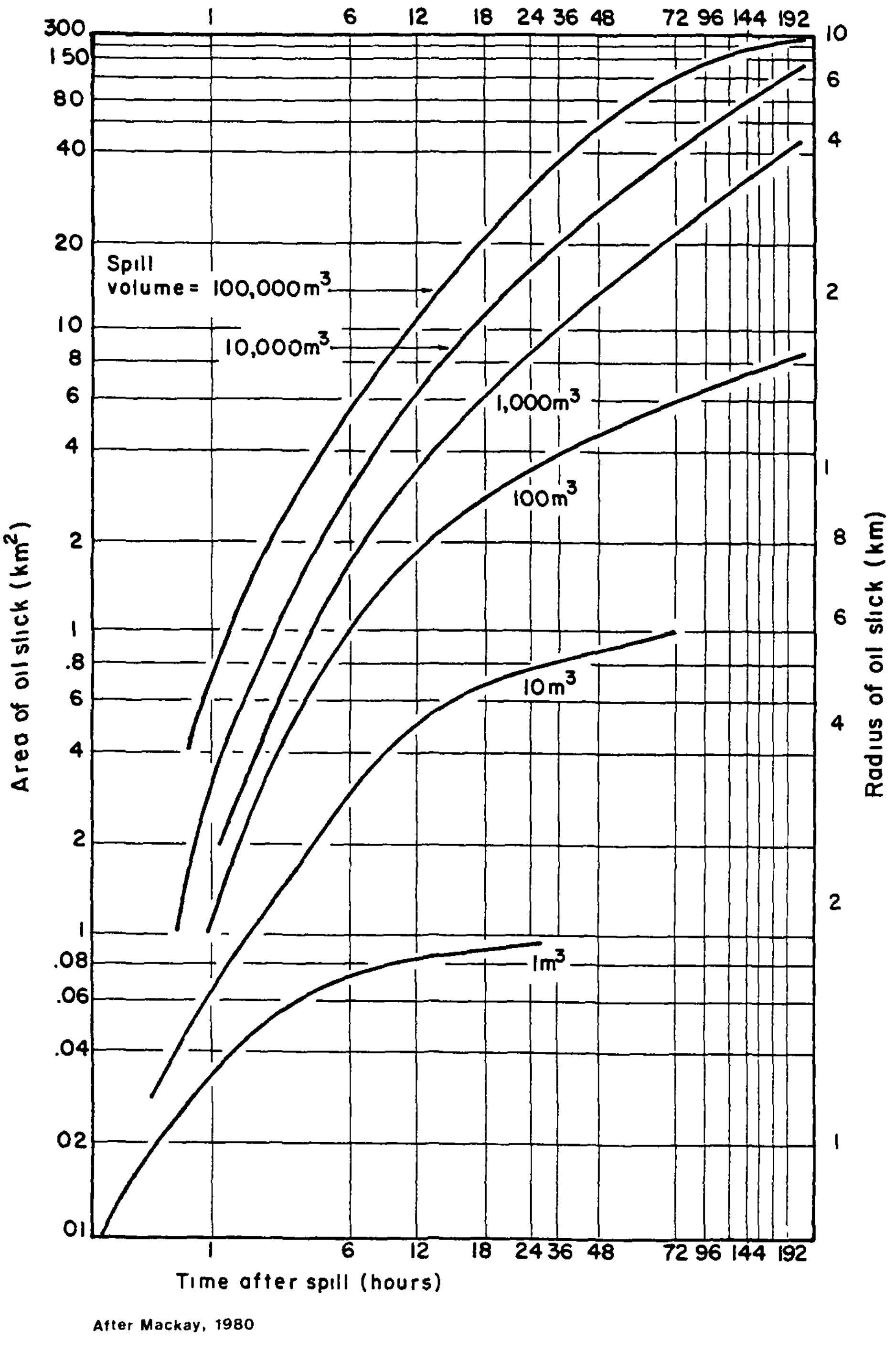


FIGURE 5 SLICK DIMENSIONS vs TIME AFTER SPILL FOR SPILLS OF VARIOUS VOLUMES

These descriptions of oil spreading, movement, dispersion, and emulsification generally apply to the slicks of both of the oil release conditions discussed earlier. However, the very different initial characteristics of the two slicks will likely result in different ultimate oil fates.

The oil released from a stationary vessel will initially be thick (in the centimetre range) and present in a relatively small area. After a period of 2 days, the slick's area will be no more than 25 $km^2$ (Figure 5). The thicker oil portion, about 10% of this area, will be particularly susceptible to emulsification and will disperse slowly. Therefore, although the slick area is minimal in a stationary release, the oil will likely persist on the surface for a considerable length of time.

If, on the other hand, the oil is released as the vessel steams on, the initial oil slick will be relatively thin (a few millimetres), narrow, and many kilometres long. This thinner oil will be dispersed more easily and will not likely form heavy mats of emulsified oil. The oil slick will, however, be much larger, reaching an area of about 120 $km^2$ after only 2 days.

The ultimate impact of these two very different slicks will depend upon the local environment and weather conditions. The smaller and more persistent slick from the stationary release will continue to drift under the influence of surface water currents and winds and could heavily contaminate significant lengths of shoreline. The slick created by the moving release will be easily dispersed in rough seas, and thus shoreline impact will be reduced. However, under calmer conditions, this long slick could lightly oil a very large extent of shoreline. Because the slick will extend over approximately 840 km, it will be subject to a variety of local currents and winds along its length. This will complicate the prediction of shoreline contact. It is possible that a number of coastal areas could become contaminated, each separated by great distances. In general, however, slicks of initial thickness in the range of millimetres or less would be expected to dissipate in the water and not survive long enough to reach coastal boundaries.

### 5.3 Oil Spilled in Partial Ice Cover

Oil spilled from a tanker under partial ice cover conditions will result in oil being discharged between and on the surface of the ice floes present. The spread of the oil will be governed by the same forces discussed in the open water case but the presence of ice will restrict the movement. No information is available to estimate what influence the presence of the ice will have on reducing the oil spreading. It can only be assumed that as the ice coverage is reduced its influence on spreading is lessened. The movement of the oil slick will generally follow the drift of the ice pack which is governed by the winds and currents of the area. The evaporation rate of the oil will be reduced compared to the open water case due to the thicker oil (Nadeau and Mackay, 1978). Work by Reimer (1981) indicates that the dispersive process is also slowed for oil present in pack ice. This appears to be due to the reduction in sea state created by the presence of the ice.

In general, it appears that the oil spilled in a partial ice cover condition will spread and disperse at a slower rate than that in open water. The effect of oil being discharged from a moving ship would simply be to increase the initial slick size. No change in the containment or dispersal altering characteristics of the ice floes would be expected. As a reduction in the ice coverage is experienced in spring, the behaviour of the oil will approach that for the open water case. If the spill were to occur as freeze-up was beginning, pockets of oil would be frozen within the floes and contained until the next thaw cycle.

### 5.4 Oil Spilled in Complete Ice Cover

The behaviour of oil discharged from a tanker under complete ice cover conditions differs considerably for the two modes of discharge.

5.4.1 **Ship Stops.** If the vessel is stationary during spillage, the oil will leak and spread under ice in a radial manner. Work by NORCOR (1975) and by Dickens (1980) has demonstrated that the minimum thicknesss that the oil will achieve under the ice is about 1.0 cm, even under very smooth ice conditions. It has also been demonstrated that the oil will not move significantly due to under-ice currents (NORCOR, 1975). The 35 000 $m^2$ spill, if distributed under the ice in this minimum thickness, would cover a maximum area of only 3.5 $km^2$. The underside of most ice sheets will be extremely rough due to pressure ridge formation, rafting and other processes. It is therefore likely that the oil will spread and pool in these depressions thus covering only a fraction of this maximum possible area.

Should the oil be spilled during a period of ice formation, new ice growth will encapsulate the oil and preserve its freshness until the spring thaw. The efforts of NORCOR (1975) and of Dome Petroleum Ltd. (1980) have been successful in monitoring the behaviour of the oil during this thaw period. As the ice melts, brine channels open up and link the subsurface oil deposits to the surface. The oil then moves up these channels due to its lighter density and pools on the ice surface. By the time breakup occurs, anywhere from 70 to 100% of the oil will be on the surface. The actual amount depends on when the oil was encapsulated in the ice.

If the oil is discharged during this thaw period, it will follow the same route as described above and eventually pool on the ice surface. With a continued thaw and breakup, the oil will eventually be subjected to the same forces discussed in the partial ice cover and open water scenarios.

5.4.2 **Ship Moves On.** If the vessel continues to move on during spillage, the oil will stream along the ship and be deposited in the path of broken ice in the wake of the ship. When the ship track freezes over, the oil will be trapped within the ice near the surface due to its buoyancy. A small amount of the 35 000 $m^3$ of oil will also be churned into the water by the ship's propellers and deposited under the ice to either side of the 480 km long ship track. As the ice melts in the spring, the surface deposits of oil would increase the surface albedo in the vicinity and increase the thaw. A swath of oil floating on water and bounded by unmelted ice would likely result from such a discharge in the early thaw period. The oil would then be contained by the surrounding ice until breakup. As the thaw progresses, the oil would be involved in a partial ice and then an open water situation. Its behaviour during these periods would be similar to that already discussed.

# 6 ARCTIC TANKER SPILL COUNTERMEASURES TECHNOLOGY: STATE-OF-THE-ART

This chapter presents a review of the state-of-the-art for cleaning up tanker oil spills in the Arctic. Discussions are intentionally kept very general and brief; a more in-depth examination of equipment and strategies is available in Chapter 7, which presents and evaluates specific hypothetical spills and response options.

The generally accepted strategies for dealing with an oil spill from a tanker utilize various combinations of the following basic procedures:

a) stopping the discharge;
b) containment of any released oil either on the open water or after shore contact;
c) mechanical removal of contained oil;
d) combustion of contained oil;
e) chemical dispersion of free-floating oil;
f) the disposal of collected oil and oiled debris;
g) monitoring and surveillance of the free-floating oil; and
h) shoreline cleanup and restoration.

Specialized equipment and techniques have been developed for these operations based primarily on conditions more temperate than those experienced in the Arctic. Several programs have, however, been underway within Canada and elsewhere to modify this equipment to meet the needs of the northern application, or to develop new technologies. A review of the present state-of-the-art in each of the above control areas follows.

## 6.1 Elimination of the Source of Discharge

The first control option to be considered is to stop the further loss of oil. The technology for the removal of the remaining oil from the damaged tanks to safe storage has been improved in recent years due to the availability of highly portable inerting and lightering systems. The technology has application in the northern climate, but the fact that the pumping hardware and storage units must be transported very long distances reduces its effectiveness. The need for a portable lightering capability in the south was developed from the lack of internal transfer and inerting systems on conventional tankers. It is likely, based on the Dome example, that the Arctic tanker will have this capability built-in. Provided that the tanker is not completely disabled, the process of lightering damaged tanks will be handled by on-board equipment and storage.

## 6.2 Oil Containment

Large and high-strength booms are available for use in the offshore environment where high seas dictate that only durable products are effective. While these booms cannot contain oil at winds greater than 35 kmph or at sea states above Beaufort 4, they must be able to survive rougher conditions during their deployment and use. These types of sea states will only be encountered with varying probability during the open water periods in the Beaufort Sea, in Baffin Bay and off the Labrador coast. The remainder of the Arctic is characterized by much calmer conditions during most of the open water season. Conventional offshore booms also have difficulty standing up to the forces exerted by the presence of moving ice. Booming in areas with ice concentrations greater than 1/10th is not currently feasible nor is it recommended (Meikle, 1978a).

Various designs of offshore boom are available which can generally be classified as light, rapidly deployable, air-inflatable barriers and as solid flotation types. The actual design and construction of specific brand names within these two basic categories represent a wide variation in capability. For the Arctic condition, a strong, smooth-walled, fence-type barrier is preferred because of its ice-shedding properties and its ability to withstand puncture. A light and transportable boom is also recommended due to the large distances involved in an Arctic response. The absence of any mechanical complexities would also be desirable in view of the remoteness of the regions to which the boom would be applied.

Smaller and lighter booms are also available for nearshore containment and deflection of oil. Booms of smaller draft and lighter materials are suitable in coastal areas where quiescent water predominates. In ice-free waters with currents less than 0.5 metres per second, these barriers have proven to be very successful in holding or deflecting oil at the shoreline. Althgough the presence of ice at Arctic shores for long periods will hamper the use of this equipment, it will afford protection against contamination of the coast.

The problem of ice damage to conventional boom has lead to the study of alternatives. An ice-deflecting barrier has been developed for use in series with a conventional barrier (Tsang, 1975). This device has shown some promise when tested in ice-infested rivers but is not yet a proven tool for Arctic situations. More promising is the use of water jets to divert or contain oil. A simple piping system with high velocity jets pointed downward toward the water surface has been shown to be effective in diverting or containing oil. The technique is relatively insensitive to ice and rough water, making its use in the Arctic appealing.

Ice also was a major consideration in the development of a very rugged boom which Dome Petroleum Ltd. now keeps on hand at its Tuktoyaktuk base in the Beaufort Sea. It features a double length of heavy conveyor belt material which houses an internal solid flotation element. The barrier can be used in conjunction with the company's antipollution barge and was conceived to deal with a sub-sea blowout. When held in a V-configuration downstream from the release point, it would funnel oil back into a skimmer positioned at the apex. Application of this system to a tanker incident is only foreseen in the Beaufort Sea region during conditions of open water.

### 6.3 Mechanical Oil Removal

The ultimate objective of a spill cleanup is the removal of oil from the environment. In this regard, numerous mechanical devices have been designed to skim oil from the surface of water. Units are available to deal with oil in specific situations such as rivers, coastal areas, and the open sea. These devices can generally be classified according to their basic principles of operation which include weirs, suction equipment, sorbent surface machines, and submersion devices. Each category in turn can be further subdivided in terms of the specific skimming configuration and/or materials used in its construction.

Skimmers are available in various sizes ranging from large, self-contained and self-propelled vessels down to small units that can be handled and operated by a single person. The selection process of identifying a suitable oil recovery device usually includes such considerations as the anticipated location of use (nearshore versus offshore); the properties of the oil to be recovered (temperature, viscosity, pour point, etc.); the conditions of the water environment (flowing or quiescent, sea state, presence of ice, etc.); and the necessity to transport it using various available means (e.g. aircraft, supply vessel and workboat). Other considerations, such as maintenance requirements and mode of operation, also figure in the selection process.

**6.3.1 Weir Skimmers.** Weir-type skimmers can be deployed to remove oil contained and concentrated in calm water conditions only. These devices have been tested and used to recover light oils such as fresh crude. Such systems usually suffer from the uptake of excessive volumes of water but do offer a lower cost, portable oil removal capability.

More sophisticated hydroadjustable weir devices incorporate an adjustable weir lip which positions automatically to a precise level allowing a maximum volume of oil to overflow into a sump. An external pump transfers the product to storage. These skimmers, like the simple weir systems, are used in conjunction with oil/water separation and concentration gear, usually tanks in which the water and oil are allowed to separate and the water is simply drained off. Their main advantage lies in their being mechanically uncomplicated. The presence of debris or ice will, however, clog the weir openings and render the equipment inoperative.

**6.3.2 Suction Devices.** Large-capacity vacuum units, which could be used in open water conditions in the Arctic to remove oil, have seen wide use during spills in all regions of the world. Their main advantage lies in their capability to recover an emulsified product and their proven mechanical reliability. These self-contained devices could also be applied to remove oil between ice floes once placed on a suitable working platform. They are a particularly valuable oil removal approach for the North because of the viscosity of oil that they can process. Their relatively large size and weight, however, present a problem in the North since air transport to the spill site will be necessary.

**6.3.3 Sorbent Surface Devices.** One of the most effective skimming approaches selected for use in the northern environment is a generic classification of machine incorporating an oil-attracting surface. Several forms of this principle exist, one of which is the rotating disc. During collection, oil or an oil/water emulsion adheres to a series of discs which are then scraped or wiped, with the product deposited in a sump and conveyed to storage. Advantages of such systems include the machine's capability of picking up a product high in oil content and its ability to operate in limited ice conditions and debris as well as in waves.

Another sorbent-surface skimmer makes use of polypropylene strands woven in the form of a rope. Oil adheres to the rope mop and is squeezed off by a wringing system. This type of skimmer can function well in limited wave conditions, with some ice infestation, and can process a range of oils similar to the disc-type skimmers. It does, however, tend to jam when applied to more viscous oils; for example, it could not be used to recover weathered crude at lower temperatures.

The Slicklicker, made famous in Canada during its use in the ARROW spill in 1970, is also available for spill response in the Arctic. It can be effectively utilized to remove contained oil, including very viscous products, by simply transferring the oil which adheres to the conveyor-type belt to a storage container. Much development work has focussed on improving the capability of the skimmer to move very heavy oils in large volume. Generally, the Slicklicker and other similar machines are limited to use in relatively calm water, free of ice.

**6.3.4 Submersion Device.** This type of skimmer features a sorbent belt inclined at an angle which forces the oil to submerge and eventually adhere to the belt. A second squeeze belt in one model removes the oil to a collection sump for transfer to storage. A skimmer of this type is presently being tested and modified to operate under northern conditions.

**6.3.5 Skimming Booms.** More recently, skimming equipment has emerged which incorporates the principles of containment and removal in a single device. Two main approaches have been researched, including a barrier which incorporates a number of weir openings and a unitized boom/skimmer which features two sweep arms and a following suction component. These systems are generally very bulky, can require multi-vessel deployment, and are relatively complicated to handle. The problems associated with ice further curtail the range of application of these systems in the Arctic.

### 6.4 Combustion

The migration of oil initially discharged under an ice sheet to surface pools during the spring thaw was discussed earlier (Chapter 5). The in-situ combustion of this oil and other oil similarly confined by ice on the ocean surface should be a prime oil removal technique in the Arctic. The use of air-deployable igniters for this purpose has been investigated by Dome Petroleum Ltd. and Environment Canada. Both have successfully developed devices for this purpose, and Dome has demonstrated its potential in a northern field trial (Dickens and Buist, 1980). Upwards of 75% of the oil discharged under an ice sheet could conceivably be removed by an extensive burning operation in the spring utilizing these devices (Dome Petroleum Ltd., 1981). This burning alternative provides an exciting opportunity to take advantage of the presence of ice during an oil spill cleanup.

A unique fireproof containment barrier has been prototyped by Dome Petroleum Ltd. The system has been designed to operate in a Beaufort 4 sea state and to survive in Beaufort 5. Its use as a one step containment/removal-by-combustion process is seen as a potential tool in the remote Arctic setting. The successful use of the boom for burning in the open water situation would require a prior concentration of the oil by conventional booms. The sea state, current and ice conditions will all combine to limit the success of such an operation.

### 6.5 Chemical Dispersion

Another method of removing oil from the ocean surface, alternative to burning or mechanical recovery, is the use of chemical dispersing agents. These chemicals, when applied to an oil slick, decrease the interfacial tension between oil and water, thus reducing the cohesiveness of the slick. The sea can then more easily break the oil up into small drops which quickly mix and dilute into the water column. The effectiveness of the technique depends upon the level of mixing energy available to break up the oil. In general, the process works best under high sea states, although newer "concentrate" products are reasonably effective on fresh oils in moderate seas. The process is not directly affected by the presence of ice, except by the ice's attenuation of wave action. Thus, the dispersing option becomes attractive when more conventional countermeasures are not feasible due to high seas or the presence of ice. Another attractive feature of this technique is that the product can be applied via aircraft; a vast area of slick can thus be treated over a relatively short period of time.

The use of dispersants in the Arctic is not without its problems, however. A basic problem is that the colder temperatures increase the oil's viscosity and thus reduce the effectiveness of the chemical agent. A large-scale dispersing operation would require an influx to the spill site of large quantities of dispersants and aircraft fuel. The distance these cargo planes would have to travel and the limited landing facilities in the North could create a serious logistical constraint for such a control measure. In fact, it is unlikely that such an operation could be mounted sooner than 3 to 4 days after the release of oil in any part of the study area. By this time, the oil's viscosity will have increased, due to evaporation, emulsification, etc., to such an extent that the addition of the chemical will have a negligible effect on the dispersion process. For this reason, aerial application of chemical dispersants is not considered a useful countermeasure for dealing with a large tanker spill in the Arctic, at least not until more effective products are developed.

### 6.6 Monitoring and Surveillance

The effectiveness of many of the control operations discussed depends to a great extent on the ability to monitor the position, direction of drift and size of the oil slicks. The vast areas and remoteness of the Arctic as well as long periods of darkness complicate this task.

The most obvious method of tracking the oil is by visual observation from aircraft and ships. In many cases this will not be sufficient in the Arctic because of prolonged periods of poor visibility due to either weather or seasonal daylight conditions. Many other methods have been developed for this purpose which will improve surveillance under northern conditions.

Radio tracking buoys monitored from land, ships or aircraft have been constructed to simulate the behaviour of specific oil types. Tracking distances of 15 km from the water and 45 km from the air for periods of up to 3 weeks are possible with the present equipment.

The use of both passive and active airborne remote-sensing packages for tracking and locating purposes has been advanced in recent years. Documentation of spill extent and location can be made through colour or filtered black and white photographs. Low light television systems can differentiate oil slicks from wind and wave patterns but are ineffective in the dark and are unable to discriminate oil from foam, slush ice or brash ice. An active day or night system, the laser fluorosensor, is able to detect oil on water, on ice, and in ice-infested conditions. It is limited to the detection of oil at, or very near, the surface of the water or ice. Dual, infrared/ultraviolet, line scanners have been successful in locating oil on a real-time basis during the day. Side Looking Airborne Radar (SLAR) is able to cover a large area in one pass when mounted on an aerial platform. These SLAR systems are effective, day or night, in detecting oil only in ice-free waters.

Satellite imagery is another means of locating and tracking oil slicks during daylight hours. At present, the Landsat series of satellites scan the Arctic with sensors in the red, green and near infrared. This information can be used to identify the position and extent of an oil slick. Plans to mount improved sensors in these orbiting stations will undoubtedly enhance the use of satellites for future monitoring.

In summary, a range of remote sensing techniques are available for the detection of oil on a water or ice surface. The effectiveness of many of these methods is, however, hampered by darkness and by the presence of cloud or haze conditions.

## 6.7 Shoreline Cleanup

Conventional shoreline cleanup in the south has involved the containment of oil at shore, the removal of oil and oiled debris by manual and mechanized means, and the cleaning of rocks and man-made structures by high-pressure water and steam. A northern cleanup and restoration operation will utilize techniques and equipment much the same as in the south. The northern shoreline cleanup operation will, however, be complicated by several factors.

A large workforce is not available in the North due to its sparse population. Since many of the cleanup steps require manual labour, a northern spill response will encounter an immediate labour shortage. Heavy equipment will have to be used sparingly due to the sensitive nature of the northern shorelines and their slow recuperative abilities. In many instances, beach material will not support heavy loads; the presence of boulders and anomalies in the surface preclude the use of any large mechanized vehicle. The lack of road access to all of the North means water or air transport is the only mode of travel. This will result in excessive transit times to the work site and lower effective worker output. The colder climate and potential periods of prolonged darkness will also complicate the northern shoreline cleanup operation.

In summary, while all of the southern shoreline cleanup techniques are generally applicable to the Arctic study area, the remote nature and harsh but fragile environment of the North will make their application more difficult and less efficient.

## 6.8 Disposal

The ultimate disposal of recovered oil or oiled debris generally takes the form of either landfilling or incinerating the material. Both of these alternatives have drawbacks in a northern application.

The burial or landfilling of oil and oiled debris is possible only if suitable sites are available to construct either subsurface pits or above-grade berms to contain the material. Such sites are not plentiful in the Arctic; where available, they may be difficult to access due to the complete absence of roads and the presence of shallow water at the shore (Hardy, 1979). Ice-rich soils, common in the Arctic, also pose a problem in summer operations since excavation in permafrost can create sloppy, unworkable conditions. Landfilling operations also require the use of heavy equipment which is obviously not plentiful in the North and which would be difficult to transport to specific disposal sites.

The major advantage of landfilling in the Arctic is the ability to permanently encapsulate the oil and debris in a frozen surrounding.

The state-of-the-art for oil spill disposal by incineration has advanced from earlier attempts at burning oil and debris in oil drums or open pits to a technology including air transportable incinerators and reciprocating kiln beach cleaners.

Oil burners have been developed which are capable of incinerating from 80 to 800 $m^3$ of oil or emulsion per day (Ross Environmental Research Ltd., 1981; Trecan Ltd., 1979). Air-portable pit incinerators presently available can burn up to 20 tonnes of oily waste per hour (P.R.O.S.C.A.R.A.C., 1980). With several of these devices available, the disposal of collected free-floating oil and other combustible debris from a major northern spill could be accomplished within a reasonable time frame.

Oiled beach materials such as sand and rock could be cleaned in simple reciprocating kiln devices but such equipment at present has a very low throughput. An unmanageably large number of these kilns, along with their manpower and logistical support, would therefore be required to carry out an extensive beach cleaning.

It is also apparent that any proposed landfill operation would involve serious logistical problems. This must be concluded for any proposed labour-intensive spill control operation in the North, either beach cleaning or debris disposal. In most cases, beaches and shorelines will likely be left to regenerate by natural means.

# 7 HYPOTHESIZED ACCIDENT SCENARIOS AND PROPOSED RESPONSE STRATEGIES

## 7.1 Scenario Selection

Oil movement and cleanup response alternatives are largely dependent on the three possible ice cover conditions: open water, partial ice cover and complete ice cover. The final selection of representative spill scenarios should therefore include a spill occurring under each of these conditions. Other factors should be considered to ensure that a wide range of possible conditions are covered by the proposed scenarios. The more important of these are:

a) the quantity of oil which is spilled;
b) the ship condition (whether or not the vessel is available as a work platform);
c) the time of year of the spill (this will determine the hours of daylight, temperatures during any cleanup attempt, etc.);
d) the location of the spill (which will reflect the logistical difficulties of different regions in the North); and
e) the biological sensitivity of the spill area.

These variables are reviewed as they pertain to the study area; difficult locations or conditions for possible spills are identified. A summary of this analysis follows. The quantity of oil to be considered, established as 35 000 $m^3$ in Chapter 5, is not varied in the spill examples for reasons of simplicity. The advantage of being able to use the damaged oil tanker as a work platform, and the possible daylight and temperature variations and their implications are discussed for each scenario.

The water to the north of Prince of Wales Strait in Viscount Melville Sound presents a worst-case condition from a logistical standpoint due to the distance from the nearest centres of Tuktoyaktuk in the west and Resolute in the east. Lancaster Sound and the Southern Beaufort Sea/Mackenzie Delta are two of the most biologically sensitive zones in the Arctic and have been selected as spill sites for this reason. Their selection allows a comparison to be made between the present cleanup capability in the western Arctic, where much oil spill equipment is now stockpiled, and the eastern Arctic where this is not the case.

The following four oil spill scenarios, identified on Figure 6 for reference, have been selected for review.

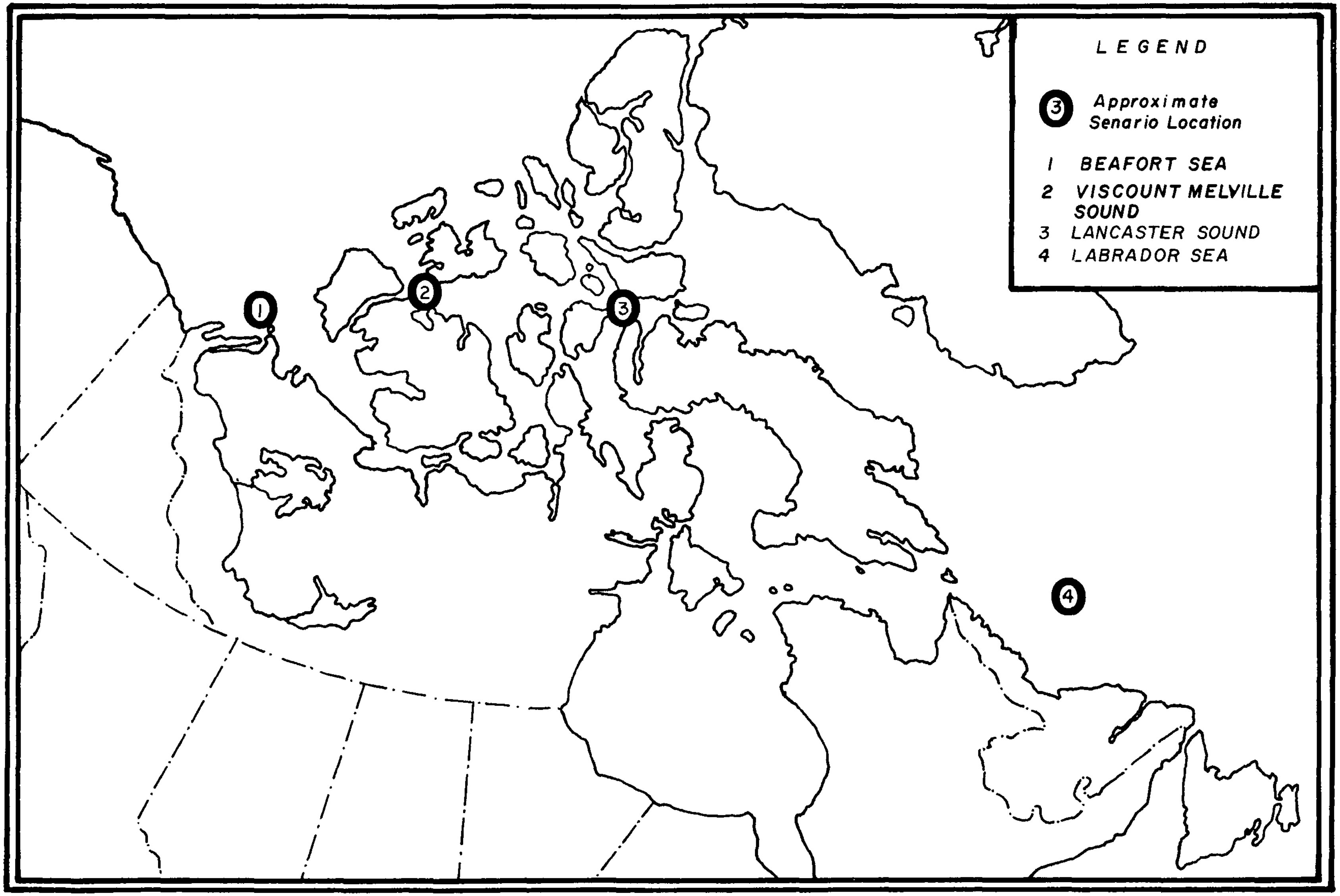


FIGURE 6 SPILL SCENARIO LOCATIONS

**7.1.1 Southern Beaufort Sea.** This first spill site is in the heart of present oil activity in the Arctic. The Beaufort Sea area is also relatively sensitive biologically, thus emphasizing the need for a proper response to any oil discharge to minimize damage. Good access to this region is available via Tuktoyaktuk where both industry and government have stores of cleanup equipment.

**7.1.2 Viscount Melville Sound.** This second spill site has ice present all year and is the most difficult location to access within the study area. A complete ice cover is assumed to be present during the spill.

**7.1.3 Lancaster Sound.** This region permits a study of a biologically sensitive area with relatively good access via Resolute and Nanisivik. A partial ice cover condition is assumed in order to identify problems associated with oil cleanup in broken ice.

**7.1.4 Labrador Sea.** This location has the potential for the highest seas in the study area during its long open water season. Since vessels would likely be travelling well offshore in the winter months to avoid ice near the Canadian coast, the spill site would also be difficult to access from the nearest staging locations.

### 7.2 Scenario Details

**7.2.1 Beaufort Sea Spill.** It is assumed that a collision between vessels in the vicinity of the production platform for Dome Petroleum's Kopanoar field results in the release of 35 000 $m^3$ of oil from an Arctic icebreaking supertanker over a period of 1 day. The incident occurs in open water during the month of August when both the water and air temperatures are about 5°C. The seas at this time of year are less than 1.5 m most of the time and currents generally less than 0.4 m per second (Dome Petroleum Ltd., 1982). Daylight hours, over the month of August, range from about 21 hours at the beginning of the month to 16 hours near the end.

The countermeasures to be taken are described in the following paragraphs. For all of the spill scenarios, it is assumed that within the crew of the damaged supertanker is a group of experienced spill control people who are ready to respond to an accident. While this is not the case for conventional tankers operating in the south, it is proposed that this complement is needed on board the northern tanker to provide an initial line of defence to prevent or reduce oil spillage.

In the event of an accident, the first priority would be to ensure the safety of the crew. The proposed ice-strengthened Arctic tankers are to be designed to provide a stable platform under these accident conditions so it is also assumed that crew safety would not be threatened in these scenarios.

After a review of the safety factors and the nature of the damage and resulting spill, steps would be taken to reduce the oil loss. It is assumed that an on-board capability to transfer crude from the damaged tanks to vacated ballast space or to additional storage areas would be in place in the supertanker. Operations utilizing this internal capability would be directed by trained personnel on board. As transfer operations continued, attention would be directed towards containing the oil spilling into the surrounding waters. This could conceivably be accomplished by equipment and crew stationed on the supertanker or by a similar response effort mounted from the nearest staging location. The success of either method would be highly dependent upon the sea conditions at the time of the spill. For this scenario, it is assumed that the seas do not limit these operations.

The on-board capability has the obvious advantage of a very rapid response. It is assumed, however, that the deployment of countermeasures equipment and manpower over the 18 metre freeboard of the proposed supertankers would not be attempted. Even if the equipment could be deployed successfully to the water surface, it would be difficult or impossible to collect and then transfer the large quantities of escaping oil to available storage space aboard the tanker. Until these problems can be worked out by the ship designers, operators and spill control experts, this cleanup alternative must be rejected for all scenarios in this study.

The second possibility, that of aid from a nearby staging location, generally lacks the guaranteed rapid response of the ship-based effort. The Beaufort Sea scenario does, however, hold some promise for this type of action. Drilling and production activities in the area provide potential platforms from which an initial fast-acting spill response could be mounted. Alternatively, Tuktoyaktuk is only about 100 km from the likely high traffic zones in the area, and both government and industry have spill response equipment ready at this location. Aid from Tuktoyaktuk could be expected on site within about 8 hours assuming an allowance of 2 hours for onshore preparation. To be effective, such an operation would require sufficient offshore boom to corral the affected area, high capacity skimmers able to collect and transfer a total of 1 500 $m^3$ of oil per hour, and storage for about 25 000 $m^3$ of collected oil (the amount which is assumed to leak, from the time the crew arrives until the tank is pumped out 16 hours later). Boom of this type and quantity is readily available in the Beaufort. Storage could be provided by local barges (and possibly the damaged tanker itself). Present high-capacity disc or vacuum skimmers are able to handle a maximum of only about 200 $m^3$ per hour which would necessitate having seven or eight of them on-site to match the assumed oil discharge rate. It is unlikely that an operation utilizing this many large skimmers could be successfully initiated in such a short time. Skimmers of much higher capacity would therefore be necessary for such a response to be completely effective. Given calm sea conditions and such high-capacity units, a high percentage of the spilled oil could be reclaimed. The oil escaping during and prior to such an operation would be marked by radio tracking buoys and monitored for future cleanup actions.

For this scenario, it is assumed that ship-side collection removes much oil but 15 000 $m^3$ of oil still escape the operation. This oil would also be marked by tracking buoys for easy location. The next plausible control alternative would be the collection and removal of free-floating oil prior to its contact with the biologically active and sensitive shorelines of the Beaufort Sea area. This option of "chasing down" slicks could be attempted but would prove to be inefficient for the following reasons.

Mobile offshore skimming barriers designed to concentrate and collect free-floating oil are available in two configurations. In both instances, a length of collection boom directs the oil to a series of weirs which remove the oil from the water surface. First, the boom/skimming weir could be attached to a single, small tanker which then provides both the working platform and ultimate storage for the collected oil. This system is able to survive in rough seas and is fairly manoeuvreable; it provides a collection swath width of about 15 m. Alternatively, the boom could be towed by two small workboats in a U-configuration with the weirs positioned at the apex of the U. This configuration lacks seaworthiness, requires more support vessels, and is much more difficult to manoeuvre than the small tanker system, but is capable of a sweeping width of about 75 to 100 m. Neither configuration is an efficient oil collector in rough seas or when operated at speeds greater than 0.5 m per second (relative to surface water movement). Furthermore, practical use of this technique is considered only where the surface oil is concentrated in narrow windrows or when it is still in thick patches prior to spreading. Collection of oil in large thin slicks by this method is known to result in poor efficiencies, i.e. high water uptake. In this scenario, after about 1 day the 15 000 $m^3$ spill would have spread in an arch covering 7 $km^2$, 10% of which would be made up of thick patches of oil (Mackay et al., 1980). A rapid deployment of these systems to intercept the more concentrated sections of the slick would encounter the problems of poor manoeuvre ability for the U-configuration system and small swath width for the tanker version. The superior seaworthiness and handling of the side-sweeping tanker system suggests that its use may be more practical in the open waters of the Beaufort Sea. Nonetheless, if these systems could not be on site in less than half a day, it is unlikely that they would be successful in removing a significant quantity of the quickly spreading oil. Even if deployed immediately, this type of operation would realistically be able to recover only about 10% of the surface oil.

The only remaining option available for the removal of the oil in the open water setting is the use of dispersants. For the purpose of this report, it is assumed that the use of dispersants is acceptable on environmental grounds and approval for use is made at the time of the actual spill.

In the cold Arctic environment, dispersants are effective only for fresh oils which have aged for little more than 1 or 2 days. Beyond this time, the combination of the low temperatures and evaporative losses is assumed to increase the oil's viscosity to the point where dispersants are ineffective. Dispersants would therefore have to be applied within 1 or 2 days of the spill for them to be of benefit.

The application of dispersants from the damaged tanker itself directly onto the leaking oil may hold some promise for their use in these types of spills. A sizeable quantity of dispersant and a pumping/spraying capability would have to be maintained on board the supertanker at all times. For a spill of the size assumed in this document, about 2 500 $m^3$ of dispersant would have to be available on board to treat the leaking oil in a 15:1 oil-to-dispersant ratio. By pumping directly from the ship onto the fresh oil, the considerable logistical and time problems associated with other dispersant application methods would be eliminated. The ability to effectively control the dosage and areal coverage of the dispersant from the tanker deck has not, however, been tested.

The effectiveness of the dispersant when applied to a very thick oil is also unknown. If future work identifies that these problems can be solved, the application of dispersants from on board a damaged tanker may prove to be the most effective way of removing large quantities of surface oil prior to shoreline contact.

In the meantime, there would be problems in successfully using more conventional, aerial application techniques for oil that has escaped the mechanical recovery operations. Large fixed wing aircraft fitted for dispersant application could not be brought to the North within 1 or even 2 days' time, i.e. prior to the oil's becoming viscous and undispersable. For dispersants to be effective in the Beaufort scenario, equipment and chemicals would have to be available nearby so that spraying could commence during the first day. It is unlikely that a large aircraft would be dedicated for this task in Tuktoyaktuk due to the excessive cost factor. Another possible alternative would be the use of slung bucket systems to apply dispersants by helicopters.

In the scenario, ship-side containment/recovery and offshore mechanical removal of oil are assumed to have reduced the surface volume of thick oil to about 10 000 $m^3$. By applying dispersants in a 15:1 oil-to-dispersant ratio, a total of about 650 $m^3$ of dispersant (4 000 barrels) would be needed. This chemical would have to be stockpiled in Tuktoyaktuk for such emergencies. The problem is that each helicopter would be able to transport only about 1 $m^3$ of dispersant and would require about 2.5 hours per application, due primarily to transit time to and from Tuktoyaktuk for dispersant reloading. Assuming an 18-hour daylight period, only seven trips per helicopter could be managed in a day. Clearly it would not be feasible to attempt to disperse the remaining oil by such a helicopter application. Even if the dispersant supply were closer to the spilled oil, 650 flights would be necessary to apply the needed dispersant.

The application of chemicals by workboat also has serious limitations, suffering from restricted application speed and the lack of suitable numbers of appropriate workboats in the Beaufort area.

Dispersants would therefore seem to have only a small role to play in the control of a widespread tanker oil spill in the Southern Beaufort Sea. This is also true for other areas of the Arctic.

Being uncontrollable by recovery or dispersing techniques, the oil remaining on the water surface after the at-site containment and recovery operations would drift with the currents and wind. Some of this oil would be dispersed by natural forces but some of it could make its way to shore. The initial placement of radio tracking buoys in the oil slicks would assist in following the oil movement and in predicting which beaches would likely be hit. The final countermeasures activities would involve the protection of these beaches and the removal of any oi which could not be prevented from going ashore.

Coastal protection techniques would involve the placement of booms across narrow inlets or bays and perhaps the application of absorbent materials to the beach prior to the arrival of oil to assist in the final cleanup. Both of these operations would be limited in that only a small portion of the entire shore could be realistically treated. The remaining beach which is contacted by oil would require manual cleanup. Rakes, forks, shovels, high-pressure water and steam cleaners, and manpower are some of the resources which would be needed for these operations. The shoreline of the Beaufort varies from steep gravel beaches with cliff backshores to extensive river deltas, open coarse-grained beaches, and mud flats. Different techniques and equipment would be needed to mount effective cleanup programs on these various beaches. As for most of the Arctic, the shoreline cleanup for the Beaufort would depend upon manual removal of oil and oiled debris. The use of heavy machinery for these tasks is often not possible due to inaccessible sites and sensitive beach areas which recover very slowly from the traffic of large equipment. The ultimate disposal of the collected waste would be accomplished by the use of portable incinerators.

The same general procedures as practised in the south for the manual cleanup operations would apply to the northern scenario. The actual work, however, would be made more difficult by the cold temperatures, poor transportation alternatives, and the limited supply of workers. While the Beaufort Sea area is one of the more active and populated areas in the coastal Arctic, it is unlikely that even it could provide a large enough work force for an extensive shoreline cleanup program. Much beach would undoubtedly be left to restore itself by natural processes, with only the most sensitive areas receiving any assistance. Based on southern experience and the problems presented by the Arctic location, shoreline cleanup operations in the North would be limited.

In summary, the probable response to a tanker incident in the Southern Beaufort Sea can be described as follows.

a) The initial action would be the transfer of oil from the damaged tanks by on-board equipment and crew.

b) Containment and removal at ship-side (of at least a portion of the leaking oil) would be accomplished by men and equipment deployed from Tuktoyaktuk. A crew from Tuk could be on-site within 8 hours to intercept two-thirds of the escaping oil.

c) A small portion of the oil (no more than about 10%) which is missed by these first two operations would be recovered by boom/weir skimming devices mounted on small tankers.

d) The location of the remaining oil would be monitored by radio tracking buoys and, where contact with shore is made, cleared from selected sensitive beaches.

**7.2.2 Viscount Melville Sound Spill.** A crude-carrying tanker is damaged while moving through the winter ice near the northern entrance to Prince of Wales Strait in Viscount Melville Sound. A total of 35 000 $m^3$ of this crude oil leaks from the cargo tanks into the surrounding water before the discharge is stopped a day later. The accident occurs in March when there is complete ice cover, the average air temperature is -30°C, and daylight can be expected for about 10 hours each day.

The countermeasures operations are described as follows. As in the first scenario, the initial response of the vessel's crew would be to reduce the amount of oil that could potentially be discharged by emptying the damaged tanks. The presence of a complete ice cover surrounding the ship prevents any ship-side containment activity but the ice itself provides a natural barrier to oil movement. As was discussed in Chapter 5, oil which leaks under an ice sheet will spread to a minimum thickness of only about 1 cm. Assuming the vessel remained stationary during the discharge, the oil would spread radially under the ice to a maximum area of $3.6 \times 10^6$ $m^2$, assuming this minimum oil thickness. A zone of ice with a maximum radius of only 1 km would thus be affected by the discharged oil. The actual radius would likely be much smaller due to the many under-ice depressions which would hold thick pools of oil. Since the oil would be naturally contained and preserved by the ice cover, rapid response is not vital. In fact, very little cleanup activity would be possible under the severe winter conditions.

The damaged tanker is assumed to make its way to a safe port after the oil release. Winter activity will thus be centred on keeping track of the oiled ice as the ice sheet drifts. Radio buoys, satellite tracking systems, and visual reconnaissance would be used in this regard.

If techniques for the detection oil under ice are improved, it may be possible in the future to locate depressions in the ice sheet containing large quantities of oil. Once located, winter crews could bore holes to these pockets and pump out the encapsulated oil during periods of favourable weather. The actual quantity of oil which could be recovered by this technique is very much a function of the roughness of the ice underside at the time of the discharge. In any event, the winter temperatures and difficulty in locating these oil pockets would likely result in a considerable quantity of oil still being present in the ice. Spring thaw would bring the migration of this oil to the surface via a network of brine channels.

Dome Petroleum has investigated the effectiveness of aerially deployed incendiaries in removing such oil; it has been found that oil deposited under the ice early in the season is exposed by ablation and that 100% of it is available for combustion in the spring. Oil discharged under thick layers of ice rises to the surface by way of the brine channel system. By spring breakup, only about 70% of this oil would have reached the surface and would be susceptible to ignition. For oil released in March, as in this scenario, about 85% of the oil could be expected on the surface by breakup (Dome Petroleum Ltd., 1981).

The timing of the burning operation is crucial. If the oil is ignited after breakup, it is not as effectively contained while burning and the operation may fail. By igniting the oil too early, time is not allowed for all of the oil to surface. Since the oiled area is relatively small in this scenario, a burning operation using a few helicopters would start ignition when significant quantities of oil appeared and would then reignite pools of oil as they formed during the thaw. Based on work by Dome Petroleum Ltd. (1981), it is conceivable that anywhere from 70 to 85% of the spilled oil could be removed by such an operation. The support needed to carry out this endeavour would consist of a small icebreaker with a helicopter pad, two medium-sized helicopters, and approximately 20 000-30 000 air-deployable igniters. The helicopters would work each with a crew of two to drop the devices onto the target oil pools. The entire operation would be completed over the 2-week spring thaw period. A minimum of about 70% of the oil discharged could be removed by a successful igniter operation.

Such a program could, however, experience some difficulties. Large quantities of helicopter fuel and igniters would have to be stored on board the icebreaker or supplied from the distant centres of Tuktoyaktuk or Resolute. Bad weather could limit the flight time available during the critical spring thaw period and a poor prediction of the start of spring breakup would dramatically reduce the effectiveness of the operation. These difficulties are minor compared to the problems which would be encountered in trying to recover the oil by other means.

If the tanker were to steam on as the oil is released, the burning operation would be altered somewhat. The released oil would be deposited in the ship track and frozen into the ice near the surface. The oiled ice would no longer be confined to a small area but instead would be a long (480 km) ribbon of contamination. Tracking of this ice over the winter would be more difficult and the final helicopter deployment would be more complex due to the longer travel lengths involved. The burning option could, however, also be successful for this type of discharge. Since the oil would be near the surface, 100% of it would be exposed by ablation early in the thaw. The dark oil would change the surface albedo and actually speed the melting process slightly. With all of the oil available for burning at least a week before breakup, the timing for the igniter drops would no longer be as critical. The icebreaker would move along the oiled track and provide a convenient platform for the helicopters. Since all of the oil would be on the surface, no repeat ignition of the pools would be necessary and the burning would progress from one end of the track to the other.

Regardless of the mode of oil discharge in a complete ice cover, ignition of the oil in the spring is an efficient way of removing a high percentage of oil from the marine environment. In either case, however, an oil residue would be present after breakup and some of this could make its way to shore.

At-sea containment or removal of this relatively non-toxic oil residue would be impossible due to the presence of ice. Dispersants would also be ineffective on this residue. The remaining removal option would be shoreline cleanup. The problems of the remote location and the lack of manpower identified in the Southern Beaufort Sea scenario are magnified in this scenario. Virtually all workers and equipment would have to be transported to and housed in the area. The presence of ice in significant quantities year-round would put an even greater strain on the transportation systems used in the operation. Unconsolidated ice at shore would also reduce the effectiveness of cleanup techniques such as booming. The existence of a combination of shore types, including steep tallus beaches, mud flats and gentle fine grained beaches, would complicate restoration programs even further. These many factors would undoubtedly result in only very selective shore-based cleanup attempts in this vicinity of the Arctic.

The most promising cleanup alternatives for an oil spill in complete ice cover in the Viscount Melville Sound area can be summarized as follows.

a) The initial response would again be the on-board transfer of oil from damaged tanks to reduce the amount of spillage.

b) The remaining winter activity would be limited to the tracking of the contaminated ice and possibly the removal of concentrated pockets of oil from under the ice.

c) A high percentage of the oil would be removed by burning with air-deployable igniters when the oil surfaces in spring melt pools.

d) Of the remaining oil, it is likely that only a small amount of it would be removed, likely that from the most sensitive shorelines impacted.

**7.2.3 Lancaster Sound Spill.** A supertanker grounds in the central region of Lancaster Sound and over a 24-hour period spills 35 000 $m^3$ of oil. The incident occurs in a 6/10ths ice cover condition in May when average air and water temperatures are -10 and 0°C, respectively. This area receives daylight for 24 hours at this time of year thus allowing continuous cleanup activities.

The initial response to such an incident would again be the on-board transfer of oil from the damaged tanks. The success of operations from this point on, however, would be limited for this scenario.

Ship-side containment of oil would be impossible with present equipment, even it is could be transported to the site, due to the presence of ice.

Containment of oil by conventional boom on the open water would again be spoiled by the presence of large ice floes.

Collection of oil by rope-mop or belt-type skimmers might be possible in some areas where the oil is naturally contained by the ice; however, the actual amount which could be recovered in this manner would be small. With only 6/10ths ice cover, a rapid spread of the oil is still likely thus reducing the effectiveness of these systems.

The use of aerially applied dispersants on a large scale would be ruled out, as was the case in the Beaufort scenario, since equipment and dispersants could not be on-site soon enough for them to be effective. It should be emphasized, however, that if a large aircraft and dispersant supply were maintained specifically for this purpose in Resolute or Nanisivik, dispersants could provide a feasible treatment possibility. Helicopter spraying would, however, be futile due to the small quantities of dispersant that could be carried per mission.

The burning of oil which had concentrated on the water between the ice floes could be possible but as yet is an unproven method. The successful development of such a technique would also improve the oil removal potential for these types of spills.

In summary, none of the existing proven countermeasures could be expected to remove a significant quantity of the spilled oil in this partial-ice scenario. Evaporation and natural dispersion would remove some of the oil, but a portion of it would inevitably reach shore. Shoreline protection and restoration would, therefore, be of primary concern in the response to this spill.

The problems confronting shoreline operations in the previous two scenarios would again be evident. The population of the eastern Arctic is even sparser than that of the Beaufort Sea area. Only a limited local work force would be available for the labour-intensive shoreline cleanup activities. Furthermore, the presence of a partial ice cover would hinder the surface transport of the equipment and men to cleanup sites. It is, therefore, likely that very little of the oil could be recovered by such operations. Fortunately, the impact of oil on the shores of this area would be limited. Currents, predominantly parallel to shore, could assist in keeping the oil away from the beaches while it naturally disperses. The shore on both sides of the Sound is composed primarily of steep erodable cliffs and rubble beaches. Any oil adhering to this type of shore could be removed by the action of waves in high energy beach areas. Also, for at least two months following this May spill, the coastal inlets are still completely iced over. Penetration of the oil into these ice-protected areas would therefore be minimal. Biologically sensitive areas not protected by shorefast ice could be protected by booming to any extent possible; these areas would be designated as priority zones for manual cleanup if required.

The summary of presently available countermeasures which could be applied to this spill scenario is necessarily brief. Only on-board transfer and shoreline cleanup methods hold any promise. The development of tanker-based dispersant application techniques and the testing of incendiary devices for the burning of oil between ice floes could, however, improve the capability of controlling such a spill in the future.

**7.2.4 Labrador Sea Spill.** The scene for the final hypothesized oil spill is an open water section of the northern Labrador Sea during January or February, a time when there is a potential for storm activity and high iceberg concentrations. It is assumed during one of these storms that the tanker strikes an iceberg which penetrates the cargo hull, discharging 35 000 $m^3$ of oil over the first day. The double-hull design and on-board transfer capability prevent any further discharge. The vessel is not disabled by the mishap and is capable of making its own way to a safe harbour or is available as a working platform. Two oil release conditions will thus be considered. In one, the ship is stationary during the spill, and in the other, the ship is in motion.

Surface water temperatures of 2°C and air temperatures of -20°C are likely at this time of the year. Daylight is present for only 6 to 9 hours each day.

**7.2.4.1 Stationary ship.** The presence of high seas during the incident does not permit the use of booms to contain the oil at the side of the stationary vessel during the initial discharge.

Dispersants stored on board the tanker could be sprayed from the vessel onto the oil as it escapes. While this has never been attempted or studied in detail, it provides an interesting method of enhancing the dispersability of the oil during a high-sea oil release (Section 7.2.1). Because the oil is treated at-source (probably by an oil-based dispersant) prior to spreading, the considerable logistical problems, generally experienced in dispersant application programs, are eliminated. More work is needed to determine the feasibility of this approach. For normal dispersant-oil ratios, a storage of only 2 500 $m^3$ of dispersant would be needed for the spill size being considered in this study.

Regardless of which at-ship countermeasure is attempted, oil will escape and spread. Tracking buoys would therefore be periodically released so that the slick's movement could be monitored for future action by cleanup crews.

High seas in the vicinity of the spill might be expected to last for a minimum of a day. During this time, no surface-based oil containment or removal operation presently available would be effective. The high seas would then naturally disperse large amounts of the surface oil present on the water and/or assist in its emulsification.

By the time the oil discharge is stopped, about a day after the accident, the slick area would have reached about 10 $km^2$. About 10% of this area would consist of relatively thick slicks, possibly with patches of heavily emulsified oil. By the time land-based vessels could respond to the site, a minimum of 2 days or more, the thick slick area itself would have grown tenfold to about 10 $km^2$ (Figure 5). Ship-based mechanical recovery or dispersal of the oil would therefore be futile due to the vast area covered by the oil.

As was outlined in discussions of the previous scenarios, the application of dispersants to the oil by either large fixed-wing aircraft or by helicopter would not be successful. The operation could not be mounted while the oil was still dispersable (generally within the first day after its release). The helicopters, on the other hand, could not carry enough dispersant to mount a significant attack.

The only remaining alternative in the open sea setting would be the no-treatment option. The oil's position would be monitored by both tracking buoys and spotter aircraft using visual contact or remote sensing apparatus. Should any oil threaten a sensitive shoreline area, preventative measures would be undertaken at shore. At this time of the year, ice which is present along the entire shoreline of Baffin Island and Labrador would effectively protect these coasts. The surface currents in the northern Labrador Sea tend to move to the west and then down the Labrador coast. Any spilled oil would likely move in this direction and be stopped by the presence of ice. Winter storms could be expected to disperse much of the remaining oil, including the emulsified patches, by the time the protective ice barrier melts during the spring thaw.

**7.2.4.2 Ship in motion.** Assuming that the tanker steams on during the oil discharge, the only countermeasure which could be effected from the vessel would be the application of dispersants from supplies on board. Such an operation could possibly be more effective in this situation since the oil would be thinner than that from a stationary release and thus more easily dispersed.

As with the stationary discharge, tracking buoys would be deployed during the release to assist in locating the surface oil for later cleanup operations.

The high seas which are assumed to persist over the first day would likely result in the dispersion of a large amount of the released oil. The initially thin slick in this instance (only a few millimetres) would inhibit the formation of heavily emulsified mats of oil. A day after the release, any oil remaining on the surface would likely be distributed in a track about 850 km in length and less than 1 km in width.

Dispersant application programs involving helicopter and fixed-wing aircraft would be ineffective in assisting the final dispersal of this oil for the reasons previously discussed.

The no-treatment option is the likely approach which would be adopted in a spill of this type. The oil's position would be monitored via tracking buoys and spotter aircraft but no action would be taken to deal with the surface oil unless it threatened sensitive shoreline. Fortunately, because of the long distance between the spill site and land, the high prevailing sea states, and the initial thinness of the oil slick, it is unlikely that any of the oil would reach shore in either a winter or summer release situation. It is highly likely that natural dispersion would be the predominant oil spill process in this scenario.

In summary, the following can be said about countermeasures options for an open water spill in the Labrador Sea.

a) Conventional containment barriers would likely be ineffective in preventing the escape of oil at the side of a stationary vessel due to high seas.

b) The application of dispersants, from a supply kept on board the supertanker, to the oil as it escapes the cargo hold could significantly improve the ultimate dispersal of the oil into the ocean if this method were proven feasible.

c) The use of mechanical recovery devices or dispersant spraying from small workboats would likely be ineffective.

d) A dispersant operation using a helicopter and dispersant supply based on the tanker would be successful only for small spills.

e) A large-scale dispersant program using fixed-wing aircraft from shore-based facilities would be ineffective because of time limitations.

f) A winter spill would likely result in very little shoreline contamination from either a stationary or moving release of oil because of the presence of ice at shorelines. For a summer spill from a moving vessel, the long residence time of the oil on the water and the potentially rough seas would likely result in a high percentage of the oil being naturally dispersed prior to any shoreline contact. The thicker and emulsified slick resulting from a stationary discharge could conceivably survive and contact the shore in a summer discharge.

# 8 GOVERNMENT STATE OF PREPAREDNESS

## 8.1 Government Contingency Planning

Starting with the Beaufort Sea developments in the 1970s, the Government of Canada has required the industry, through Drilling Authority reviews, to prepare contingency plans for potential spills (Mansfield and Hoffman, 1978). At the same time, the development of a "backup" Government Contingency Plan for major oil spills in the Beaufort began. At present, this plan has been extended to include the entire Arctic; its main purpose is "to provide a coordinated government response to a major spill or blowout which is assessed as being beyond the capacity of the polluter and the oil industry to handle" (Transport Canada, 1979). The adage that "the polluter pays" for any oil spillage is reflected in this philosophy but it is also recognized that the government must be prepared to protect the public's interest in the event that the polluter is incapable of dealing with a spill.

The primary purpose of the plan is to outline the responsibilities and interconnections of the many federal and territorial government departments which would be involved in combatting a major spill. This interim document is, out of necessity, very general. Although it cannot be considered an "Action Plan", it does explain the mechanisms through which the resources of the many departments can be quickly accessed and assembled at the scene of a spill. The plan has been continuously improved and amended through a series of scenario-oriented sessions termed the Beaufort Response Exercises (BREX) (Mansfield and Hoffman, 1978). In these "war games" exercises, the members of the various departments with responsibilities in the Beaufort Sea area are brought together to evaluate the capacity of the general plan to provide an organized response to a large spill. With increased activity throughout the Arctic, these exercises will undoubtedly be expanded to include other locations so that the individuals responsible for the different departments get an opportunity to meet and work with their counterparts towards the common goal of oil spill response.

## 8.2 Responsible Agencies in the Government Plan

The organizational magnitude of fighting a major spill in the Arctic is reflected in the following list of agencies that are represented in the plan.

Department of Indian Affairs and Northern Development (DIAND)
Government of the Northwest Territories (GNWT)
Canadian Coast Guard (CCG)
Department of National Defence (DND)
Department of Environment (DOE)
Department of Energy, Mines and Resources (EMR)
Department of Fisheries and Oceans (DFO)
Department of Communications (DOC)
Canadian Employment and Immigration Commission (CEIC)
Emergency Planning Canada (EPC)
Department of Labour (DOL)
Government of the Yukon Territory/Provincial Governments (YTG/PROV)
Department of Justice (DOJ)
Canadian Broadcasting Corporation (CBC)
Royal Canadian Mounted Police (RCMP)

The general structure as to how these agencies fit into the attack plan is presented in Figure 7. As mentioned, this plan is at present only an interim document and future changes are likely. As an example, the present formation of the Canadian Oil and Gas Lands Administration (COGLA) group could possibly result in some shifting of responsibilities.

Communications, labour supply, legal counselling, security, and environmental impact guidance are some of the resources which would be provided by the above groups. The group responsible for the actual offshore cleanup work is the Canadian Coast Guard which maintains and operates the bulk of the federal government's oil spill response equipment. The Coast Guard, through legislation, interagency agreement, custom and precedent, has a lead agency responsibility in the Canadian Arctic for all marine emergencies associated with ships including their crews, machinery, equipment, cargo, fuel and stores, and has a resource agency responsibility when a spill occurs from a non-ship source (Transport Canada, 1981a).

The Coast Guard is also responsible for the day-to-day control of tanker traffic in Canadian waters. This agency thus provides the government's operational arm in the prevention and control of ship-based oil spills in the Arctic. The present capability

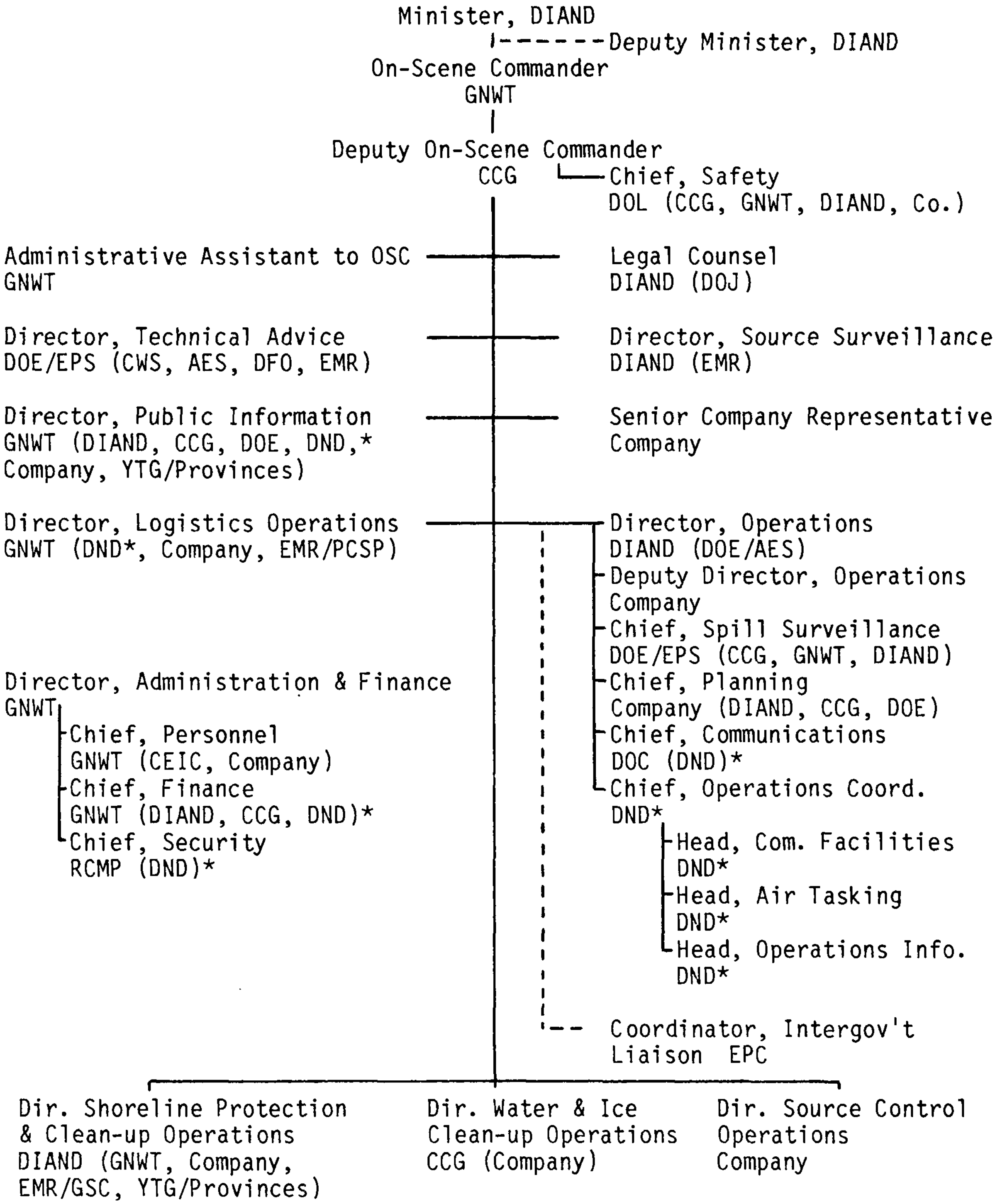


FIGURE 7 ORGANIZATIONAL STRUCTURE: GOVERNMENT CONTINGENCY PLAN

* Possible DND Involvement upon request (after Environment Canada, 1980).

of this group and its future plans must be considered above all in assessing the government commitment to oil spill response in the North.

## 8.3 The Canadian Coast Guard

The capability of the Coast Guard to deal with potential tanker spills in the Arctic depends on existing and future government policy as to this agency's responsibilities in this regard and on the effectiveness of the equipment that it will purchase, maintain, and operate for this purpose.

**8.3.1 CCG Responsibilities.** The responsibilities of the Canadian Coast Guard in the North, as seen by the Marine Administration group of Transport Canada, are embodied in the department's Arctic Marine Services Policy (Transport Canada, 1981a). The general proposals within this policy are as follows:

"Within the framework of the role of Transport Canada which is to attend to the development of a safe and efficient transportation system that contributes to the achievement of Government objectives, and in conformity with Marine Administration national responsibilities, it is the objective of the Arctic Marine Services Policy to:

a) provide for marine transportation and related activities in the Arctic in a timeframe that is compatible with socio-economic development in the north, a level of resources, facilities, services and regulation sufficient to:

    i) ensure an adequate level of safety to persons, property and the environment.

    ii) foster a service environment which supports the efficient development, provision and operation of all elements of an Arctic marine transportation system.

    iii) support the achievement of Federal Government objectives as they apply to the Arctic, including those relating to social and economic development, and to industrial, environmental, energy, sovereignty and other policies.

b) achieve maximum productivity from Government resources provided for the Arctic, and arrange that marine transportation and related activities, so far as is practicable, bear a fair proportion of the cost of such resources."

The role of the CCG within these very general guidelines falls into the categories of shipping safety, general traffic management and oil spill response. The initial service proposed by the Marine Administration agency is the provision for training Coast Guard personnel in these areas. Search and Rescue (SAR) and Vessel Traffic Management (VTM) are two services within this plan that are CCG operations. A year-round SAR capability is proposed, and VTM will be implemented via the Arctic Canada Traffic System (NORDREG) installation presently in place in Frobisher Bay.

As part of the NORDREG operation, the CCG would give vessel clearance for Arctic waters, control general ship movements, and provide information on ice and weather conditions. These services provide important preventative measures for oil spill control. The program presently in existence covers the waters illustrated in Figure 8. NORDREG's primary objectives are to enhance Arctic maritime transportation capabilities, the prevention of pollution in Arctic waters, and to strengthen Canadian sovereignty in Arctic waters (Transport Canada, 1981a). It is a lack of international acceptance of Canadian sovereignty which, in part, limits the control of NORDREG over Arctic traffic to that of a voluntary acceptance of its service. The sovereignty question also poses potential difficulties in dealing with a foreign vessel spill in Arctic waters. The implications of this are not dealt with in this study.

In the event that a tanker spill occurs in the Arctic, the CCG is designated as the lead agency within the Marine Administration proposal and is responsible for cleanup if the tanker owner involved does not take appropriate and sufficient actions. The success of these actions will depend on the CCG equipment and manpower supplies that are available for Arctic use.

**8.3.2 Present CCG Organization and Equipment Supplies.** The mechanisms by which the Canadian Coast Guard is to respond to a marine emergency in the central and eastern Arctic is presented in the Arctic Marine Emergency Plan (Transport Canada CG, 1979). The plan provides a breakdown of general personnel responsibilities and appropriate administrative actions in the event of a spill. Under the present plan, the Western Regional office of the Coast Guard is responsible for the western Arctic and the Head Office responds to the eastern Arctic area.

The geographical breakdown can be seen in Figure 9. Response to a spill in the west would be initiated from the Tuktoyaktuk office of the CCG. An eastern incident would be coordinated by head office personnel with the use of equipment based in St.

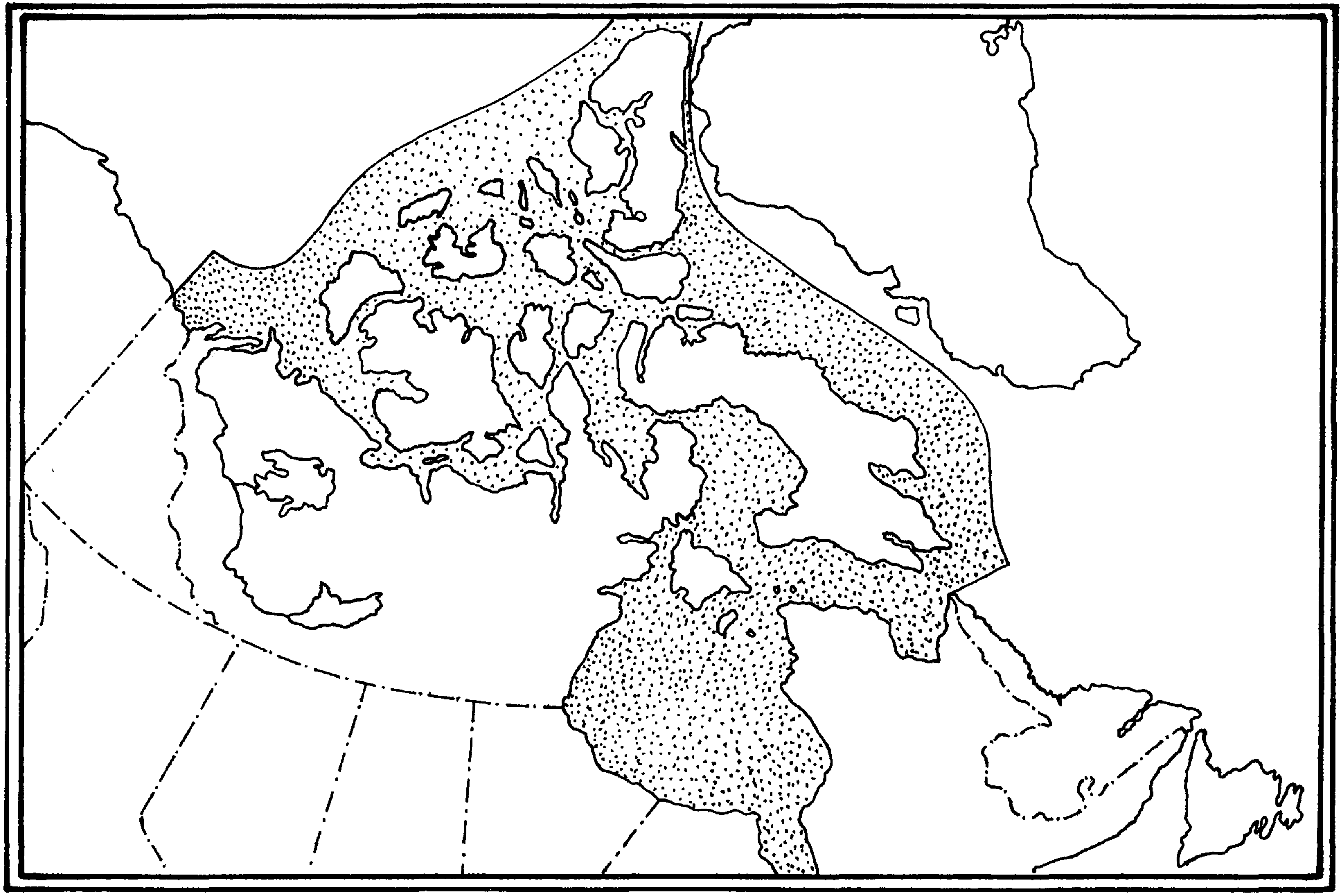

FIGURE 8 ARCTIC CANADA TRAFFIC ZONE (NORDREG CANADA) - (after Transport Canada),
N.B. For precise definition of seaward boundary, see "Arctic Waters Pollution Prevention Act".

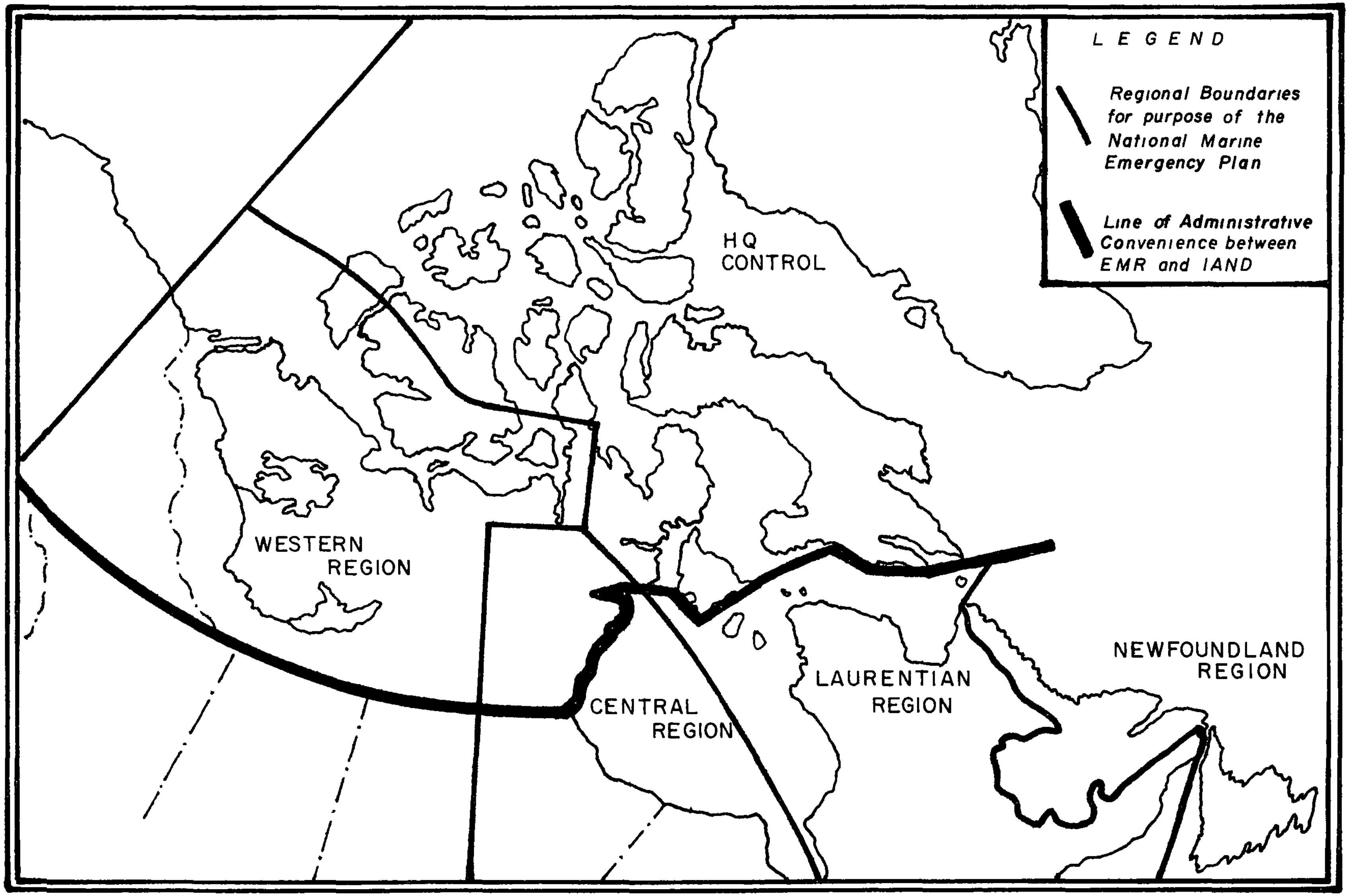


FIGURE 9 CCG REGIONAL OFFICE BOUNDARIES (after Transport Canada CG, 1977)

John's, Newfoundland, and personnel from any or all of the CCG district offices. A major spill would be dealt with on an individual, case-by-case basis by the CCG using nationally available equipment and personnel.

A summary of major pieces of CCG equipment which are currently available for Northern spills is as follows:

Western Region : Tuktoyaktuk

| Item | Quantity |
|---|---|
| 58 cm Inshore Boom | 3 810 m |
| 8 metre Sea Truck | 2 |
| Oil Mop | 3 |
| Vikoma Sea Pack | 2 |
| Komara Skimmer | 4 |
| Framo ACW 400 Skimmer | 1 |
| Adapt Pumping System | 1 |
| Dispersant Spray Equipment | 2 |

Eastern Arctic : St. John's

| Item | Quantity |
|---|---|
| 91 cm Offshore Boom | 1 219 m |
| 45.7 cm Boom | 457 m |
| Slicklicker | 4 |
| Framo ACW 400 Skimmer | 1 |
| Oil Mop | 1 |
| Sea Truck | 3 |
| Sp Barge | 1 |
| Vikoma Ocean Pack | 1 |
| 6.7 m Boston Whaler | 2 |
| Komara Skimmer | 1 |

Plans are underway at present to add to the equipment stockpile in St. John's. Approximatley 3 million dollars will be spent in this regard by 1985. The major equipment is to consist of light-weight boom, sea trucks, ice tracking equipment, light oil skimmers, incinerators, a high capacity skimmer and, possibly, oil igniters (Gill, 1982).

## 8.4 Evaluation of Government Capability

**8.4.1 Planning.** The lack of success, historically, in dealing with tanker oil spills has been, in many cases, due to a lack of preplanning on the part of the responsible organizations. This has been recognized by the Canadian government and is not doubt the incentive for the preparation of the "Government Contingency Plan for Major Oil Spills in the Arctic Seas". This planning document for oil spill responses is well thought out but one could encounter the usual difficulties in actually implementing it. In a crisis situation, it might be difficult to coordinate the activities of the 15-odd agencies which are part of the plan. Environmental vs operational and financial vs managerial conflicts are just two of the problems which could arise.

The standard approach to improve the potential workability of such complicated plans is to stage regular, simulated spill and response sessions for those individuals identified in the plan who are responsible for key decision-making during the emergency event. The BREX workshops mentioned earlier are an example of this form of preparation. As oil activity spreads throughout the North, this type of "war games" exercise can be expected to become more frequent so that the individuals within the regional government groups can familiarize themselves with the complex workings of a major oil spill response in their area.

The oil transport proposals being put forward for the Arctic involve the very large crude carrier class of vessel. Any significant accident might therefore result in a release of a large quantity of oil. Such spills could very likely be beyond the capability of the polluter or even the Canadian oil industry collectively to control.

Within the government, the CCG's "Arctic Marine Emergency Plan", in detail similar to its National Plan, outlines the potential actions of the CCG in the event of a northern spill. In this regard, the Coast Guard has advanced its planning in the North to the same level as in the remainder of Canada.

**8.4.2 Equipment.** The lists of equipment presented in Section 8.3 are not indicative of all of the equipment controlled by the CCG. The lists do, however, demonstrate the type of major equipment which the Coast Guard has available to respond to spills such as those hypothesized in Chapter 7. The probable success of the available CCG equipment in dealing with each of the four scenarios is now considered.

**8.4.2.1 Beaufort Sea scenario.** The calm, open water setting chosen for the Beaufort scenario provides the best opportunity for the use of the conventional containment and recovery equipment held by the CCG. It was demonstrated that, with a rapid response to this spill, the best control alternative would be to contain the oil alongside the damaged vessel. High-capacity skimmers would then be used to transfer the collected oil to storage. The CCG inventory could easily respond to the task of oil containment in this scenario, but its skimming capacity is not suited to the high volume which would be presented in this tanker spill scenario. Skimmers capable of transferring upwards of 1 000 $m^3$ per hour would be needed to remove oil contained at the site of a large tanker spill.

Since, to be effective, a large-scale dispersant application would have to commence during the first day of release, large aircraft and dispersant supplies would have to be permanently dedicated to this purpose. Although this is technically feasible, it is not considered to be economically viable. Hence, large-scale dispersant application programs for tanker spills in the Beaufort Sea, and in fact for large tanker spills throughout the Arctic, are viewed as having limited application at this time.

**8.4.2.2 Viscount Melville Sound.** The Coast Guard is currently not prepared for the response to an oil spill under ice since technology for such action is just now under development. The proposed equipment acquisitions projected into 1985 do, however, call for the purchase of oil spill incendiary devices and ice tracking equipment; both are items recommended for the response to the Viscount Melville Sound spill. The additional purchase of oil-under-ice detection equipment (if and when practical units become available) would complete the equipment arsenal needed to deal with a large spill of oil under ice. The Coast Guard has the helicopter and icebreaker capability to support the recommended air-based igniter operation.

**8.4.2.3 Lancaster Sound and Labrador Sea.** Conventional containment/removal and dispersant operations were ruled out in both of these scenarios. Efficient containment and collection are impossible due to either the presence of ice or high seas. Dispersants are not effective in the North unless applied within the first 24 hours, and the remoteness of the spill sites makes this impossible.

Two speculative methods for dealing with these types of spills were presented in these scenarios. The first, application of dispersant from a supply kept on-board the damaged tanker directly onto the discharging oil, could assist in the ultimate dispersal of the oil. The second, burning of oil on the open water or between ice floes, could provide another means of removing the discharged crude. If these are identified through research as being feasible alternatives, the Coast Guard would be responsible for developing these countermeasures approaches into operational, workable systems.

In general, the Coast Guard's present ability to deal with a large tanker spill in open water in the North is not too different from its capability in southern Canada. The acquisition and development of equipment to deal with oil in an ice-covered or ice-infested environment is, however, needed.

# 9 CONCLUSIONS AND RECOMMENDATIONS

## 9.1 Conclusions

Several conclusions are made concerning the effectiveness of existing oil spill cleanup technology when applied to a large tanker spill in Arctic waters.

### 9.1.1 Specific.

1) At present, high-capacity skimmers are able to handle a maximum of about 150 $m^3$ of oil per hour. For a large tanker spill, recovery devices which could transfer upwards of 1 000 $m^3$/h would be needed for a manageable and efficient operation.
2) For existing dispersants to be effective in the North, they must be applied to the oil spill while it is still fresh, generally less than a day after the oil's release. Large aircraft (DC-6 type) and dispersant stockpiles (upwards of 2 500 $m^3$) would have to be permanently dedicated and manned at strategic locations along the tanker route to accomplish this. The considerable cost of doing this is considered prohibitive.
3) A high percentage of the oil released from a tanker in a complete ice cover setting could be removed by burning during the spring thaw. Upwards of 20 000 air-deployable incendiary devices would be needed to ignite the oil from a large spill. At present, a stockpile of such a large supply of igniters is not available.
4) No proven or tested technology exists which can efficiently remove oil from a partial ice cover setting.
5) In a rough open water situation, little can be done at-source with present equipment to contain or collect the oil released from a tanker accident.

**9.1.2 General.** In general, the government's technological capability to cleanup a major oil spill in the North is not too different from its southern capacity. For both cases, the capability depends strongly on the ocean's surface condition. Open water in the Arctic is often calmer than that in the south due to the North's shorter open water reaches. Containment and collection methods in ice-free situations may therefore be more successful in the North if they can be implemented rapidly. A partial ice cover in northern waters has the potential for mixed effects on an oil removal operation. It may contain the oil sufficiently to allow it to be burned or it may prevent any attempt to artificially contain and mechanically remove the oil. Oil released in a complete ice cover environment is naturally contained and preserved by the ice. The removal of a high percentage of this oil by burning is technically feasible. Under this ice condition, an oil removal operation in the Arctic will be much more effective than one mounted in the open waters of the south.

The conclusions thus far have concentrated on the ability of available equipment to remove oil from the northern marine environment assuming that there is no restriction on transporting the equipment and manpower to the site. A northern oil spill cleanup operation, however, has obvious logistical and environmental difficulties which will hamper a countermeasure operation; first, there is a severe lack of local manpower available; second, land-based transportation is non-existent, and the distances between major southern centres and northern air fields and between the northern communities and possible spill sites are large; third, the accommodation and servicing of large work forces in the North will be more difficult than in the southern regions of Canada; and finally, the Arctic climate can be much more severe than in the south. The technological ability to respond to a northern spill may be equivalent to a southern operation but these additional problems necessitate a much more complex support organization and planning structure.

A potential method of reducing difficult logistics problems could be the use of the damaged tanker as a work platform. If an experienced crew with oil spill response equipment were kept on board the vessel, dispersant operations, oil containment and recovery attempts and aerial ignition programs could be mounted directly from the tanker. Nevertheless, even if the tanker operators commit themselves to this concept and details of such strategies are studied and proven effective, a large Arctic oil spill will require the additional support of other resources.

Government contingency plans for a northern tanker spill are as advanced as those in place for a southern tanker spill. However, the additional planning and personnel training needed to cope effectively with the more difficult northern logistics and environment have not yet been established.

Since large shipments of crude oil in the Arctic are not likely to take place for several years, the current absence of equipment stockpiling, detailed logistical planning, and personnel training by the responsible agencies is understandable. Recognition of the future need for such activities, however, has been expressed in Transport Canada's Arctic Marine Services Policy.

## 9.2 Recommendations

### 9.2.1 Technological.

1) Studies should be conducted to determine the feasibility of using the Arctic tanker as a working platform for countermeasures operations. Crew safety, ship stability and safety, operator acceptance, and personnel requirements are some of the factors to consider in such a study.
2) The feasibility of deploying men and spill response equipment over the side of an Arctic tanker to attempt to contain and remove escaping oil at the source should be investigated. This study would necessarily include the review of potential methods of transferring the collected oil to suitable storage on board the damaged vessel.
3) The feasibility of applying dispersants, from supplies kept on board the Arctic tanker, directly from the tanker deck onto the escaping oil should be studied. Application techniques, dispersant transfer problems on the tanker, and dosage control all require investigation.
4) Research should continue into the development of new dispersants which are effective on viscous oils so that they may be more useful in northern applications.
5) Dispersant use guidelines for the Arctic should be established to permit fast and accurate decisions to be made regarding their use.
6) Research on the combustibility of thick oil slicks present on open water or contained by a partial ice cover should be undertaken.
7) Research and development on very high capacity skimmers and transfer pumps (upwards of 1 000 $m^3$/h) is required.
8) A better understanding of the competing processes of oil dispersion and emulsification is needed to allow better predictions of oil behaviour and fate to be made. This will then assist in designing realistic oil cleanup operations.
9) A detailed analysis of the feasibility and logistics of extensive Arctic operations for shoreline cleanup and oiled debris disposal is required.
10) Attempts should be made to ensure that the countermeasures equipment held by government and private industry are compatible and can be integrated into a joint response action during a major oil spill response operation.

### 9.2.2 Planning.

1) Contingency planning must recognize the fact that the resources of the entire country, both government and industry, may be needed to respond to a major tanker spill in the Arctic.
2) "BREX" type exercises should be held throughout the Arctic on a regular basis. This will ensure that the delegated officials are familiar with the actions necessary to implement the best possible national response to an oil spill within their area of responsibility.
3) Personnel training programs, such as those outlined in the CCG's proposed NORDREG operation and expanded to include hands-on experience in oil spill response methods in the Arctic, should be an integral part of the preparation for a northern tanker spill.

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