SCIENTIFIC STUDIES TO BE CONDUCTED IN RESPONSE TO AN OIL SPILL IN THE BEAUFORT SEA

BY

JOHN G. WARD
C. ERIC TULL

LGL LIMITED
environmental research associates

FOR

ARCTIC MARINE SCIENCES
INSTITUTE OF OCEAN SCIENCES
DEPARTMENT OF FISHERIES AND ENVIRONMENT
VICTORIA, B.C.

APRIL, 1977

LGL LIMITED
environmental research associates • SUITE 201, 10110 - 124 STREET, EDMONTON, CANADA T5N 1P6 (403) 488-4832
(TELEX) 037-3775

May 4, 1977

Mr. A.R. Milne
Head, Arctic Marine Sciences
Institute of Ocean Sciences
Department of Fisheries and
Environment
512 - 1230 Government Street
VICTORIA, B.C.
V8W 1Y4

Dear Allen:

We are pleased to submit the required 100 copies of the report entitled "Scientific Studies to be Conducted in Response to an Oil Spill in the Beaufort Sea".

The various study descriptions contained in this report provide a detailed outline of the types of studies that should be considered for inclusion in a functional scientific response plan. As I have discussed with you and with Rod Paterson, the specifics of the methodology and funding of some of these studies will change because of decisions made during the formulation of the functional scientific response plan, because of changing methodologies, because of individual preferences of the investigators that are assigned responsibility for various studies, or because of the specific characteristics of the oil spill.

We have enjoyed preparing this report and hope that it meets your needs in developing an oil spill scientific response plan for the Beaufort Sea.

Sincerely

John Ward

John G. Ward, Ph.D.
Project Director

JGW/je
Encl.

SCIENTIFIC STUDIES TO BE CONDUCTED IN RESPONSE TO AN OIL SPILL IN THE BEAUFORT SEA

By

John G. Ward
C. Eric Tull

LGL LIMITED
Edmonton, Alberta

For

Arctic Marine Sciences
Institute of Ocean Sciences
Department of Fisheries and Environment
Victoria, B.C.

April, 1977

ABSTRACT

This study has been conducted in order to identify those scientific studies that should possibly be conducted following a major oil spill in the Beaufort Sea. Studies would be conducted to assess the immediate impact of such an oil spill, to establish baseline information for the assessment of the long-term impact of such a spill, and to increase the knowledge (and hence the predictive capabilities) concerning the behaviour and fate of oil in Arctic marine environments.

Thirty scientific response studies have been described. For each study the following aspects of the study have been given: rationale; objectives; methods; timing; criteria for initiation; government agency and contacts; personnel, equipment, logistical and funding requirements; priority; and relationship to other studies. A summary is presented in tabular form of the priorities of the studies, relationships between the studies, timing of the studies, and major logistical and funding requirements of the studies.

The procedures that will be required in order to convert these study outlines into a functional scientific response plan have been identified, and guidelines have been given for the conduct of the scientific studies.

ACKNOWLEDGEMENTS

This study has only been possible because of the enthusiastic and willing co-operation we received from numerous people in government, universities and industry. We wish to acknowledge the co-operation and assistance of the following people:

Department of Energy Mines and Resources

Canada Centre for Remote Sensing: J. Cihlar, E. McLaren, K.P.B. Thompson.

Geological Survey of Canada: B. Bornhold, C.F.M. Lewis, C.P. Lewis, B.R. Pelletier, R.G. Skinner.

Resource, Geophysics and Geochemistry Division: W.J. Scott.

Science Technology Branch: B. Huff, F. Hunt, G. Hobson.

Department of Fisheries and Environment

Arctic Biological Station: J.N. Bunch, E.H. Grainger, S.I.C. Hsiao, J.G. Hunter, A.W. Mansfield, J.A. Percy, T.G. Smith, D.E. Sergeant, J.W. Wacasey.

Atmospheric Environment Service: J.A. Clodman, D. Fraser, E.C. Jarvis.

Bedford Institute of Oceanography: R. Sheldon, J.H. Vandermeulen.

Canadian Wildlife Service: D. Andriashek, T.W. Barry, E. Kuyt, I. Stirling.

Environmental Protection Service: M. Fingas, R. Percy, R.K. Pettigrew, C. Ross, D. Thornton.

Freshwater Institute: M. Lawrence, R. Paterson, J. Stein, D. Wright.

Frozen Sea Research Group: E.L. Lewis, D. Topham.

Inland Waters Directorate: W.A. Adams.

Institute of Ocean Sciences: A.B. Ages, R.H. Herlinveaux, F. Henry, J. Marko, A. Milne, B. Smiley.

Ocean Chemistry Division: W. Cretney, R.W. Macdonald, D. Macdonald, C.S. Wong.

Department of Indian and Northern Affairs: S. Meldrum.

Department of Transport: H.R. Dubinsky.

Fish and Wildlife Service, N.W.T. Government: H. Monahan, A. Simmons.

McGill University

Marine Sciences Centre: M.J. Dunbar, G. Ingram.

LGL Limited: R. Buchanan, P. Craig, W. Fricker, W. Griffiths, W.J. Richardson, A.D. Sekerak, D. Thomson.

University of Guelph: R. Hallett, Department of Physics; D. St. Aubin, Department of Pathology.

Others: J. Burns, North West Survey Corp. (Yukon) Ltd; M. Fraker, F.F. Slaney and Company Ltd.; H. Roddis, Orion Electronics Limited; G. Smith, Hermes Electronics Limited.

Many people contributed in varying degrees to this project, and some may have been omitted from the above list. We wish to apologize to anyone that we have omitted from the list and acknowledge their assistance.

In addition to providing useful assistance during the study, the following people have critically reviewed the report and offered many helpful suggestions: M.J. Dunbar, G. Ingram, M. Lawrence, A. Milne, R. Paterson, W.J. Richardson, A.D. Sekerak and J. Stein. L. Burke, R. Ebel, J. Erwin, D. Hollingdale, W.R. Koski, D. Tse, and T.T. Wetmore assisted in the preparation of the manuscript.

TABLE OF CONTENTS

LIST OF TABLES, FIGURES, AND APPENDICES

INTRODUCTION

If large quantities of oil are found under the continental shelf area of the Beaufort Sea, there is a high probability (based on the history of oil spills to date) that at least one accidental oil spill of a major nature will occur in this area as a result of an oil well blowout, a tanker or barge accident, or a subsea pipeline rupture. On the basis of small-scale experiments, baseline studies, and literature reviews conducted during the Beaufort Sea Project, scientists have made predictions both on the possible behaviours and fates of oil spilled in the Beaufort Sea and on the possible environmental impacts of such oil spills. The accuracy of these predictions is unknown. More importantly, the time required for an Arctic marine area to recover from an oil spill is unknown. The use of large experimental spills to obtain answers to many of these questions is environmentally unacceptable. Moreover, the nature of environmental impacts will depend on how, when, and where the oil is spilled, on the quantity and type of oil that is spilled, and on the degree of success of the oil spill countermeasures.

The most acceptable method of ascertaining the behaviour, fate and environmental impact of oil spills is through monitoring accidental spills. In view of the amount of petroleum exploration activity expected in the Beaufort Sea and in other parts of the Arctic (e.g., Lancaster Sound, Davis Strait), and the lack of information on the environmental consequences and the significance of oil spills in Arctic waters, it is important that adequate monitoring studies be carried out during and after any major oil spill that occurs in Arctic waters, and especially after the first such oil spill.

A meaningful assessment of the impact of an oil spill is dependent on many types of information that can only be obtained at the time of the spill. Because scientists are generally unprepared in terms of both preplanned studies and availability of equipment, some or all of this information is frequently not collected during the early stages following a spill. In the Beaufort Sea the difficulty in responding to an oil spill will be further increased by the large distances both between the spill area and the centres with scientific expertise and equipment (e.g., Edmonton, Winnipeg, Victoria) and between the centres themselves, and by the limited amount of logistical support (e.g., aircraft, boats, accommodation) that would be available in the Beaufort Sea area. (In the event of an oil spill in the Beaufort Sea, much of the available logistical support in the Beaufort Sea area will be required for oil spill countermeasures, which will of necessity take first priority). An ad hoc approach to the scientific study of a major oil spill in the Beaufort Sea would probably result in unco-ordinated studies, major gaps in the information obtained, and a more inefficient utilization of available logistic resources than could occur with prior planning.

The development of an oil spill scientific response plan for the Beaufort Sea is consequently particularly important. The response plan will serve

1) to identify, previous to an oil spill, the important studies that should be conducted during or immediately after a spill;
2) to provide descriptions of these studies, their interrelationships, and the circumstances under which each should be initiated;
3) to identify the scientific equipment and supplies that should be purchased and maintained in readiness either near the Beaufort Sea or at various institutions;
4) to allow the merging of the scientific response plan with the countermeasures response plan; and,
5) to provide a basis on which rational decisions can be made during a spill regarding the necessity, relative importance, and logistic feasibility of various scientific studies.

The oil spill scientific response plan for the Beaufort Sea should be developed to cope with the worst possible case of an oil spill. In the event of a lesser spill, only the applicable studies would be required and the scope of these studies would be reduced to a level warranted by the situation. At present, an oil well blowout or a ship or barge accident would be the most probable cause of a large oil spill in the Beaufort Sea. An oil well blowout (particularly in the transition ice zone) is predicted to be the most serious type of oil spill; it could release large quantities of oil over a long period of time and could potentially affect extensive areas of the Beaufort Sea (Milne and Smiley 1976). Therefore, studies that are included in the scientific response plan should (for the present) address the scenario of an oil well blowout in the Beaufort Sea. The basic features of such a scenario would be one or more of the following:

1) the blowout would occur some time during the drilling season (i.e., open-water period);
2) during the initial years of drilling, the blowout would occur somewhere off the Tuktoyaktuk Peninsula or Richards Island;
3) the blowout would continue to flow during the winter but a relief well would probably stop the flow during the following open-water period;
4) wind conditions would occasionally (or perhaps regularly) hamper effective clean-up operations during the open-water period and would blow some oil onto shore;
5) any storm surges would move quantities of oil inland over low-lying areas;
6) during winter, extensive areas of the transition ice zone would be contaminated with oil; and
7) in spring, oil would rise to the surface of the ice and would also be released into ice leads in the contaminated area.

The area of concern consists of the continental shelf area of the Beaufort Sea from the Alaska-Yukon border eastward to Cape Bathurst, plus the western edge of the Amundsen Gulf (Figure 1). At present the drilling activity is situated off Richards Island and the Tuktoyaktuk Peninsula. Based on the blowout scenarios for these areas by Milne and Smiley (1976), oil could be carried to the western edge of the Amundsen Gulf as well as far to the west (and out of the study area).

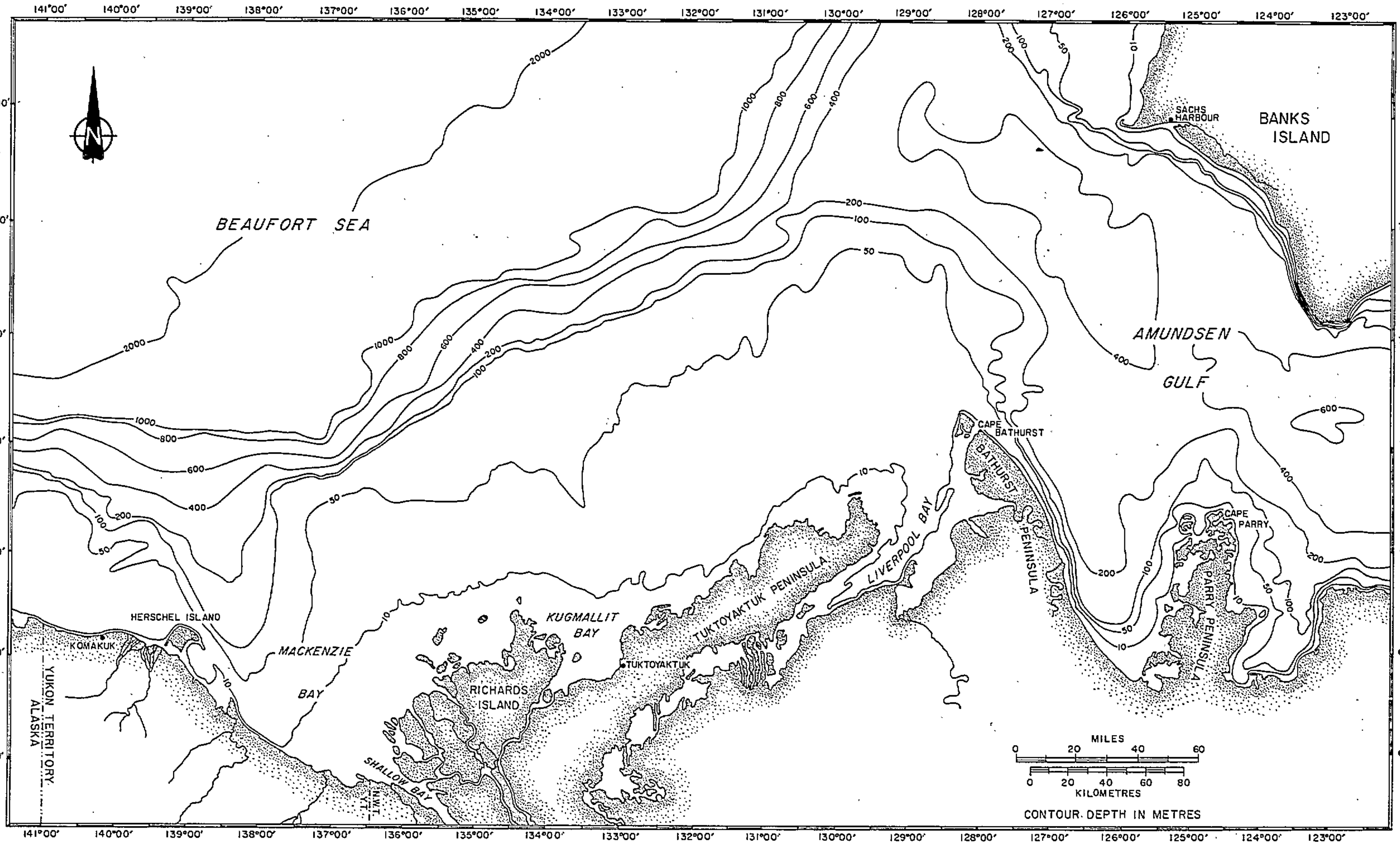


FIGURE 1. Study Area for the Beaufort Sea Oil Spill Scientific Response Plan.

OBJECTIVES

This report is the first phase in the development of a functional scientific response plan for an oil spill in the Beaufort Sea. The specific objectives of the present study are the following:

1) to identify appropriate scientific studies that may be required during the first 12 months following a major oil spill in the Beaufort Sea;
2) to describe the specifics of each study;
3) to provide a breakdown of funds required both to place the plan in a state of preparedness and to implement the plan; and,
4) to describe for each study the type of oil spill that would necessitate the study, the relative importance of the study in the overall scientific response plan, and any potential problems associated with the successful completion of the study.

The general objectives of studies included in the scientific response plan are the following:

1) to assess the immediate impacts of an oil spill;
2) to obtain information during or immediately after an oil spill that is important to the long-term assessments both of the chronic effects of the spill and of the recovery rates from the spill; and,
3) to obtain information that will increase predictive capabilities with respect to the behaviour and fate of oil that is spilled both specifically in the Beaufort Sea and generally in Arctic marine environments.

The specific objectives are given later for each individual study.

The delineation of studies for the scientific response plan has been done under two basic guidelines. The first guideline is that the role of the scientific response plan is to monitor the oil spill and its impact. Scientific programs to evaluate the effectiveness of countermeasure activities have not been included as part of this study. The second guideline is that the scientific response plan would be no longer than 12 months in duration. Although not a part of the 12 month response plan, studies of longer duration have been identified where it is felt that studies on chronic impact will be needed.

SOURCES OF INFORMATION

Many people, the majority government research scientists, have contributed to the studies described in this report. Wherever appropriate, non-government scientists and technical people (in university and industry) were also contacted in order to obtain information required for the planning process. The majority of the input was obtained from government personnel for the following reasons:

1) the majority of scientists with recent research experience in the Beaufort Sea are in government;
2) in the event of a major oil spill in the Beaufort Sea, government agencies will be responsible for conducting and/or directing studies on the environmental impact of the spill; and,
3) most scientists in private industry and universities would be unable to respond immediately to an oil spill in the Beaufort Sea because of contractual or other commitments.

The primary role of scientists of LGL Limited in the development of studies in this report has been to co-ordinate, organize and interrelate within the response plan the various study descriptions that were received from government personnel, to ensure that important studies that should be addressed in a scientific response plan have been included, and to determine the relative priorities of studies that have been included in the plan.

SCIENTIFIC STUDIES

Although the general aspects of an oil spill can be described in advance, an oil spill is an unpredictable event and the specific characteristics of a spill will be known only when the spill occurs. Consequently, a response plan must be flexible in order that any oil spill situation can be readily addressed. Study descriptions have accordingly been presented in small, relatively discrete units that can be conducted individually, combined with other studies, or not conducted at all, depending on the circumstances associated with the particular spill.

In the various study descriptions, the importance of each study by itself, the importance as a prerequisite for other studies, and the importance in the interpretation of other studies have each been indicated. Specifically the study descriptions include the following:

1) brief discussion of the rationale for the study,
2) objectives,
3) methods,
4) timing of study,
5) criteria for initiation,
6) government agency and contact persons,
7) personnel requirements,
8) equipment requirements both in readiness on site and on hand elsewhere,
9) logistic support,
10) funds required both to prepare and to implement the study,
11) priority of the study, and
12) relationship to other studies.

Methods are often general because the specific methods can be determined only when the characteristics of the spill become known, because the methods are identical to those used during the Beaufort Sea project, or because the specific methodology for sampling in oil-contaminated waters or ice has not yet been perfected.

The timing of studies refers to the period of year (e.g., spring breakup, open-water period) during which the study should be conducted.

The criteria for initiation generally indicate the oil spill circumstances under which the study should be conducted. Occasionally the criteria will include other studies in the plan that are prerequisites for the study, or a study or development of methodology that should be conducted before any spill occurs.

The government agency listed for each study is generally the one that would logically be assigned the responsibility for the study because of the particular expertise of the staff. The contact person is usually the head of the division (section, department, etc.), but where a scientist has indicated a desire to do the particular study, his name has also been included. In some cases no particular agency or individual could be identified.

The personnel requirements for a study generally identify the types of personnel required to conduct the study. The assumption has been made that these people will be available from government; however, this will depend on when the spill occurs and on what priority it is given by government agencies.

Equipment requirements in readiness on site are those that should be kept on hand in Inuvik or Tuktoyaktuk in order to be available immediately upon need. Equipment requirements on hand elsewhere would include those that could be stored elsewhere but that could be made available and transported to the Beaufort Sea on very short notice.

Logistic support is often difficult to estimate realistically (particularly helicopter time) because it depends on the sampling intensity, which will be determined by the characteristics of the spill. Consequently, the costs listed to implement the study may be considerably under or over the actual costs that will be required. Appendix 1 describes major support facilities and equipment in the Beaufort Sea area. Appendix 2 lists the basic funding assumptions that have been used in this report.

Studies have been assigned priorities in order to stress those studies in this report that it is most important to conduct in order to attain the objectives of the scientific response plan.

The priorities have been listed as first, second, third, or fourth level. First level studies are those studies that are prerequisites for the successful implementation of the plan. Second level studies are those studies that will adequately and convincingly measure immediate impacts of the oil spill, that will provide adequate information to improve predictive capabilities with regard to oil spills, or that are critical to long-term studies on the recovery rate of impacted areas. Third level studies are those studies that would assist in improving predictive capabilities or measuring impacts, but that would probably be severely limited in the amount of data that could be collected because of logistical difficulties. Fourth level studies are studies that are useful but less critical than the higher priority studies in meeting the objectives of the plan.

The study descriptions that follow fall under the following main headings:

1) Monitoring the Movement of Oil,
2) Factors Affecting Movement of Oil,
3) Monitoring of the Blowout Plume,
4) Deposition and Decomposition of Spilled Oil,
5) Toxicity of Spilled Oil,
6) Effects of Oil on Coastal Ecosystems,
7) Effects of Oil on Under-Ice Flora and Fauna,
8) Effects of Oil on Plankton and Fish Populations,
9) Effects of Oil on Water Birds,
10) Effects of Oil on Seals,
11) Effects of Oil on Polar Bears,
12) Effects of Oil on Whales, and
13) Effects of Oil on Human Utilization of Wildlife.

1. Monitoring the Movement of Oil

In the past when large quantities of oil have been accidentally spilled in the marine environment (e.g., Torrey Canyon spill, 1967; Arrow spill, 1970; Argo Merchant spill, 1976), the oil has generally moved large distances and has spread to cover extensive areas. This is expected to be the case in the event of a major oil spill in the Beaufort Sea, particularly in the case of an oil well blowout in the transition zone (Milne and Smiley 1976).

During oil spills, oil also dissolves and disperses into the water column where water currents can carry it substantial distances, usually accompanied by further dilution from mixing in the water column. During a blowout there is considerable turbulence where the oil is released and the quantities of oil entering the water column could be substantial. In contrast to the movement and fate of surface oil (which can be followed fairly readily through visual means) the movement and fate of subsurface oil cannot be monitored quantitatively in a detailed manner at the present time, largely because the means of rapidly detecting oil in the water column are undeveloped.

The studies in this section are restricted to the movement of surface oil for the following reasons:

1) it is the only type of oil whose movements can be monitored directly and in detail,
2) a major portion of the spilled oil occurs as surface oil during the early stages following a spill, and
3) surface oil frequently has very major impacts.

1A. Aerial Reconnaissance

Aerial reconnaissance of the oil spill will be essential to any scientific response to an oil spill in the Beaufort Sea and should be the first priority in such a response. Aerial reconnaissance will also be essential for efficient clean-up activities.

From aerial reconnaissance flights, qualitative and quantitative information can be obtained on the location, movement, extent, and fate of oil slicks; on the location and extent of shorelines affected by oil; and, in the event of a blowout, on the behaviour of oil in the vicinity of the blowout plume. On a short-term basis, this information (in conjunction with that on the availability of logistic support) will enable a scientific co-ordinator to identify those scientific studies that are warranted by the circumstances. On a long-term basis, this information will be essential to the interpretation of the fate and the environmental impact of the spill, and will serve to increase the predictive capabilities with respect to the behaviour, fate, and environmental impact of future oil spills in Arctic waters.

Objectives

1) To record quantitatively and qualitatively the location, movement, extent, and fate of oil slicks from the spill.
2) To provide baseline information necessary to determine the need for other studies contained in the scientific response plan, and the location, timing and intensity of implementation of these studies.

Methods

In the event of any major oil spill the following aspects of the spill should be investigated through the aerial reconnaissance program:

1) the location and extent of oil slicks on a daily basis (if possible),
2) the direction and rate of movement of slicks (see study 1B Radio Tracking of Surface Oil),

3) the movement of oil in ice-infested waters,
4) the behaviour of oil when leads open and close,
5) the timing of the movement of oil up through the ice during the spring melt period and the extent of the area over which this movement occurs (see study 1D Effects of Under-Ice Topography), and
6) the presence or absence of birds and marine mammals in oil-contaminated waters.

In the event of an oil well blowout the following additional aspects of the spill should also be recorded:

1) the behaviour of the oil with respect to the wave ring created by the blowout plume,
2) the surfacing of oil droplets released into the water column from the plume (if visible),
3) the behaviour of rising oil when various types of ice move over the plume, and
4) the effect of the plume on the freezing of water and the behaviour of the oil during the freezing process.

Information relative to these aspects of oil spills should be recorded as quantitatively as possible, using photographs wherever possible.

Because of ice cover and the available daylight hours, useful aerial reconnaissance of oil spills will be largely restricted to spills occurring during the period from late April to possibly as late as early November. Within this period, weather conditions will often restrict the amount of aerial reconnaissance possible.

There are two forms of aerial reconnaissance that should be conducted during this period. The first type will provide information that is more qualitative than quantitative in nature. This information will serve primarily to determine the need for other studies contained in the scientific response plan and will also serve to provide a record of events during the spill. Because the flights will probably extend long distances over the Beaufort Sea, a twin-engine fixed-wing aircraft will be required for the flights. Flights should ideally be flown daily, weather permitting, during the period from late April to early November, except on those days when the area is to be surveyed by a photo reconnaissance aircraft (see below).

During the flights, the observer should be equipped with a stop watch, a large format camera (70 mm) that records the date and time on the film, and a tape recorder. Ideally the camera should have some type of levelling device on it in order that pictures can be taken perpendicular to the water surface. With complementary information on camera lens and altitude, useful measurements can be made from the photographs. Approximate linear distances can be obtained through use of a stop watch in combination with the approximate ground speed of the aircraft. Range finders may also be of use.

In order to accurately record the position of any offshore oil slicks, it will be necessary that the reconnaissance aircraft contain some type of positioning system (ideally OMEGA and/or an inertial system). A system that automatically records the time and position would be preferable. Distance-and-bearing fixes from DEW radars will be necessary if aircraft with suitable navigational equipment are unavailable.

The second form of aerial reconnaissance would involve formal photo reconnaissance flights in order to record permanently in a quantitative manner the behaviour of the oil spill. Such flights would require special aircraft designed for this type of work. The Canada Centre for Remote Sensing (CCRS) presently has three such aircraft (see Appendix 1); one of these aircraft would be available on very short notice in the event of a major oil spill in the Beaufort Sea. These aircraft are equipped with conventional 9x9 R/C cameras, an IR line scanner (two channel), and closed circuit B&W video recording equipment. Moreover, the people operating these aircraft have experience in photographing oil spills, which should ensure that the most useful types of photographs (i.e., black and white or IR) were obtained. A Convair 580 will be added to the CCRS fleet in September 1977. In addition to the above equipment, it will have colour closed-circuit video recording equipment and a laser flow sensor. The video recording equipment will be especially useful because the video tape can be replayed at the base of operations immediately after the flight.

Other aircraft that might be available and on site as part of the countermeasures operation for a major spill include the Argus aircraft from the Department of National Defence (DND) and the Lockheed Electra from the Atmospheric Environment Service (AES) of DFE. Both of these aircraft have side-looking airborne radars (SLAR) that are capable of mapping the extent of oil slicks (even very thin ones) on open water (see Logan *et al.* 1976). In the future one of the Orions that are being purchased by DND would possibly be assigned to assist at a major oil spill. These aircraft will probably contain sophisticated surveillance equipment that could be used to monitor oil spills.

The exact requirements for sophisticated photo reconnaissance aircraft are difficult to predict. To determine the initial behaviour of an oil spill, photo reconnaissance flights could be flown three times a day for a period of five days as soon as possible after the spill has occurred. (Flights have been assumed to be of three hours duration.) Some additional surveys would probably be required during the open-water period. In the event of a blowout that lasted through the winter, surveys should be flown once daily during the spring melt period (see study 2D).

Because of weather conditions and cost of aircraft, it will not be possible to obtain good quantitative information on the direction and rate of movement of individual oil slicks through intensive aerial surveillance. A method that will provide this type of information is described in the study 1B Radio Tracking of Surface Oil.

During the period from late November through to late April, occasional aerial reconnaissance flights will be required to monitor events in leads and at the blowout site, but tracking of oil by visual means will be of little value because of ice cover (see study 1C Radio Tracking of Oil Under Ice). These flights should be conducted by helicopter so that stops could be made on the ice wherever required.

<u>Timing of Study</u> -- For the purposes of the response plan, the reconnaissance study would be carried out for the duration of the spill. The majority of the reconnaissance flights would occur between late April and early November. In the event of a blowout lasting for more than one year, reconnaissance flights should be continued on a longer-term basis.

Criteria for Initiation -- An aerial reconnaissance study should be initiated for any spill for which a scientific response is considered.

Government Agency and Contact Person

(Aerial Reconnaissance Observer)

Agency & Contact: To be designated.

(Air Photo Reconnaissance)

Agency: Airborne Operations Section
Canada Centre for Remote Sensing
Department of Energy Mines and Resources
Ottawa, Ontario

Contact: Mr. Ernest McLaren, Head
Telephone: (613) 998-3101-Office
(613) 737-4199-Home

Personnel Requirements -- The reconnaissance person(s) should be located within easy reach of the Beaufort Sea and should be experienced in dealing with oil spills. In the event of a long-term spill, such as an oil well blowout, a second person would be required as a relief observer. These people would work closely with the scientific co-ordinator(s) during the spill and during the preparation of reports after the spill.

During winter flights over the Beaufort Sea, the pilot and observer should be accompanied by a person experienced in winter survival and travel on the ice.

The reconnaissance person(s) would also be required to interpret photos and to write up the observations, probably both during and after the spill (any equipment required for this activity would be readily available).

Equipment Requirements

On site in readiness:
- binoculars (7 x 50)
- range finder
- stop watch

- large format camera (70 mm) with date and time recording capability, and with levelling device for vertical aerial photographs*
- 35 mm camera
- 2 tape recorders, tapes and extra batteries
- notebook and pencil
- 5 rolls each of infrared and H.S. Ektachrome film for 35 mm and for 70 mm cameras
- Arctic winter survival gear (3 people)

Elsewhere: None

*CCRS aircraft may not be available in all circumstances and the reconnaissance observer should have some capability to take aerial photos other than with a standard 35 mm camera.

Logistic Support -- 480 hrs twin-engine fixed-wing aircraft (Cessna 337) with a radar altimeter (ideally) and a position-locating device

- 45 hrs of CCRS aircraft during a 5 day period
- 30 hrs helicopter (Bell 206) during winter reconnaissance
- accommodation in Tuktoyaktuk for up to 12 months for two people (pilot and observer)
- transportation Edmonton-Tuktoyaktuk to facilitate personnel relief every 3 weeks

The calculation of aircraft time may be very artificial because the weather variable is unpredictable. Sophisticated surveillance aircraft may be present during much of the active period of a spill, and surveillance activity will probably also be conducted by the countermeasures team. For the above calculations of aircraft time it has been assumed that between late April and early November, CCRS surveillance aircraft would be available for five of the 28 weeks. Four of the five weeks would be for a project described in the study 2D Effects of Under-Ice Topography; aerial reconnaissance would be combined with that project. Of the remaining 23 weeks, flying by the fixed-wing aircraft is assumed to be possible for only

75% of the time or approximately 120 days. A reconnaissance flight has been assigned a value of four hours. Thus 480 hours of aircraft time could be required.

In winter a Bell 206 helicopter could be used over the ice. Only occasional flights will probably be required, and these flights could be combined with flights required to deploy radio beacons for tracking ice (see study 1C Radio Tracking of Oil Under Ice).

Funds Required --	To prepare:	binoculars	53
		range finder	55
		stop watch	45
		cameras	1,600
		tape recorders	200
		film	250
		survival gear	1,500
		miscellaneous (tapes, etc.)	300
	TOTAL		4,003
	To implement:	fixed-wing aircraft	92,160
		helicopter	10,110
		CCRS aircraft	49,500
		accommodation	40,150
		air fare	6,688
		native guide	7,500
		extra film	1,000
		film development	1,250
	TOTAL		208,358

Priority -- First level.

Relationship to Other Studies -- This study will be required to determine the need for the following studies and the timing and location for their implementation:

2D	Effects of Under-Ice Topography
4B	Oil in the Coastal Zone
4C	Oil in Sediment-Laden Waters
6	Effects of Oil on Coastal Ecosystems
8	Effects of Oil on Plankton and Fish Populations
9A	Bird Mortality During Spring Migration
9B	Mortality of Moulting Sea Ducks
9C	Mortality of Birds In Offshore Open Waters
9D	Effects of Storm Surges on Birds
10A	Spring Distribution and Numbers of Seals
10B	Effects on Seals in the Fast Ice Zone
10C	Effects on Seals in the Transition Zone
11	Effects of Oil on Polar Bears
12A	Effects on Whales During Spring
12B	Effects on Whales During Summer

The following studies require that the Aerial Reconnaissance study be carried out in conjunction with them in order to ensure meaningful results:

1B	Radio Tracking of Surface Oil
2A	Effects of Surface Currents and Wind
2B	Effects of Subsurface Currents During Open Water
4D	Chemical Weathering of Oil
4E	Microbial Decomposition of Oil

The results of the Aerial Reconnaissance study will assist in the interpretation of the results of most other studies and particularly the following studies:

1C	Radio Tracking of Oil Under Ice
3A	Measurement of Plume Profile
4A	Oil in the Water Column

Studies 1B, 1C and 2A are dependent on the aircraft support described in the Aerial Reconnaissance study.

1B. Radio Tracking of Surface Oil

During open-water periods in the Beaufort Sea, weather conditions such as fog, high winds, or snow will often prevent tracking of oil slicks by aerial reconnaissance. In the past it has often been impossible with aerial reconnaissance to find oil slicks following an interruption in surveillance due to weather conditions. Such slicks have often been assumed to have either dispersed or been carried out to sea only to have the oil reappear on a shoreline. Apparently the lost oil had formed an oil-in-water emulsion located just below the water surface; and, although it still travelled with the surface currents, it was not readily visible from the air. A radio tracking buoy (Appendix 3) that will apparently stay with oil slicks (i.e., it moves in the same manner as the oil) has been developed and tested; it should greatly assist the aerial reconnaissance of oil spills in the Beaufort Sea. Information on the rate and direction of movements of radio buoys will be necessary to the interpretation of effects of surface currents and wind on the movement of oil slicks on open water.

Drift cards have also been used as a means of determining possible movements of oil slicks in open water, but the value of the cards depends entirely on their being found when they wash ashore. In the sparsely populated Arctic this might prove to be a major limitation. Clean-up crews working on oiled beaches and scientists working on other studies within the response plan would probably be the source of most of the returned cards.

Objectives

1) To provide a means of relocating large oil slicks after interruptions in the aerial reconnaissance flights due to weather.
2) To provide a basis for accurately measuring the rate and direction of movement of oil slicks.

Methods -- Large slicks that escaped confinement would be marked with two or more radio buoys (at least one as a back-up) during aerial reconnaissance flights in order that the slicks could readily be relocated when flights were interrupted by bad weather. In general, the pattern of release of radio buoys would be determined by the nature of the spill.

Although drift cards are not a radio-tracking method, they are cheap to produce. The release of individually marked cards in both large and small slicks could provide some useful qualitative information on the movements and fates of oil. The use of fluorescent orange cards might increase their conspicuousness (depending on the degree to which they become oil-covered) and hence the number of returns. Even oil-covered drift cards could be found in the course of cleaning oiled beaches.

Both the radio buoys and the drift cards would be released from the aerial reconnaissance aircraft. Tracking of the radio buoys would also be done by the aerial reconnaissance aircraft.

The analysis of data and preparation of the report on the rates and directions of movements of oil slicks would be combined with that on the effects of surface currents and wind on the movement of oil (study 2A).

Timing of Study -- Duration of the open-water period.

Criteria for Initiation -- Any oil spill that occurred during the open water period and for which the 'Aerial Reconnaissance' study was initiated.

Government Agency and Contact Person -- Same as Aerial Reconnaissance study.

Personnel Requirements -- This study would be carried out as part of the Aerial Reconnaissance study. Although it is not essential, it would be preferable if the observer has had some previous experience in deploying and tracking these buoys.

Equipment Requirements

On site in readiness -- 50 radio buoys
- tracking antenna
- 1000 drift cards

On hand elsewhere -- 50 radio buoys

Logistic Support -- Utilizes logistic support of study 1A Aerial Reconnaissance.

Funds Required -- To prepare:	radio buoys*	22,000	
	tracking antenna	700	
	drift cards	750	(estimated)
TOTAL		23,450	
To implement:	Utilizes same aircraft funds described in 1A Aerial Reconnaissance		

*Significant cost reductions are available through volume discount and capacity of manufacturer to recycle used buoys.

Priority -- First level

Bad flying weather could be more the rule than the exception in the Beaufort Sea; this would make radio buoys very important for aerial reconnaissance.

Relationship to Other Studies -- This study would be combined with the Aerial Reconnaissance study (1A). Results of this study are necessary for the interpretation of the results of studies 2A Effects of Surface Currents and Wind, 4D Chemical Weathering of Oil, and 4E Microbial Decomposition of Oil; the results would also assist in the interpretation of the study 4C Oil in Sediment-Laden Waters.

1C. Radio Tracking of Oil Under Ice

During the winter it is expected that oil released from a blowout on the sea floor will gather under the ice and that much of this oil will become incorporated into the ice. Although there will be some movement of the under-ice oil relative to the ice (see studies 2C and 2D), major movements of the oil are expected to take place only in association with movements of the ice. In the fast ice zone, where the ice moves very little, the oil is expected to remain in the vicinity of the blowout. In the transition zone, where the ice normally moves substantial distances during the winter, it should be possible to determine the location of oil released during the winter by placing radio beacons on the ice that moves over the blowout and then tracking the movement of this ice.

Information from this study will be important for the determination of the area under the ice that is affected by the blowout. This will determine the need for biological studies on the effects of oil on populations of birds, polar bears, seals and whales that may encounter the oil on the ice, under the ice, or in leads. The information will also be useful in interpreting the significance of the results of the study on the effects of oil on under-ice flora and fauna.

Objectives -- To track the movement of ice that moves over an oil well blowout in order to determine the extent of the area over which the oil spreads during the period of ice cover.

Methods -- RAMS (Random Access Monitoring System) buoys would be deployed as required on large multi-year ice floes that move over or near the blowout site. These buoys, which can have a transmitting life of up to one year, produce a one second UHF radio signal each minute. The signals are monitored daily by satellite. The buoys can be located with a resolution of 2 km.

The RAMS data collection system utilizes the Nimbus satellite--an experimental satellite that will be superceded at some time during 1978 by the French ARGOS data collection system. Because the Nimbus satellite is experimental there are no user fees charged; however, the French ARGOS will have a user fee in the order of $20/day/transmitting buoy.

The satellite system has the advantage over the use of aircraft-monitored radio beacons that bad weather should not interfere to any extent with the tracking of the beacons. In the absence of any (or enough) RAMS buoys, aircraft-monitored radio beacons could be used. The buoys used for the tracking of oil on the water surface (described in Appendix 3) could probably be used here; however, their transmitting life is only approximately three weeks.

Timing of Study -- Duration of the period in which ice covers the blowout site.

Criteria for Initiation -- This type of study should be initiated whenever there is a major spillage of oil under ice in the transition zone. In the fast ice zone the use of RAMS buoys should be considered optional; but their use would guard against any unexpected ice movements.

Personnel Requirements -- One person who is familiar with the deployment of RAMS buoys would be required for one or more days according to the extent of ice movement during the winter. Because flights to deploy buoys would also be used for aerial reconnaissance, the aerial reconnaissance observer would presumably fill this role. A native assistant experienced in winter travel and survival on the ice should accompany the pilot and observer; he would be required to assist with the deployment of the buoy.

Government Agency and Contact Person

Agency: Arctic Marine Sciences
Institute of Ocean Sciences
Department of Fisheries and Environment
512 - 1230 Government Street
Victoria, British Columbia V8W 1Y4
Telephone: (604) 388-3331

Contact: Mr. A.R. Milne, Head

Equipment Requirements

On site in readiness -- ice auger (9")

- Arctic winter survival gear (3 people); cost previously included in the Aerial Reconnaissance study.

On hand elsewhere -- 10 RAMS buoys.

Logistic Support -- Utilizes same logistic support as that described for Aerial Reconnaissance (1A) during the winter.

Funds Required --	To prepare:	RAMS buoys	45,000
		ice auger	250
	TOTAL		45,250
	To implement:	Satellite Fees	-
		Native assistant	375
	TOTAL		375

As long as the Nimbus satellite remains in operation there would be no user fees. In the event that the French ARGOS was used, cost could be as high as $15-20,000 for 10 buoys deployed between early November and the end of May at varying intervals (assuming an additional buoy was activated each month). This would still be far less costly than aircraft surveillance.

Priority -- First level.

Relationship to Other Studies -- This study is logistically dependent on the helicopter support described in the Aerial Reconnaissance study (1A). This study is required to determine the need for the following studies:

7 Effects of Oil on Under-Ice Flora and Fauna

8 Effects of Oil on Plankton and Fish Populations

9A Bird Mortality During Spring Migration

10A Spring Distribution and Numbers of Seals

10C Effects on Seals in the Transition Zone

11 Effects of Oil on Polar Bears

12A Effects on Whales During Summer

This study will be necessary for the interpretation of the results of studies 2D Effects of Under-Ice Topography and 4D Chemical Weathering of Oil. It will assist in the interpretation of the results of study 4A Oil in the Water Column.

1D. Satellite Reconnaissance

The present extent of satellite reconnaissance of the Beaufort Sea is restricted to automatic photo coverage of the area by LANDSAT and NOAA satellites. In the event of a spill, this coverage would be available for later analysis and interpretation either in connection with ice conditions or with the Mackenzie River plume during the open-water period. Present satellites do not have the capability to monitor oil spills.

In theory, two LANDSAT satellites provide complete photo coverage of the Beaufort Sea area (in visible and near infrared light ranges) twice every 18 days. Because of photo overlap, it is possible to have coverage of some smaller areas more frequently. In practice, however, cloud obscures many images, especially during the open-water period. Present LANDSAT satellites do not have thermal infrared photo capabilities for the dark periods. Photos have a resolution of approximately 80 m and a scale of 1:1,000,000; they cover an area of 100 mi x 100 mi.

NOAA satellites provide daily photographic coverage of the Beaufort Sea in both black-and-white and thermal infrared. The resolution of these photos, however, is only 1 km.

In the future, it may be possible to carry out more sophisticated reconnaissance by satellites. LANDSAT C will be launched in early 1978 and will have the same 4-band multi-spectral scanner (MSS) as the present LANDSAT satellites plus a thermal infrared band. LANDSAT D is to be launched in 1981 and will have a MSS with 5 visible and near infrared bands and a thermal infrared band. A new processing system to be operational in early 1978 will increase the resolution of LANDSAT photographs to 57 m from the present 79 m. LANDSAT D resolution will be 30 m. In both cases the thermal infrared resolution will be poorer--approximately three times the values for the visible bands.

An operational ocean dynamics satellite system is in the development stages (Elson 1975). Seasat-A will be the first (experimental) satellite in the system and will be launched in a polar orbit. It will carry three radars and two passive radiometers. It is intended (among other things) to chart ice fields and leads, to measure the sea-surface topography that results from currents, tides, and storm surges, and to monitor wave height and direction, surface winds, current patterns, and ocean surface temperature.

Present Sources of Satellite Photos

(for colour photos)

LANDSAT: Canada Centre for Remote Sensing
825 Belfast Road
Ottawa, Ontario
Telephone: (613) 995-1210
Attention: Jean Heffernan

COST: Prints - $4.00; transparencies - $7.00

(for black and white)

LANDSAT: Donald Fisher and Associates*
P.O. Box 1630
Prince Albert, Saskatchewan
S6U 5T2

COST: Prints - $3.00; transparencies - $5.00

*Quick-look imagery can be obtained by mail in a few days or by facsimile in a few hours. NOAA photos are also available from this source or from those listed below.

(on a real-time basis)

NOAA: Mr. Eugene Hoppe
NOAA/EDS World Weather Building
Room 606
Washington, D.C. 20233

COST: $2.60 (US)/frame for both types

User would receive all photos for area and period requested irrespective of degree of obscuring by cloud cover.

(on a retrospective basis)

NOAA: Mr. Michael Petrik
NOAANES/UPSB
Federal Building 4, Room 1069
Washington, D.C. 20233

COST: $3.50 (US)/frame for both types

User would receive only those photos for the area and period requested that were not obscured by cloud cover.

2. Factors Affecting Movement of Oil

In order to increase general predictive capabilities with regard to the impacts of oil spills in Arctic waters, it will be necessary to know not only where the oil goes and what its impact is, but also the factors that have caused the oil to move. The major factors causing the oil to move in the Beaufort Sea will be currents, winds, and ice. These factors will be interrelated in their effects on the movement of oil.

2A. Effects of Surface Currents and Wind

Surface currents and winds are the primary factors responsible for the movement of oil slicks and for the deposition of oil in coastal areas (where the greatest impact usually occurs). In the Beaufort Sea, oil spills are expected to occur on the continental shelf. Surface currents over the continental shelf area during the open water period vary considerably. They are driven primarily by the Mackenzie River flow and by the wind (MacNeill and Garrett 1975). Northwest and southeast winds are the predominant winds during the open-water periods. Surface currents tend to flow in a northeasterly direction along the coast during northwest winds, but they move offshore in a northwest direction during southeast winds.

Oil slicks tend to move with the surface currents but there is also a force component exerted directly on the oil by the wind (Mattson and Chan 1976) that could cause the oil to move in directions somewhat different from those of the surface currents. This aspect will be of most interest during northwest winds; the winds will tend to force oil towards the coast but the currents will tend to sweep the oil northeastwards towards the Amundsen Gulf. Knowledge of the fate of oil under these conditions (see also studies 4B, 4C) will improve predictive capabilities with regard to the fates of oil spills in general

Measurement of the direction and velocity of surface currents at and near oil slicks will be useful only if similar data are obtained on winds and on the movements of oil slicks (see 1B Radio Tracking of Surface Oil).

Objective -- To describe quantitatively the effects of surface currents and wind on the movement and fate of oil slicks.

Methods -- Current drogues would be used to obtain data on the velocity and direction of surface currents. Drogues would be released at the same time and place as oil-tracking buoys. By recording the position of drogues and buoys at 24 or 12 hr intervals, information can be obtained on the velocity and direction of movement of both surface currents and oil slicks.

Deployment and tracking of drogues and buoys would be carried out during aerial reconnaissance flights. However, it would occasionally be desirable to make tracking flights more often than once per day and supplementary aircraft time has accordingly been included in the logistic requirements of this study.

The current drogues should be equipped with transmitting devices of the same frequency as the oil-tracking buoys. The Bedford Institute of Oceanography is apparently designing current drogues of this type at the present time.

In the event of an oil spill, sufficient information on winds in the area will presumably be available. Weather data are routinely recorded at DEW sites on the Beaufort Sea coast, and an automatic weather monitoring station developed by AES has been placed on the polar pack in the Beaufort Sea in order to provide advance weather warnings for drill ships operating in the Beaufort Sea. Weather parameters are also routinely recorded from the drill ships. It should be stressed, however, that weather data (particularly wind) should be recorded on a regular basis from any ships operating in the spill area and during any studies conducted on shore or on the ice.

On the basis of wind and current information it should be possible to quantify the relative importance of these two factors in the observed movements of oil slicks.

Timing of Study -- Duration of the open-water period.

Criteria for Initiation -- The implementation of this study would depend on the occurrence of an oil spill during the open-water period and on the implementation of the studies 1A Aerial Reconnaissance and 1B Radio Tracking of Surface Oil.

Government Agency and Contact Person

(for currents)

Agency: Arctic Marine Sciences
Institute of Ocean Sciences
Department of Fisheries and Environment
512-1230 Government Street
Victoria, B.C. V8W 1Y4
Telephone: (604) 388-3331

Contact: Mr. A.R. Milne, Head

(for weather)

Agency: Arctic Weather Central
Atmospheric Environment Service
Edmonton International Airport
Edmonton, Alberta
Telephone: (403) 955-8323

Contact: Mr. David Fraser, Head

Personnel Requirements -- The field portion of this study would require a person who was experienced in deploying and tracking current drogues and oil-tracking buoys. The analysis of the data on winds and on movement of drogues and buoys would require an experienced oceanographer.

Equipment Requirements

On site in readiness -- 50 radio buoys suitably modified to function as current drogues
- tracking antenna (same unit as that described in study 1A)

On hand elsewhere -- none

Logistic Support -- 30 hours twin-engine fixed-wing aircraft (Cessna 337) with suitable positioning system plus aircraft time of Aerial Reconnaissance study (1A)

- accommodation in Tuktoyaktuk for one person (2 1/2 months maximum)
- air fare Victoria-Tuktoyaktuk return (2 trips)

Funds Required --	To prepare:	current drogues	11,000
	TOTAL		11,000
	To implement:	aircraft	5,760
		accommodation	4,125
		air fare	1,120
	TOTAL		11,005

Priority -- Second level.

Relationship to Other Studies -- This study would be carried out as part of the Aerial Reconnaissance study (1A) and in conjunction with study 2A Radio Tracking of Surface Oil. The results of this study and those of the studies 4B Oil in the Coastal Zone and 4C Oil in Sediment-Laden Waters would provide a relatively complete description of the short-term fate of surface oil in coastal areas.

Pre-spill Studies -- A study using current drogues and oil-tracking buoys that move in a manner similar to oil slicks could be carried out prior to any oil spill in order to learn how and where spilled oil will move. The obvious sites for releasing the buoys and drogues are the offshore drilling sites. This type of study, if carried out in sufficient detail, would be extremely beneficial to countermeasures planning.

2B. Effects of Subsurface Currents During Open Water

Subsurface currents for the continental shelf area of the Beaufort Sea are also variable; they often flow in directions that are different from those of the surface currents. The main purpose of monitoring subsurface currents during the open-water period is to determine where and how fast the dissolved or dispersed oil from a blowout will be moved. When this information is combined with that from detailed studies on the quantity and quality of hydrocarbons present in the water column (see study 4A) and from toxicity tests on the oil (see study 5), it provides information that can be used to predict both the concentrations and distributions of dissolved or dispersed hydrocarbons and the resultant biological impacts that could be expected to occur in other areas under similar conditions. At present, however, there are major logistical constraints in conducting detailed studies of both the subsurface currents and the hydrocarbon levels in the water column. A study description for monitoring subsurface currents during the open-water period is presented below; but for the reasons given in the methods it is considered a third level priority study.

Objectives -- To monitor the rate and direction of flow of subsurface currents in the vicinity of a blowout during the open-water period.

Methods -- Ideally, strings of current meters capable of monitoring rate and direction of flow, temperature, and salinity of water at various depths for extended periods of time would be deployed in a circular or triangular grid around the blowout at a distance sufficient to avoid monitoring localized currents generated by the plume. Other strings of current meters would be placed at still greater distances from the blowout site. A string of current meters would contain at least three meters and would consist of a heavy anchor, several current meters separated by suitable lengths of cable, a large float to hold the string upright, and an acoustical release mechanism immediately above the anchor.

In ice-infested waters, such as the Beaufort Sea, the floats at the upper ends of the strings must be kept several metres below the surface of the water in order to avoid being dragged away by moving ice. The deployment positions of current meters must consequently be accurately known in order that the recovery vessel can return sufficiently close to the locations to trigger the release mechanisms.

Automatic-recording current meters are expensive units ($5500) that would not be deployed in large numbers if the possibility is high that many would be swept away (along with the data) by deep-draught multi-year ice floes. Moreover, a study of this intensity will be of little use until a method is developed to quickly obtain detailed information on the distribution, quantity and physical state of the hydrocarbons in the water column (see study 4A Oil in the Water Column). A suitable vessel would be required to deploy the current meters and to retrieve them.

At present the only practical methods to obtain current, salinity and temperature data appear to be similar to those described by Herlinveaux and and de Lange Boom (1975). These methods yield fewer data collected at a limited number of times rather than continuously as in the above methods. Current profiles and measurements on salinity, temperature, and turbidity would be taken from a ship at several locations around and at varying distances from the blowout. The number of times that stations could be visited would depend on the availability of a suitable vessel. This vessel would also be used for other studies (3A, 4A). The remainder of the study description is for this latter method, although many of the descriptions could apply equally to either method.

Timing of Study -- The study would be carried out during the open-water period for as long as ships could operate in the vicinity of the blowout without danger of being trapped by the ice.

Criteria for Initiation -- This study would be implemented only in the event of a long-term spill such as an oil well blowout, and probably only for a spill occurring during the first half of the open-water period.

Personnel Requirements -- The study would require a physical oceanographer and an assistant to conduct the field portion of the study. The oceanographer would also be required to interpret and summarize the data.

Government Agency and Contact Persons

Agency: Arctic Marine Sciences
Institute of Ocean Sciences
Department of Fisheries and Environment
512-1230 Government Street
Victoria, B.C. V8W 1Y4
Telephone: (604) 388-3331

Contact: Mr. A.R. Milne, Head

Equipment Requirements

On site in readiness: none

On hand elsewhere: current meters

equipment for salinity-temperature-turbidity measurements (all of the above already on hand in Victoria and in other centres)

Logistic Support -- deep water vessel

- accommodation at Tuktoyaktuk for two months (2 people)
- air fare: Victoria-Tuktoyaktuk return (4 trips)

Funds Required -- To prepare: none

To implement:	accommodation	6,600
	air fares	2,240
	air freight	500
TOTAL		9,340

Priority -- Third level.

Until intensive studies can be conducted to measure the quantities and physical states of the hydrocarbons in the water column, an intensive current study by itself will be interesting but of little value in terms of increasing predictive capabilities. The less intensive current study described above would provide useful qualitative information if combined with a limited hydrocarbon sampling program.

Relationship to Other Studies -- This study would be conducted only in conjunction with the limited hydrocarbon analysis program described in study 4A Oil in the Water Column. The results of these studies and study 1A Aerial Reconnaissance would be required for the interpretation of the study on Effects of Oil on Plankton and Fish Populations (8).

2C. Effects of Under-Ice Currents

The winter movement and distribution of oil from a blowout in the fast ice zone will be determined by the direction and the speed of currents immediately below the undersurface of the ice, by the topography of the under-ice surface (see study 2D) and, to a lesser extent, by subsurface currents.

In the transition zone the movement and distribution of oil that is released from a blowout will be determined by the ice movement, by the currents immediately under and subsurface to the ice, and by the ice morphology (i.e., shallow-draught first year ice *vs*. deep-draught multi-year ice). Ice movement will be the most important of these three factors; it will probably completely mask the effects caused by currents and by ice morphology. A study of ice movement has previously been described (see 1C).

The monitoring of under-ice currents alone is of limited interest; but when it is combined with the study on the effects of under-ice topography on the movement of oil the information obtained will be useful in predicting the impacts of oil spills under ice-covered waters (see studies 2D, 7, and 9A).

Methods -- Any attempts to deploy current meters for extended periods in the transition zone will probably result in their loss. In the fast ice zone current meters could be deployed through the ice and retrieved the following summer. This method, however, would require that the top of the current meter float be well below any ice that might form during the winter and that the deployment position be precisely known in order that a vessel could locate them during the open-water period. This method would not give information on the currents immediately below the ice surface--the currents of greatest importance to the movement of oil.

As an alternative, it is proposed that several helicopter trips be made to the vicinity of the blowout site in order to take current profiles and salinity-temperature-turbidity measurements through the ice at several locations surrounding the blowout site (*cf*. Herlinveaux and de Lange Boom 1975).

The location of these sites will depend on safety considerations (e.g., presence of flammable gas under the ice or seeping up through it; countermeasures activity). The timing of these flights will depend on weather conditions, ice conditions, and available daylight. Because there is little available daylight between late November and late January, flights may not be feasible until February.

Timing of Study -- November (perhaps) and during the winter ice period between late February and May.

Criteria for Initiation -- An oil well blowout that continued to flow during the winter. Unless study 2D is also conducted, there is little value in conducting this study.

Government Agency and Contact Persons

Agency: Arctic Marine Sciences
Institute of Ocean Sciences
Department of Fisheries and Environment
512-1230 Government Street
Victoria, B.C. V8W 1Y4
Telephone: (604) 388-3331

Contact: Mr. Allen R. Milne, Head

Personnel Requirements -- One person, experienced in conducting current profiles and salinity-temperature-turbidity measurements, and an assistant would be required to conduct the field work. The analysis and summarization of data would require a physical oceanographer. The party should also include a native assistant familiar with survival and travel on ice; this person would probably be able to function in the capacity as the assistant to the oceanographer.

Equipment Requirements

On site in readiness -- none

On hand elsewhere -- current meters
- ice auger
- winch
- equipment for salinity-temperature-turbidity measurements

(all of the above already on hand in Victoria or previously described in study 1C)

Logistic Support -- 20 hrs helicopter (Bell 205) [estimated]
- accommodation at Tuktoyaktuk for two months (2 people)
- air fare: Victoria-Tuktoyaktuk (4 trips)

Funds Required --

To prepare:	none	
To implement:	helicopter	15,320
	air fare	2,240
	accommodation	6,600
	air freight	750
	survival gear	1,000
TOTAL		25,910

Priority -- Third level.

Relationship to Other Studies -- This study would be carried out only in conjunction with the winter portion of the study on Oil in the Water Column (4A) and with the studies on Ice Movement (1C) and the Effects of Under-Ice Topography (2D). The results of these three studies and the study on Toxicity of Spilled Oil (5) will provide some assessment of the impact on under-ice flora and fauna (7) and on plankton and fish populations (8).

2D. Effects of Under-Ice Topography

Oil released under ice (from a blowout) will be moved along under the ice by currents until it collects in pockets on the undersurface of the ice. It is expected that oil stranded in these areas will be frozen into the ice as the ice thickens during the winter.

In the fast ice zone, pressure ridges will probably be the major blockage to the movement of oil under ice. It is in these areas that ringed seals have their breathing holes and birth lairs (see study 10B).

In the transition zone (which is important to wintering seals and to migrating birds and whales in spring) oil will accumulate in any open leads and in the many under-ice pockets created by the mixture of deep-draught multi-year ice, shallow-draught first year ice, and recently frozen leads. Because this ice moves to the west (due to the Beaufort Sea gyre), the oil trapped by the ice will be moved to the west (Milne and Smiley 1976). When the ice moves slowly considerable quantities of oil will probably accumulate under and in a relatively small amount of ice; when the ice moves rapidly small amounts of oil will probably be dispersed under and in a large area of ice. Milne and Smiley (1976) predict that the oil will be distributed in a narrow band that could be several hundred kilometres in length.

The actual distribution of oil under or in the ice of the fast ice zone or the transition zone is of considerable interest in assessing the biological impact of the spill on under-ice flora and fauna, and on birds, seals, polar bears, and whales (see studies 7, 9A, 10A, 10B, 10C, 11, 12A).

During the melt period in May and June, oil trapped in or under the ice will migrate up through the ice and form pools on the surface of the ice or it will be released into leads. A photographic record of the size and distribution of oil pools on the ice surface, relative to ice features such as pressure ridges, would provide quantitative information that could be used to assess the importance of the under-ice topography in the movement of oil under the ice.

Objectives

1) To determine the size and distribution of surface pools of oil and the surface characteristics of ice in the same area.
2) To relate the information on the oil to the under-ice topography.

Methods -- Photo reconnaissance flights would be initiated when oil began to surface (determined by study 1A Aerial Reconnaissance) and would probably be continued for approximately one month (on the basis of information in NORCOR 1975). The frequency of flights would vary depending on weather conditions, but flights could be as often as daily if circumstances warranted them. An accurate positioning of all flight lines would be required. In the fast ice zone the area to be photographed would be quite small. In the transition zone the area could be quite large depending on the movement of the ice. Ideally, the study would be carried out by a CCRS aircraft, which is equipped with both standard 9x9 R/C photogrammetric cameras and infrared scanners. The infrared scanners would be particularly useful in mapping oil on ice.

It may also be possible to map the oil in and under the ice before it reaches the surface. Present studies on the optical properties of ice- and snow-covered lakes suggest that during spring the surface reflectance of light in the visible and near IR region would provide a means of detecting oil in and under ice (W.A. Adams, pers. comm.). If feasible, this method would reduce the number of flights required for a detailed documentation of the distribution of oil under the ice.

Timing of Study -- Approximately one month commencing when the oil started to surface (sometime in early May).

Criteria for Initiation -- Any oil spill where large quantities of oil were released under the ice over an extended period of time, either in the transition zone or in the fast ice zone.

Government Agency and Contact

Agency: Airborne Operations Section
Canada Centre for Remote Sensing
Department of Energy Mines and Resources
Ottawa, Ontario

Contact: Mr. Ernest McLaren, Head
Telephone: (613) 998-3101-Office
(613) 737-4199-Home

Agency: Ice Properties Section
Glaciology Division
Water Resources Branch
Inland Waters Directorate
Department of Fisheries and Environment
Ottawa, Ontario K1A 0E7

Contact: Dr. W.A. Adams

Personnel -- None

Logistic Support -- one CCRS aircraft for one month
- accommodation for one month in Inuvik (flight crew)

Funds Required -- To prepare: None

To implement: $6,600 plus cost of CCRS aircraft which will depend on the size of area being photographed, on the number of flights, and on cost of aircraft charged to project.

Priority -- Second level.

Relationship to Other Studies -- The Aerial Reconnaissance study (1A) will be required to determine the start-up time of this study. The studies 1C Radio Tracking of Oil under Ice and 2C Effects of Under Ice Currents will be required to interpret the results of this study with regard to movement of oil. The results of this study will be critical to the interpretation of results from studies 7 Effects of Oil on Under-Ice Flora and Fauna, 9A Bird Mortality During Spring Migration, and 10B Effects on Seals in the Fast Ice Zone.

It would also be interrelated with the results of two other studies to increase predictive capabilities with regard to movement of oil:

1C Radio Tracking of Oil Under Ice

2C Effects of Under-Ice Currents

3. Monitoring of the Blowout Plume

The only information available on the probable behaviour and plume characteristics of an oil well blowout in the Beaufort Sea has been obtained from related literature and from open-water experiments conducted during the Beaufort Sea project (Topham 1975). No information is available on the effects of an oil well blowout plume on ice cover, or on the effects of large multi-year floes on a blowout plume. Documentation of what happens at the blowout site would help to increase the predictive capabilities with regard to the movement, fate, and impact of oil that is released from an oil well blowout in Arctic waters.

The hazards of a blowout situation (large quantities of flammable gas will probably accompany the oil) will probably be too great to permit an approach to the plume that is sufficiently close to make useful instrumental measurements on the jet. It may be possible to make some meaningful measurements of the plume profile with a side-scan sonar but there are some potentially major limitations (see below).

Photographic and written descriptions of both the plume characteristics at the surface of the water and the effects of the plume on the movement and fate of the oil would be very useful. Aspects that should be noted specifically include the following:

1) Does the wave ring have any confining effect on the oil?
2) Does the plume keep water ice-free in the immediate vicinity of the blowout?
3) Does oil flow onto the ice or under it?
4) What happens when various types of ice move over the plume?

Time-lapse photographic records of the blowout site would be ideal for these purposes. A procedure to obtain these photographs is briefly described; however, there would be major logistical constraints in conducting the study and it is probably not a practical study. Some useful photographs will be obtained from studies 1A and 1D.

3A. Measurement of Plume Profile

Objective -- To obtain quantitative measurements on the shape and diameter of the blowout plume in order to put further points on the curves generated from Topham's theory regarding blowout plumes (see Topham 1975).

Methods -- A side-scan sonar would be used to obtain measurements of the plume profile. The first measurement would be made as soon as possible after the blowout occurred. Further measurements (approximately seven) would be made at monthly intervals (see "Potential Limitations" below) to record any changes in the plume shape and diameter.

Complementary Information Required -- In order to put further points on the curves from Topham's theory, it will be necessary to have a good estimate of the rate of release of oil and gas.

Potential Limitations -- A side-scan sonar must be within 150 m of the blowout plume in order to obtain an acceptable reading. During the open-water season it is possible that ships will not be able to proceed this close to the blowout site because of safety precautions or clean-up operations (particularly if the blowout has been set afire). Moreover, ships may not be available for the project. During the winter it may not be safe to work on the ice within 150 metres of the blowout site (depending on ice conditions, presence of gas, and countermeasure activities). During certain months of the year, it will be impossible to conduct this study. From approximately late October to late December, ice conditions will prevent ships from reaching the blowout site (depending on the ships, the year, and the location of the blowout), and the lack of a firm ice-cover will prevent the use of helicopters to reach the site. During breakup in May, June, and July similar logistic problems will again occur.

Timing of Study -- For the purposes of the response plan, the study would continue for the lesser of one year or the duration of the blowout.

Criteria for Initiation -- The study would be initiated only if there was a blowout of an oil well on the ocean floor. This type of study would not be relevant to a blowout on an artificial island.

Government Agency and Contact Person

Agency: Frozen Sea Research Group
Department of Fisheries and Environment
825 Devonshire Road
Victoria, B.C. V9A 4T5
Telephone: (604) 388-3676

Contact: Dr. E.L. Lewis, Head

Personnel Requirements -- One person, trained in the use of a side-scan sonar, and an assistant would be required for approximately one day each trip to make the necessary measurements. The actual measurements would require about two hours. Additional time would be required each trip for travel (two days) and for any delays caused by weather or the lack of immediate transportation to the blowout site. During the winter, a native guide should accompany the people making measurements from the ice (four trips).

Equipment Requirements

On site in readiness: Ice auger - 9"

Portable winch with 150 m cable capacity
(both probably already available)

Elsewhere: Side-scan sonar and associated accessories
(available in Victoria)

Logistic Support -- 8 hrs helicopter (Bell 205); 2 hrs/trip

- Suitable ship transport to site for 4 trips (Government operated vessels may be available)
- Accommodation (two people) in Tuktoyaktuk for 24 days (average of 3 days/trip)
- Air fares: Victoria-Tuktoyaktuk return (8 trips)

Development Requirements -- Approximately two months of development time by Frozen Sea Research Group (FSRG) will be required in order to make the technique operational.

Funds Required -- To prepare: none

To implement:	Helicopter	6,128
	Accommodation	1,320
	Air fares	4,480
	Air freight	800
	Native guide	600
TOTAL		13,328

FSRG does not have a side-scan sonar but other government departments do (Defence Research Establishment-Pacific Region, Victoria; Energy Mines and Resources, Ottawa). Considering the cost of this device (≈$35,000) and the limited use that would be made of one in this study, the purchase of one for this study is not warranted. Prior arrangements could presumably be made with another government department for use of a side-scan sonar.

Priority -- Fourth level.

Relationship to Other Studies -- This study would be complemented by results from the study 1A Aerial Reconnaissance.

3B. Time Lapse Photographic Record of Blowout

Gower (1975) discusses the use of time-lapse cameras attached to helium balloons to obtain systematic photographic records of upwellings. This technique has direct application to oil well blowouts, but it requires a stable mooring location. In the Beaufort Sea this mooring location could be a ship during the open-water period or an oversnow machine during the winter. As with the side-scan sonar, there are a number of potentially major limitations:

1) The study could interfere with clean-up operations.
2) The large balloon (30 ft in length, 15 ft in diameter, 60 lb of lift) may be difficult to inflate on a smaller vessel.
3) It could not be used in strong winds.
4) The technique would require a large vessel in offshore waters, either to anchor the balloon or to provide a base from which a smaller boat could operate.
5) During freeze-up and break-up the site would not be accessible to boats or oversnow vehicles.

Because of the expected conditions in the Beaufort Sea and the major logistical problems associated with this technique, the use of other less systematic photographic methods (described in 1A Aerial Reconnaissance) is preferable, and will probably have a better chance of producing the desired information on the characteristics of the plume at the surface of the water.

4. Deposition and Decomposition of Spilled Oil

Two of the more important questions concerning an oil spill in the Arctic are how much oil is likely to be deposited in various habitats, and how quickly does the oil decompose in these habitats. Oil does not disperse uniformly through the marine environment but tends to concentrate in different amounts in different areas. Moreover, the initial areas of deposition are often not the final areas of concentration.

The habitats likely to prove most vulnerable to oil intrusion during or immediately after a spill include the surface of the water, the water column, the ice, the bottom areas in zones of high sediment deposition, and the coastal areas (open shorelines, coastal embayments, and inland areas flooded during storm surges). In the event of an oil spill in the Beaufort Sea, assessments of the fate of the oil and of the ecological damage caused by the oil will depend on both a knowledge of the maximum concentrations or quantities of oil that intrude into the various habitats and a knowledge of the extent of the affected areas. Quality (i.e., physical form--dissolved, coarsely dispersed, finely dispersed, adsorbed on sediments, intact on beaches) and composition of the oil will be as important factors as is the quantity in influencing toxicity. Both should be assessed as part of the overall sampling program.

4A. Oil in the Water Column

The major impacts of the oil that is dissolved or dispersed in the water column will be on plankton, on the egg and larval stages of fish, and to a lesser extent on adult fish. The extent of these effects has usually been inferred from laboratory toxicity experiments (see study 5) due to the difficulty in detecting such effects in the field (see studies 6, 7, and 8). The relationship of the experimental conditions to the actual field conditions, however, is not well known--largely because measurement of the quantity and quality of oil present in the water column has been and continues to be one of the most difficult studies to carry out in any detail during an oil spill. In particular, oil contamination of the sampling gear is a major problem because it results in contamination of water samples.

Ideally, most of the sampling methodology requires an oceanographic support vessel; in practice, such a ship is unlikely to be present or available in the Beaufort Sea on short notice when a major oil spill occurs.

Methods for measuring quality and quantity of hydrocarbons in the water column in the Beaufort Sea are briefly discussed under the assumption that an oceanographic vessel will not be available; but these methods are either logistically difficult to implement or they are still theoretical in nature.

Objectives -- To determine concentrations, composition, and quality of oil present in the water column as a result of an oil spill or oil well blowout.

Methods -- If any suitable deep-water vessel is available after an offshore oil well blowout during the open-water period, a limited number of water samples could be obtained using Blumer samplers. Samples could be obtained on several occasions from several depths and at various locations in the general vicinity of a blowout. During winter, a similar series of water samples could be obtained through the ice. Preliminary processing of water samples for total hydrocarbon content (dissolved and dispersed) could be carried out at a shore-based laboratory, preferably in Tuktoyaktuk, and final analyses could be completed in Victoria at the DFE Ocean Chemistry labs.

The determination of size and density of oil droplets in water samples could be carried out using a Coulter counter, but there are problems associated with this technique. The Coulter counter cannot distinguish between oil and non-oil particles; consequently the results obtained through use of a Coulter counter may be of little value in the Beaufort Sea where levels of suspended matter are quite variable. Because oil droplets will tend to come out of suspension and adhere to the sides of the sample containers, it is necessary that these determinations be carried out soon after the sampling (preferably on the same day). This will present a problem if the oil spill is some distance offshore and the ship remains offshore for several days in succession. If the vessel is serviced by helicopter, the samples could be flown out in this manner. The Coulter counter could easily be placed on a large vessel, but ship vibrations possibly would seriously affect the operation of the counter.

The above methods will not provide a detailed quantitative record of the distribution, quantity, and quality of oil in the water column. They will, however, provide crude estimates of concentrations and quality of oil in the water column. This information will be of use to toxicity determinations, particularly when combined with measurements on salinity, temperature, and turbidity. It is also important that the studies 2B and 2C on subsurface currents be conducted in conjunction with this study.

A second method of measuring the hydrocarbons in the water column is presently in a hypothetical stage. If developed, it could provide a fairly detailed picture of the quantity and behaviour of the oil in the water column during oil spills in open water. A submersible towed-pump would pump water through a tubing system to a fluorometer on the ship where the relative fluorescence of samples could be immediately measured. The system would be calibrated by tapping off samples directly after fluorescence measurements and later conducting hydrocarbon extraction procedures at a shore-based laboratory and using a Coulter counter to obtain information on the sizes and concentrations of droplets. A similar system is already in existence for hydrocarbons of low molecular weight.

An alternative device to the Coulter counter may be a laser light scattering device. This device, which measures 3'x2'x6', is larger than the Coulter counter and is less portable. Its operation, however, would not be affected by ship vibrations and samples could be processed much more rapidly. However, this device also cannot distinguish between oil and non-oil particles. Further testing of this device is required to fully evaluate its usefulness.

Timing of Study -- Open-water period and winter period.

Criteria for Initiation -- Ideally, any major spill should be responded to; in practice, only oil well blowouts are likely to present any opportunities to carry out this study. An oil spill from a ship or pipeline is a relatively short-lived event, and it is probable that the study could not be initiated sufficiently quickly. A blowout would be a long-term occurrence and would provide sufficient time to mobilize and conduct the study and thus obtain useful data.

Government Agency and Contact Persons

Agency: Ocean Chemistry Division
Institute of Ocean Sciences
Department of Fisheries and Environment
211 Harbour Road
Victoria, B.C.
Telephone: (604) 388-3698

Contact: Dr. C.S. Wong, Head

(laser light scattering device)

Agency: Department of Physics
University of Guelph
Guelph, Ontario
Telephone: (519) 824-4120 Ext. 3989

Contact: Dr. Ross Hallett

Personnel Requirements -- A chemist, experienced in sampling for hydrocarbons, and a chemical technician would be required to collect the data during the period of open water and during the winter, to conduct the laboratory analyses, and to summarize the results.

Equipment Requirements

On site in readiness -- none

On hand elsewhere -- Blumer sampler plus 20 bottle inserts
- Coulter counter (available in Victoria)
- lab equipment for hydrocarbon extraction and analysis (available in Victoria)
- ice auger (9") (already available)

Logistic Support -- A ship with a suitable positioning system
- 20 hr helicopter (Bell 205) for winter sampling [estimated]
- Laboratory space with power and adequate ventilation, preferably at Tuktoyaktuk
- Air fare: Victoria-Tuktoyaktuk return (8 trips)
- Accommodation for two people at Tuktoyaktuk (3 months open-water period; 3 months winter)

Funds Required --	To prepare:	sampling equipment	8,500
	TOTAL		8,500
	To implement:	Helicopter	15,320
		Lab supplies (estimated)	1,000
		Air fare	4,480
		Air freight	1,000
		Accommodation	19,800
	TOTAL		41,600

Priority -- Third level.

The implementation of this study is important but the severe logistical constraints at present on successfully conducting the study make it a third level priority study. Hydrocarbon analyses are also important components of several studies (4B, 4D, 6) that are of higher priority. Hydrocarbon sampling methods for these studies are probably more feasible logistically than for the situation described above.

Relationship to Other Studies -- This study would be carried out in conjunction with studies 2B and 2C on subsurface currents. The results of studies 1A Aerial Reconnaissance, 1C Radio Tracking of Oil Under Ice, 4C Oil in Sediment-Laden Waters, and 4D Chemical Weathering of Oil would assist in the interpretation of the results of this study. The results of this study will be useful to the interpretation of studies 4E Microbial Decomposition of Oil, 7 Effects of Oil on Under-Ice Flora and Fauna, and 8 Effects of Oil on Plankton and Fish Populations.

4B. Oil in the Coastal Zone

For the purposes of this study, the coastal zone has been defined as the portion of the coast extending from the 10 m depth contour inland to the highest storm surge level.

In the event of a major oil spill in the Beaufort Sea, the quantities of oil deposited along the shore or inland and the extent of the area affected will depend on winds, currents, and the type of spill (i.e., oil well blowout, tanker accident, etc.). In the Beaufort Sea area, beaches have been classified according to five types--cliffs, sand beaches, shingle beaches, tundra, and mudflats. Existing techniques for clean-up of beaches are likely to be feasible and effective only for sand beaches and to a limited extent for shingle beaches (Logan *et al.* 1976). In the case of the other types of beaches and also for inland areas, more damage (e.g., increased erosion) would probably result from trying to remove the oil than from leaving it. A combination of chemical weathering and sea action will be important on beaches to remove the visible evidence of oil contamination. In inland areas, particularly tundra and marshes, chemical weathering will be important in degrading the oil. It will be important, accordingly, to monitor the deposition of oil in the coastal zone, to determine the fate of such oil and to assess the effects of the oil on vegetation, particularly in marsh or tundra areas that are critical to nesting or staging water birds (e.g., snow geese).

Objectives

1) To trace the movement, the pattern of deposition, and the ultimate disposition of oil in the Beaufort Sea coastal zone.
2) To assess the effects of oil on vegetation in the coastal zone.
3) To assess the short and long-term effects of clean-up operations on the land forms of the coastal zone.
4) To determine the rate of weathering of oil that is left along the beach or on inland areas.

Methods -- This study represents the initial phase of a long-term study. The methods described below are those required for the first year.

1) Whenever aerial reconnaissance (study 1A) indicated that oil was being deposited on a section of coastline, an aerial survey would be carried out to record the length of shoreline contaminated and the extent of contamination. Oblique aerial photographs (in colour) would be obtained during this survey. If an extensive length of shoreline or inland area were impacted by oil, a photo reconnaissance flight by a CCRS aircraft would be made to obtain a detailed photo record of the affected area. The IR (infra-red) photo capabilities of CCRS aircraft would provide useful information on both oil distribution and vegetation.

2) Five or more sample sites would be established as beaches or inland areas become oiled. Sites would be established in different beach and habitat types and according to different conditions applying to the beaches (i.e., whether or not the beach was to be cleaned up, degree of oiling).

Sites would be surveyed immediately after selection (where applicable, preferably before clean-up). Initial surveys of each site would involve vegetation mapping, sampling of beach sediments, and description and sampling of deposited oil. As soon as possible after these initial surveys, the following additional sampling would be carried out: comparative studies of bordering areas unaffected by oil; shallow drilling (5-10 m) at each site to define the initial geotechnical properties of the sediment beneath each sample area; drilling to a depth of 30 m and installation of ground temperature cables to monitor changes in the ground thermal regime over time; and sampling from a boat of the bottom sediments offshore from the sites in order to determine the presence of hydrocarbons. Samples of oil on the beach would probably be obtained from sites at monthly intervals until freeze-up and snow cover occurred.

In the event of clean-up activities, a storm surge, or further deposition of oil, the sites would be resurveyed immediately after the event. On a long-term basis the sites would be revisited at one year intervals to obtain information on geotechnical and vegetative changes. The frequency necessary for taking oil samples in successive years would be dependent on the rate of weathering of the oil as suggested by the studies during the first year.

Timing of Study -- The study would be carried out when oil reached the coastal zone, which would occur only during the open-water period. In the event that the spill occurred after the start of freeze-up, the study would probably not be required until the following open-water period.

Criteria for Initiation -- This study would be initiated immediately after the deposition of any significant quantities of oil in the coastal zone.

Government Agency and Contact Person

(For Geology)

Agency: Marine and Coastal Section
Terrain Sciences Division
Geological Survey of Canada
Department of Energy Mines and Resources
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 593-6085

Contact: Dr. C.F.M. Lewis, Head

(For Oil Analyses)

Agency: Ocean Chemistry Division
Institute of Ocean Sciences
Department of Fisheries and Environment
211 Harbour Road
Victoria, B.C.
Telephone: (604) 388-3698

Contact: Dr. C.S. Wong, Head

(For Vegetation)

Agency: To be designated

Personnel Requirements -- For the coastal zone surveys, a botanist, a geologist, and a geological technician would be required. The shallow drilling would require a driller and two labourers. The sediment sampling offshore would require a sedimentologist, a chemist, and one assistant. The chemist would be required to provide instructions for the collection of oil samples, to assist in the sampling of sediments for hydrocarbon analysis, and to analyze oil and sediment samples. Depending on the number of samples taken, a considerable amount of time could be required in Victoria for laboratory analysis of samples. The botanist, chemist, and geologist would be required for report preparation.

Equipment Requirements

On site in readiness -- sample containers used in collecting oil for analysis

On hand elsewhere -- sampler for nearshore bottom sediments (Petersen's grab sampler or pipe dredge; see Wong *et al.* 1976).

- shallow drilling equipment (available from EMR in Ottawa)
- temperature probe (available from EMR in Ottawa)
- Laboratory equipment for analyses of oil and sediment samples (available at Ocean Chemistry Labs [DFE], Victoria)

Logistic Support -- 10 hr helicopter (Bell 205)

- 10 hr helicopter (Bell 206)
- small nearshore vessel (presently available at Polar Continental Shelf, Tuktoyaktuk)
- 2 hr CCRS photo reconnaissance aircraft [estimated]
- accommodation at Tuktoyaktuk for one month for six people and for two weeks for three others
- air fare: Ottawa-Tuktoyaktuk return (8 trips)
- air fare: Victoria-Tuktoyaktuk return (1 trip)
- air freight: Ottawa-Tuktoyaktuk

Funds Required -- To prepare:

To prepare:	-- sampling equipment (dredges, etc.)	500
	- sample containers	200
TOTAL		700
To implement:	helicopter	11,030
	CCRS aircraft	2,200
	lab supplies [estimated]	500
	accommodation	12,210
	air fare	6,608
	air freight	1,500
TOTAL		34,048

The logistic support and funds required have been calculated on the assumption of one major oiling of a coastal area with five sample sites being established following this oiling. The funds required will increase if oilings of beaches are more frequent or repeated, if more sample sites are established, or if the sample sites are established at different times.

Priority -- Second level.

Relationship to Other Studies -- This study would be a prerequisite to a long-term study on the ultimate fate of spilled oil in Arctic coastal areas. It will be important in interpreting the significance of results from the studies on the effect of oil on the coastal ecosystem (6), on the effects of oil on moulting sea ducks (9B), and on the effects of storm surges on birds (9D). Studies 4E (microbiology), 6 (coastal ecosystem study), and 9D (studies of bird mortality caused by a storm surge) could be combined with portions of this study (e.g., selecting same study sites, utilizing same aircraft, etc.).

4C. Oil in Sediment-Laden Waters

It is known that suspended sediment particles will adsorb oil and carry it to the bottom (Kolpack 1971:342). In the Beaufort Sea, however, it is not known how much oil is likely to be carried to the bottom via this mechanism in the Mackenzie River plume. The rate at which oil is blown across the plume area will probably determine both the amount that is carried to the bottom by sediment particles and the amount that crosses the plume and reaches shore.

In order to understand the behaviour and the impact of oil spills in the Beaufort Sea, it would be useful to sample suspended matter and bottom sediments immediately after and, if possible, during the movement of oil through the river plume area. Aerial and satellite photographs of the process would also be useful. Information on the initial location, composition, and quantity of oil deposited on the bottom would be required in order to interpret the long-term fate of the oil released from a spill.

Objectives

1) To assess the significance of suspended matter in removing oil from the water surface.
2) To determine the immediate fate of oiled particles (i.e., do they settle rapidly to the bottom or do they float for some distance before reaching the bottom).

Methods -- Water samples would be taken at various depths and locations in the river plume after and, if possible, during the movement of oil across the plume. The particles in the samples would be examined for adsorbed oil, and samples would be analyzed for total oil content. Different types of particles (e.g., clay, silt, etc.) settle at different rates; the types of particles adsorbing the oil will thus determine where the oil is deposited. Bottom samples from various locations across the plume would be collected and analyzed for oil content with respect to depth in the bottom layer. Nearshore work (to the 10 m contour line) would be done with a small vessel; offshore work would require a larger vessel.

Delineation of the initial settling locations of oiled particles would be necessary for the interpretation of the long-term fate of oil in the Beaufort Sea (i.e., how much oiled sediment is remobilized and deposited elsewhere and when this occurs). The long-term program would involve a yearly repetition of the bottom sampling program.

Information from the Aerial Reconnaissance study on the location and movement of oil in the river plume (1A), and on the movement of oil-tracking buoys (1B) and current drogues (2A) would be important to the determination of sampling strategy. The number of samples that are taken would probably be determined by the restrictions on the number that can reasonably be analyzed for hydrocarbons.

Timing of Study -- The study would be carried out during the open-water period. It would probably require approximately two weeks of field time during and after the movement of oil into the area of the river plume. Long-term follow-up studies should be conducted during the open-water period in subsequent years.

Criteria for Initiation -- The study would be initiated only if extensive oil slicks were blown into the river plume area. Initiation would depend on the availability of suitable vessels.

Government Agency and Contact Person

(Suspended matter)

Agency: Marine and Coastal Section
Terrain Sciences Division
Geological Survey of Canada
Department of Energy Mines and Resources
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 593-6085

Contact: Dr. C.F.M. Lewis, Head

(Hydrocarbon analysis)

Agency: Ocean Chemistry Division
Institute of Ocean Sciences
Department of Fisheries and Environment
211 Harbour Road
Victoria, B.C.
Telephone: (604) 388-3698

Contact: Dr. C.S. Wong, Head

Personnel Requirements -- A sedimentologist and two assistants, a chemist, and an assistant to the chemist would be required for nearshore field work. Depending on the number of samples taken, the analysis of the samples for hydrocarbons could require considerable time from the chemist and assistant. It would presumably be carried out in Victoria at the Ocean Chemistry Labs (DFE). The sedimentologist and chemist would be required for report preparation.

Because offshore work would require a large ship, more people, and a lead time of at least a month, it is unlikely that the study could be carried out as part of the scientific response plan. The description of the equipment and logistic requirements given below is for the nearshore situation.

Equipment Requirements

On site in readiness -- None

On hand elsewhere -- shipek grab sampler
- benthos gravity corer
- teflon bucket
- subsurface niskin bottle
- vacuum pump flask
- portable STD and O_2 probe
- microscope
(all of the above are probably already on hand)
- pipe dredges

Logistic Support -- 40 foot shallow draft vessel with positioning system

- Facilities for chemical analysis of oil (Victoria)
- Accommodation at Tuktoyaktuk for one month (five people)
- Air fare: Ottawa-Tuktoyaktuk return (3 fares)
- Air fare: Victoria-Tuktoyaktuk return (2 fares)
- Air freight: Ottawa-Tuktoyaktuk (2 ways)
- Air freight: Victoria-Tuktoyaktuk (2 ways)

Funds Required --

To prepare:	Sampling equipment (dredges)	500
TOTAL		500
To implement:	Accommodation	8,250
	Air fare	3,388
	Air freight	1,250
TOTAL		12,888

Priority -- Third level.

The results of this study would be important to the interpretation of the long-term fate of oiled sediment. The ultimate fate of oiled sediment will determine the biological recovery rate of an area extensively affected by oil. However, the results of this study may not be generally applicable to other parts of the Arctic where there are no major river deltas. Because of this aspect and because of the major logistical requirements, this study has been considered a third level priority.

Relationship to Other Studies -- A meaningful conduct of this study would require detailed information from 1A Aerial Reconnaissance and would be greatly assisted by studies 1B Radio Tracking of Surface Oil, 2A Effects of Surface Currents and Wind, 4A Oil in the Water Column, and 4B Oil in the Coastal Zone. The results of this study, when combined with those from the study on the Effects of Oil on Coastal Ecosystems (6), would permit some assessment of the probable impact of the spill on the relatively scarce benthic fauna of the river plume.

4D. Chemical Weathering of Oil

Chemical weathering of spilled oil refers to the chemical alteration of oil by the environment and includes the following processes: dissolution, evaporation, photo-oxidation, and biodegradation. Dissolution and evaporation are the most rapid processes; they involve only the lighter, more volatile compounds. (Approximately 27% by weight of Norman Wells crude [a relatively light oil] spilled on a freshwater pond with a water temperature of 0°C had weathered within 24 hours [Scott 1975; cited in Bunch and Harland 1976].) The portion of spilled oil that evaporates or dissolves and the rate of evaporation will generally depend on the composition of the oil and on the ambient temperature and water temperature. Biodegradation (see study 4E) and photo-oxidation are relatively slow processes that involve the heavier components. The heaviest components will remain as residues in the ecosystem; in temperate waters they commonly occur as 'tar balls'.

Objective -- To determine the rate of chemical weathering of spilled oil under various environmental conditions.

Methods -- In order to determine the rate of chemical weathering it is necessary to analyse the hydrocarbon content of the oil initially when it enters the water and again at later dates. By a comparison of the hydrocarbon components in the samples it is possible to determine the rate of weathering.

In order to determine the evaporation and dissolution rates for the more volatile portions of the spilled oil, it will be necessary to sample freshly released oil and to continue sampling the same oil at appropriate intervals over several days. During the open water period, oil-tracking buoys will provide a convenient means of marking the oil being sampled and ensuring that the same oil mass is being sampled repeatedly.

During the winter, it will be logistically more difficult to obtain a series of samples of the same oil mass. In the event of a blowout in the transition zone, samples could be taken of oil in leads at or near the blowout, and in leads at varying distances from the blowout. The tracking of ice (study 1C) will provide an estimated age for the oil. Oil deposited on the ice surface could also be marked (with radio buoys) and sampled at convenient intervals. Through use of ice corers, oil in or under various types of ice could be sampled. Oil could also be sampled when it migrated to the ice surface in spring. Oil samples obtained from the ice or leads during the winter would be examined to determine the degree and rate of chemical weathering.

The sampling of oils deposited on beaches and in sediments has already been described as parts of other studies (see 4B, 4C and 6). The analysis of the hydrocarbon content of these samples when first deposited and at later dates would give the rates of photo-oxidation and biodegradation.

Timing of Study -- Throughout the year, depending on the type of spill.

Criteria for Initiation -- Any oil spill and particularly one of crude oil.

Government Agency and Contact

Agency: Ocean Chemistry Division
Institute of Ocean Sciences
Department of Fisheries and Environment
211 Harbour Road
Victoria, B.C.
Telephone: (604) 388-3698

Contact: Dr. C.S. Wong, Head

Personnel Requirements -- A chemist would be required to carry out the sampling program. The analyses of samples, which would presumably be conducted in Victoria, would require the services of a technician (under the supervision of a chemist). A chemist would be required for the interpretation and write-up of the hydrocarbon analyses.

Equipment Requirements

On site in readiness -- sample containers
- SIPRE corer

On hand elsewhere -- laboratory equipment for hydrocarbon analyses (available in Victoria)

Logistic Support -- Deep water vessel (open-water period offshore)

- Nearshore vessel (open-water period)
- 15 hr helicopter (Bell 206) for winter use; this could easily be combined with other winter studies
- Freezer facilities on the ship (for offshore) and in Tuktoyaktuk
- Accommodation in Tuktoyaktuk for 6 months (one man)
- Air fare: Victoria-Tuktoyaktuk return (4 fares)
- Air freight

Funds Required --

To prepare:	sample containers	200
	SIPRE corer [estimated]	2,500
TOTAL		2,700
To implement:	Helicopter	5,055
	Accommodation	9,900
	Air fare	2,240
	Air freight	750
TOTAL		17,945

Priority -- Second level.

Relationship to Other Studies -- This study would be carried out in conjunction with studies on the movement of oil (1A, 1B, 1C). The results of this study would assist in the interpretation of studies on coastal ecosystems (6) and under-ice flora and fauna (7).

4E. Microbial Decomposition of Oil

The rate of biodegradation of oil spilled in Arctic marine environments is of considerable interest; it is also an area for which little information is available. Marine microbial flora capable of the degradation of hydrocarbons are present in the Beaufort Sea (Bunch and Harland 1976), but it is not known with certainty how rapidly this flora will respond to an influx of petroleum--particularly at low temperatures. As a best guess, major changes in the composition of the flora might be expected within two weeks (at 5°C) provided the spilled petroleum remains with the same water mass. In the Beaufort Sea, however, temperatures lower than 5°C can be expected. Physiological changes in the flora existing at the time of the spill might be expected within several days of the event.

Objectives

1) To measure the rate of change in the composition of marine microbial flora present in the immediate area affected by a spill.
2) To measure the rate of physiological change in the microbial flora exposed to a spill.
3) To relate these changes to the rate of microbial decomposition of oil.

Methods -- By means of Niskin S.S.1.5 bag samplers, water should be collected from immediately under surface oil and, as a control, from an area adjacent to the spill. Sample water must remain chilled and must be processed at a land-based facility within eight hours. Similar sampling, preferably of the same oil mass should be repeated at monthly intervals or, as is more likely to be the case, until the spill disperses or reaches the shoreline.

The most useful information would be obtained by long-term site-specific sampling in the event of the spill reaching a semi-enclosed bay. An amount of petroleum can be expected to remain in the bay after clean-up efforts, and sampling in such a bay should be continued at 4-6 month intervals for 2-4 years.

The following microbiological laboratory procedures should be conducted with the sample water within 8 hours:

1) total viable count of bacteria on an appropriate plating medium,
2) total direct count by epifluorescence,
3) total numbers of oleoclastic bacteria by the most probable number procedure,
4) heterotrophic potential of flora using radiolabelled glutamate and/or acetate as substrates,
5) rate of CO_2 evolution from radiolabelled petroleum incubated with sample water.

Determinations of nutrients, temperature, salinity, oxygen, and particulate and dissolved carbon should be made as part of the microbiological research. Of greatest importance is the long-term determination of various hydrocarbon fractions in the water column (4A), in sediments (4C), and on beaches (4B).

<u>Timing of Study</u> -- Open-water period.

<u>Criteria for Initiation</u> -- Any oil spill.

<u>Government Agency and Contact Persons</u>

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Microbiology Scientist: Dr. J.N. Bunch

<u>Personnel Requirements</u> -- A microbiologist and a technician would be required to conduct this study. Each sampling session would require one day in the field, followed by a seven day processing of the samples in Inuvik and a sixty day processing at the Arctic Biological Station.

Equipment Requirements

On site in readiness -- laboratory equipment at Inuvik Research Laboratory

On hand elsewhere -- All necessary scientific equipment (samplers, incubators, microscope equipped for epifluorescence, liquid scintillator, etc.) is presently available at the Arctic Biological Station.

Logistic Support -- Use of facilities in the Inuvik Research Laboratory

(per sampling session)

- Vessel for offshore work
- 4 hr helicopter (Bell 206)
- Air fare: Montreal-Inuvik (2 fares)
- Air freight: Montreal-Inuvik
- Accommodation in Inuvik for 2 weeks (2 people)

Funds Required -- To prepare: None

To implement:	Helicopter	1,348
	Water analysis [estimated]	750
	Air fare	1,380
	Air freight	500
	Accommodation	1,540
TOTAL		5,518

Priority -- Second level

Relationship to Other Studies -- Meaningfulness of sampling during this study will be greatly enhanced if this study is conducted in close co-operation with studies 1A Aerial Reconnaissance and 1B Radio Tracking of Surface Oil. The results of studies 4A Oil in the Water Column and 4D Chemical Weathering of Oil will assist the interpretation of the results of this study. Results of this study will be of use to the study on coastal ecosystems (6).

5. Toxicity of Spilled Oil

Crude oils from different sources can vary widely in their toxicities--a consequence of the great variations in physical properties and chemical composition of the crude oils. One of the major uncertainties in predicting the general ecological consequences of a major blowout in the Beaufort Sea arises from the fact that the toxicity of the oil likely to be encountered is unknown. There is also no indication of the toxicity of the oil when it is mixed with the type of dispersants that could be employed in the area. In order to assess the degree of risk associated with various clean-up options it would be very valuable to have such information available.

This study is described as a part of the scientific response plan, but it is also a pre-spill study that should be initiated as soon as oil is found under the Beaufort Sea.

Objectives

1) To assess the toxicity of oil from a spill.
2) To assess the toxicity of oil-dispersant mixtures.
3) To assess the reaction of test organisms to various concentrations of oil and oil-dispersant mixtures.

Methods -- The toxicities of crude oil and of various oil-dispersant mixtures would be tested at various degrees of dilution. A variety of techniques are available for this testing; each has advantages and disadvantages in particular situations. The ideal method is to employ a flow-through exposure system with automatic dilutors. However, the technical difficulties involved in dealing with unstable dispersions in such a system do not make this technique an attractive method for routine bioassays. A static system of the type outlined in La Roche *et al.* (1970) will probably be adequate for present purposes.

Instant Ocean Synthetic Seawater can be utilized for maintaining many arctic species (J. Percy, pers. comm.). It is produced by a reputable supplier, has been very widely used in a broad range of toxicity studies (it is a more stable, reproducible, and uncontaminated medium than the natural seawater in many localities), and comes ready mixed in standard packages that simply require dissolving in tap water. A few of the Aquarium System refrigerated aquaria would also be useful for holding stocks of the animals in the laboratory prior to testing.

The methods that would be employed in this study involve monitoring the exposure groups at frequent intervals and determining the time of death (in contrast to La Roche's method of measuring the mortality after a fixed time interval). From these data the time required for 50% mortality at a given oil concentration can readily be calculated. Plotting the results for several concentrations will provide an estimate of the incipient lethal level.

The fact that the organisms of concern are from a low temperature environment demands that the tests be carried out in a refrigerated incubator in order that ambient temperatures for organisms can be duplicated.

Selection of test species for evaluating toxicity of the oil is difficult. One approach (and perhaps the best) would be to choose a few of the species (depending upon availability at the time--some are very seasonal in abundance) designated as relatively sensitive in the Beaufort Sea Project Technical Report No. 11 (Percy and Mullin 1975). The amphipod *Onisimus affinis* is probably a good candidate because it is reasonably sensitive to oil, survives well in captivity, and is available year round in large numbers (in localized areas). Another approach would be to use invertebrates that are key food organisms and/or the most sensitive developmental stages of invertebrates (e.g., eggs, larvae, brooding female amphipods).

The interpretation of the results of the toxicity experiments would be greatly aided if avoidance/preference experiments were also conducted as part of this study. Standard procedures would be used to test the reaction of test organisms to concentrations of oil and oil-dispersant mixtures that are above, at and below the levels tested in the toxicity experiments.

<u>Timing of Study</u> -- Three to five months starting immediately after the spill (or preferably upon discovery of oil in the Beaufort Sea).

<u>Criteria for Initiation</u> -- Any major oil spill.

Government Agency and Contact Person

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Research Scientist: Dr. Jon A. Percy

Personnel Requirements -- One full-time trained technician should be adequate to conduct the study. Study design, data analysis, and interpretation of the results would require a research scientist experienced in conducting toxicity studies and avoidance/preference experiments.

Equipment Requirements

On site in Readiness -- None

On hand elsewhere -- refrigerated incubators (2)
- refrigerated aquaria (3)
- sea salts (10 boxes)
- reciprocating shaker
- air pumps
- assorted glassware
- equipment for avoidance/preference experiments
- collecting gear (traps, plankton nets, dredges, insulated carriers) would probably be available
- filters, fibre wound, carbon core
- general laboratory supplies

Logistic Support -- 10 hr helicopter (Bell 206)
- Laboratory facilities in Inuvik with bench space, running fresh water, electrical power, etc. (Inuvik Research Laboratory)
- Collection of test organisms would be carried out in conjunction with other studies
- Air fare: Montreal-Inuvik return (7 fares)
- Accommodation in Inuvik for 5 months (1 person)
- Air freight

Funds Required --	To prepare:	incubators	2,000
		aquaria	1,950
		salts	350
		shaker	500
		filters, etc.	400
		other equipment	1,800
	TOTAL		7,000
	To implement:	helicopter	3,370
		air fare	4,830
		accommodation	8,250
		air freight	750
	TOTAL		17,200

Priority -- Second level.

Relationship to Other Studies -- Because of the implications of this study to the use of dispersants in countermeasures planning (*cf.* O'Rourke 1977) toxicity studies should be initiated for each type of crude oil that is discovered in the Beaufort Sea. If possible, these studies should be initiated prior to any spill of the oil.

The results of this study will be important to the interpretation of the results from the studies on the effects of oil on coastal ecosystems (6), on under-ice flora and fauna (7), and on plankton and fish (8).

6. Effects of Oil on Coastal Ecosystems

Semi-enclosed embayments, lagoons, breached lakes, and shallow coastal waters are important to a variety of organisms, especially anadromous fish and some birds. Biologically, these areas may be the most vulnerable to oil spills in the Beaufort Sea (in the absence of an intertidal flora and fauna, which are strongly affected by oil spills in temperate waters). They may also be the areas that are contaminated most heavily because of the potential for large amounts of oil to be driven inshore and to concentrate in such regions. Entrapment of oil in the sediments of the coastal region may also occur; this entrapment is of particular interest because of the slow degradation of the oil in such a situation. It is consequently highly probable that the greatest impact, both short-term and long-term, of an oil spill will occur in coastal areas. This study then will be particularly important in assessing the biological impact of the spill. It may also serve as the starting point of a long-term study to determine the recovery rate of an impacted coastal area.

Objectives -- To determine the fate and the biological impact of oil that reaches a coastal embayment.

Specifically, the objectives are to determine:

1) the amount of oil in the water column that is suspended, dissolved or adsorbed to particulate matter, the distribution of each with respect to depth, and the variation of each of these quantities with time;
2) the amount of oil being deposited into the sediments and the variation of this deposition with time;
3) the effect that the presence of oil in the sediment is having on the benthic invertebrate community structure;
4) the rate at which oil is being incorporated into selected invertebrate tissue;
5) the levels of oil that are being incorporated into fish tissue; and
6) the effect that oil is having both on biological oxygen demand (BOD) in the water and on primary productivity.

<u>Methods</u> -- The scope and types of research that could be conducted in a study of this nature will be limited by the time of year during which the spill occurs, by the geographical area affected by the spill, and by the ability to predict the time and location of shoreline impact by the spilled oil. Under optimum circumstances, the following studies should be carried out.

Following the study site selection, a sampling program would, if possible, be initiated at four to six locations within the study area before the area is impacted by oil, and at four to six locations in a control area that will not be impacted. Sampling in the study area would be repeated immediately after impact. Sampling in a study area and in a control area should be performed even if the study area is impacted before sampling can begin and there is no information on pre-oiled conditions in the study area. The study of a control area will be necessary in order to distinguish between those changes in the oiled area that are natural changes and those that were caused by the oil.

It is anticipated that sampling after the impact by oil would take place in each area on a weekly basis for the first four weeks, biweekly for the next eight weeks, then at monthly intervals thereafter with a reduced level of sampling during winter. At each sampling location the following collections or analyses would be performed:

1) sampling of water and sediments for hydrocarbon analysis,
2) water sample profile including BOD analysis,
3) primary production estimates at intervals through the euphotic zone,
4) benthic invertebrate sampling for community structure analysis and hydrocarbon analysis, and
5) fish sampling for hydrocarbon analysis of tissue.

The sampling of the water and sediments for hydrocarbon analyses would be carried out by chemists, preferably in conjunction with other studies on hydrocarbons, but in full co-operation with the present research program. BOD and primary production measurements would be conducted by standard biological methods.

In sampling zoobenthos both infauna and epifauna should be considered. Sampling of infauna should be conducted using a Petersen type grab. Enough samples should be taken at each station to sample about $0.25m^2$ of bottom. Substrate from grabs should be washed through a 0.5mm screen and the retained invertebrates preserved in formalin. Samples would then be transported back to the Arctic Biological Station or Freshwater Institute for processing. Sampling stations should be selected on a depth transect basis. Critical depths suggested are 2m, 4m, 8-10m, and the deepest part of the bay. If sampling can be conducted before the area is impacted by oil, 5-20 stations should be sampled for benthic infauna both before and immediately after the oil contaimination. Sampling thereafter would only be required at 4-5 stations. Other parameters that should be measured are salinity, temperature of the water near the bottom, and substrate particle size.

Appraisal of the epifaunal contribution to the zoobenthos is more difficult because of sampling problems. Epifauna is rather sparse in the inshore waters of the Beaufort Sea and sessile species are extremely rare. The epifauna consists of mostly motile forms such as isopods, mysids, and amphipods. In the event of a spill, these motile animals may be able to escape from or evade oil-contaminated areas, but there is also a possibility that they will be attracted to oil-contaminated areas.

Epifauna could be sampled by dredge or trawl, but data arising from such techniques are not always quantitatively reliable. Divers could possibly be of use in this project, but their vision may be impaired by turbidity of inshore waters, and the presence of oil could render diving difficult or impossible. Divers would cover bottom transects that were laid out in strips (1 m by 100 m) -- a more quantitative collection method than the use of bottom trawls. Visual observations by qualified divers would also be useful for a more thorough knowledge of the distribution of oiled sediments, substrate types, and large species of epifauna.

The animal material selected for hydrocarbon analysis should consist of several different types of fish and invertebrate species. Animal material would be frozen on site and transported to Victoria for hydrocarbon analysis.

Waves and storm surges will be important factors in changing the amounts of hydrocarbons present in the water and sediments. Weather variables (temperature and wind) should be monitored at both sites. If available, temporary tide gauges should be installed.

This study is one that should be continued on a long-term basis in order to establish the recovery rate for impacted areas. The long-term study requires that very similar sampling stations be used from year to year (the exact same sampling site could not be used because of removal of organisms by previous sampling). During any particular year buoys could be used to mark stations but these would probably be moved by ice during spring melt. Triangulation from shore-based markers could be used to record and relocate sampling stations.

Term of Study -- Open-water period and on a reduced level during winter. This study, however, should be continued on a long-term basis in order to determine the recovery time of an area impacted by oil.

Criteria for Initiation -- Any large oil spill that moves into a coastal embayment.

Government Agency and Contact Person

(Biological)

Agency: Environmental Impact Assessment Division
Freshwater Institute
Department of Fisheries and Environment
501 University Crescent
Winnipeg, Manitoba R3T 2N6
Telephone: (204) 269-7379

Contact: Mr. J. N. Stein, Acting Division Head

(Chemical)

Agency: Ocean Chemistry Division
Institute of Ocean Sciences
Department of Fisheries and Environment
211 Harbour Road
Victoria, B.C.
Telephone: (604) 388-3698

Contact: Dr. C. S. Wong

Personnel Requirements -- The biological portion of this study would require a marine invertebrate biologist, a technician, and an assistant for the field study. Two of these people should preferably be qualified divers. The biologist and technician would be required to carry out the identification of invertebrate samples, to analyze the data, and to prepare the report.

Sampling of water and sediments for hydrocarbon analysis would require a chemist and probably an assistant. These people would also be required to carry out the hydrocarbon analyses and summarize the results for incorporation into the overall report.

Equipment Requirements

On site in readiness -- 16' inflatable rubber boat (2)
- 20-40 H.P. outboard motor (2)
- Parcoll tent (12 x 16) (1)
- heater (1)
- generator (diesel 3.5 kw) (1)
- freezer (1)
- minnow traps (for amphipods)
- trap nets
- miscellaneous sampling equipment
- anemometer and thermometer (air)

On hand elsewhere -- laboratory equipment for hydrocarbon analyses (available in Victoria)
- laboratory equipment for invertebrate identification (available at FWI in Winnipeg)
- tide gauge (available in Ottawa)
- Ekman dredge sampler (1)
- Lubinsky dredge sampler (1)
- thermistor and meter
- conductivity/salinity meter
- pH meter
- light meter
- primary production apparati
- BOD analysis apparati

Logistic Support -- 10 hr helicopter (Bell 205) for camp establishment, or use available nearshore vessel (preferable)

- 30 hr helicopter (Bell 206) for servicing camp and transportation to and from area for chemist, or use available nearshore vessel (preferable) during open water and helicopter largely during winter.
- field camp costs (food etc.)
- air fares: Winnipeg-Tuktoyaktuk return (9 fares during open-water period; 18 fares during winter)
- air fares: Victoria-Tuktoyaktuk return (4 fares during open-water period; 8 fares during winter)
- accommodation at Tuktoyaktuk (chemist and assistant) for three months.

Funds Required -- To prepare:

To prepare:	boats and motors	11,000
	samplers	600
	camp equipment	8,950
	freezer	300
	various meters	1,900
	traps and nets	500
	primary production apparati	1,000
	BOD analysis apparati	300
	miscellaneous	3,000
TOTAL		27,550
To implement:	helicopter	21,600
	air fares	23,088
	accommodation	9,900
	field camp subsistence	5,985
	fuel (boats and heater)	2,000
	computer costs and sample analysis	10,000
TOTAL		71,673

Priority -- Second level.

If this study is pursued in sufficient detail, it will provide a sound basis on which to assess the recovery rate of an Arctic area impacted by oil. The results should be applicable to Arctic areas in general.

Relationship to Other Studies -- The interpretation of results from this study will be assisted by those from studies on the toxicity of oil (5), on oil in the coastal zone (4B), on the behaviour of oil in sediment-laden waters (4C), and on chemical weathering of oil (4D). To reduce logistic costs this study should, wherever possible, be co-ordinated with studies 4E Microbial Decomposition of Oil and 4B Oil in the Coastal Zone.

7. Effects of Oil on Under-Ice Flora and Fauna

During late winter and spring in the arctic, an abundant flora develops on and near the lower surface of sea ice and within the ice itself. Although the overall importance of this flora is not well known, the primary production by this flora is substantial. It apparently serves as the base of a food chain that reaches to pelagic fish through one or two crustacean links (copepod, amphipod). Of the fish, the arctic cod (*Boreogadus saida*) is the most abundant pelagic marine species in many parts of the arctic seas and is a major food item of several predators, including the ringed seal. Arctic cod appear to be indirectly dependent for at least part of the year upon the under-ice flora as the primary source of their food.

An oil spill under the ice could affect this flora in three ways. 1) The presence of oil in the ice could produce a shading effect on the ice flora below and inhibit photosynthesis. 2) Because oil released under the ice does not degrade, the volatile components, which are generally the most toxic, could inhibit primary production. 3) The oil could cause physical damage to the flora by directly coating it.

The direct effects of oil on the under-ice fauna, which feed on the flora, will probably be to exclude them from those portions of the under-ice surface that are covered by oil or that are affected by dissolved components of the oil. There may also be mortality due to coating of the fauna and due to the toxicity of components of the oil that are dissolved in the water.

Objectives

1) To compare the primary productivity in oiled and unoiled ice.

2) To compare the densities of invertebrates on under-ice surfaces in oiled and unoiled areas.

Methods -- The major sampling effort during this study should be made during the period of greatest growth of ice flora. Sampling would be carried out through use of ice corers and under-ice net tows and possibly through use of divers. Ice core sampling should begin in early March and initially would be important in detecting the beginning of the period of major growth of the ice flora.

Choice of sampling sites would depend upon information on the extent of the oiled area. Ideally, samples should be taken close to the point of maximum impact and at a series of points "downstream" from the spill to its edge. At approximately the same time, control samples should be taken close to but outside the spill area. Care should be taken to choose control sites with ice and snow cover thicknesses similar to those found in the spill area.

A standard SIPRE corer would be used to obtain ice cores at the sampling sites. Parts of cores should be melted immediately and preserved for later microscopic examination of the plant specimens. Sampling in oiled areas will probably be a serious problem. Samples obtained by ice coring or under-ice net tows in oiled areas will possibly be so badly contaminated with oil during the sampling procedure that they will be of little use.

The use of divers will possibly be the only feasible way of obtaining useful samples from the under-surface of ice containing encapsulated oil. Divers may also be able to obtain samples from the lower surface of ice that is covered with oil by first removing the oil by some suction device. This latter technique would only be feasible for small pockets of oil. Sampling by divers would be carried out in both the oiled and the control area. The number of sites that could be sampled by divers, however, would be smaller than the number that could be sampled by ice corers and in many parts of the oiled area diving would not be feasible.

Under-ice photography and descriptions based on visual observations of the under-ice conditions by divers would fill important roles in this study. In addition to sampling the flora, divers would be able both to carry out primary production studies utilizing C_{14} techniques and to make observations on the densities and distributions of under-ice invertebrates and on the presence of arctic cod. They could also collect samples of the invertebrate fauna.

If, as recommended, divers are used in an under-ice study, the logistical and safety requirements will be considerable and will perhaps be impossible to meet in the transition zone far offshore.

The part of the study that utilizes divers should be concentrated in a 4-6 week period when the growth of the flora is the greatest. The exact timing would be obtained through the ice core sampling program.

Timing of Study -- Early March to June with the major effort concentrated in a 4-6 week period when growth of the flora is maximum.

Criteria for Initiation -- Any major spillage of oil under the ice.

Government Agency and Contacts

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec, H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Research Scientists: Dr. E.H. Grainger and Dr. Steven Hsiao

Personnel Requirements -- A phytoplankton specialist would be required to conduct the field portion of this study, to identify the organisms in the samples, and to summarize the results. During the peak of floral growth, two (or three) divers and two assistants would be required to conduct the under-ice sampling and observations. These people should have biological training. An invertebrate specialist would be required to assist in the field program, to carry out the identification of invertebrates, and to summarize the results obtained by the divers.

Equipment Requirements

On site in readiness -- none

On hand elsewhere -- SIPRE corer
- field microscope (available from Arctic Biological Station)
- miscellaneous field materials and equipment
- diving equipment with closed circuit breathing system
- ice camp equipment
- generator (300 W)
- underwater TV camera and video recorder
- underwater camera (still photos)
- system for surface to diver communications

Logistic Support -- 50 hr helicopter (Bell 206)
- 10 hr helicopter (Bell 205) for establishment and dismantling of ice camp
- accommodation for 5 months at Tuktoyaktuk (1 person)
- air fare: Montreal-Tuktoyaktuk return (6)
- air fare: divers (est. $2,000)

Funds Required --	To prepare:	Equipment purchase	29,735
	To implement:	Equipment rental (generator, radio)	700
		Helicopter	24,510
		Air fare	6,608
		Accommodation	8,250
		Ice camp subsistence	3,675
		Air freight	2,000
	TOTAL		45,743

Priority -- Second level

Relationship to Other Studies -- This study should be carried out in co-operation with studies on tracking oil under ice (1C), on the hydrocarbon levels in the water column under the ice (4A), on the weathering of hydrocarbons in and under the ice (4D), and on the under-ice currents in the vicinity of a blowout (2C). When the results of this study are combined with those from the studies on the quantity and distribution of oil on the ice surface (2D) and on the toxicity of oil (5), an assessment could be made of the overall effects of the spill both on primary production by the ice flora and on the fauna utilizing the flora.

8. Effects of Oil on Plankton and Fish Populations

The probability of major losses of adult and large juvenile fish that result directly from an oil spill is generally believed to be low because the fish are mobile and thus may avoid or move out of oiled areas (Hay 1976). If there is a large mortality, it will be difficult to detect it as such because the dead fish will probably be quickly consumed by invertebrates (if the invertebrates are not also affected), and because the sampling variability will make it difficult to detect significant differences between oiled and control areas. Moreover, during an offshore oil spill in the Beaufort Sea, it is highly probable that the limited availability of suitable vessels would prohibit the conduct of any sampling program that was sufficiently extensive to quantify the effect of the oil on adult fish populations.

Plankton and the eggs and larval stages of fish are relatively non-mobile (compared to adult fish) and are thus susceptible to the toxic effects of oil. Unfortunately, there are sampling problems associated with estimating their relative abundance because of their patchy distributions, their avoidance reactions to sampling gear, and the actual mechanics of sampling. In addition, sampling in oil-contaminated waters will probably result in clogging of plankton nets and matting of samples by oil. Despite these problems, there are some useful measurements that could be made.

On the basis of information on the density of plankton and of fish eggs and young of the year in the general vicinity of the affected area, information on oil in the water column, and information on toxicity of the oil, assessments can be made regarding the probable effects of the oil on the populations of plankton and fish eggs and young. Long-term studies on the age structure of fish populations in subsequent years would indicate any major mortality of eggs or young during the year of the spill. They could not, however, establish that the mortality was due to the oil spill.

Objectives

1) To assess the densities of plankton and of fish eggs and young of

the year in the general vicinity of the spill during both summer and winter.

2) To collect plankton and fish specimens for hydrocarbon analysis.
3) To assess the probable impact of the oil on plankton and on fish eggs and young.

Methods -- During the open-water period plankton tows would be conducted in an area near and similar to the contaminated area in order to obtain density estimates for plankton and for fish eggs and young of the year. Tows would also be carried out in contaminated areas to obtain samples for hydrocarbon analysis. Bottom and mid-water trawls would be made in contaminated and uncontaminated areas to obtain fish specimens for hydrocarbon analysis.

During winter, plankton would be sampled by making vertical tows from the ice surface. This would be carried out in conjunction with the under-ice flora and fauna study (7). If divers are employed in the under-ice study, they could obtain useful information on the reaction of adult arctic cod (if present) to oil present on the under-ice surface. Arctic cod would also be collected to test for hydrocarbons in the flesh and in the food organisms in the stomach.

Timing of Study -- open-water period, and March to May for ice studies.

Criteria for Initiation -- This study would be conducted only in conjunction with other studies. During the open-water period, these studies would include the study on subsurface currents (2B) and the study on oil in the water column (4A). During the winter, these studies would include the study on under-ice flora and fauna (7) and the study on under-ice currents (2C). The laboratory study on the toxicity of the oil (5) would also be required.

Government Agency and Contact

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Personnel Requirements -- The portion of the study conducted during the open-water period would require a biologist and perhaps an assistant (additional assistance required to conduct trawls and tows could come from other investigators present). The biologist would be required to carry out plankton identification of samples and to summarize the results. Preservation of samples for hydrocarbon analysis would be carried out by a chemist, who would be present for the study on oil in the water column (4A). An assistant to the chemist would be required to carry out the tissue analyses. The chemist would be required to interpret and summarize the results.

Equipment Requirements

On site in readiness -- none

On hand elsewhere -- bottom and mid-water trawls
- plankton nets (all of the above presently stored in Tuktoyaktuk)

Logistic Support -- deep water vessel
- helicopter support (part of under-ice flora study)
- air fare: Montreal-Tuktoyaktuk return (3)
- accommodation for 3 months at Tuktoyaktuk (1 person)

Funds Required -- To prepare: none

To implement:	air fare	2,304
	accommodation	4,950
	air freight	300
TOTAL		7,554

Priority -- Third level

Relationship to Other Studies -- The implementation of this study would depend on the results of studies 1A and 1C on movement of oil and would only be carried out in conjunction with studies described previously in the criteria for initiation (2B, 2C, 4A and 7). The results of this study, when combined with those from the toxicity study (5), the study on oil in the water column (4A), and the study on coastal ecosystems (6), could be used to infer probable impacts of the oil spill on plankton and on fish eggs and young of the year.

9. Effects of Oil on Water Birds

Water birds are particularly susceptible to oil spills. The oil mats the feathers, destroying their insulation and buoyant qualities. As a result the birds may succumb to the cold, they may sink and drown, or they may leave the water and consequently starve or be taken by predators. They may also succumb to the effects of preening and ingesting oil from their plumage.

Because of the obvious and frequently heavy mortality and because of the emotional attachment that many people have for birds, bird mortality usually receives considerable attention from the press. An oil spill in the Beaufort Sea will probably be no exception.

Methods of reducing bird mortality are the responsibility of those involved in countermeasures planning and are not addressed in this study. The studies described in this section are concerned only with assessing the extent of bird mortality from an oil spill.

9A. Bird Mortality During Spring Migration

During May and June, tens of thousands of water birds (predominantly eiders and Oldsquaw) are known to migrate into or through the Beaufort Sea area via coastal and offshore routes (Richardson *et al.* 1975; Searing *et al.* 1975). During this migration period these birds are dependent for resting and feeding on the presence of patches of open water, ice leads, and melt ponds in the transition zone (*cf.* Barry 1968). A major oil well blowout during May or June, particularly in the transition zone, could result in the presence of many oil-covered leads and of numerous pools of oil on the ice surface along the migration route of these birds. It is expected that migrant water birds would mistake these areas for open water and land in them (*cf.* Barry 1970; NORCOR 1975; Milne and Smiley 1976). The resulting mortality could be substantial.

Objectives

1) To determine the species and numbers of water birds that are killed as a result of the presence during spring of oil-contaminated ice and leads.
2) To determine the reactions of migrant birds to oil pools on the ice surface and to oil-covered leads.
3) To determine the extent of utilization of oiled birds by scavengers (e.g. arctic fox).

Methods -- Helicopter surveys of oil-covered leads and of pools of surface oil within the contaminated area would be flown twice weekly. If numbers of oiled birds are able to move out of the oil onto the ice or into oil-free water it will be possible to survey them from the air. The helicopter will have to be landed frequently in order to determine numbers of birds actually in the oil (where they will be difficult to see), to identify heavily oiled birds, and to mark dead birds (by removal of a wing). Dead birds would be marked in order to determine both the rate of scavenging and the number of additional birds that had died.

On several occasions the observer would spend some time in a white blind on the ice in the vicinity of oil-covered leads or surface pools of oil in order to study the reaction of flying (migrant) birds to the oil. The observer would record the species, flock sizes, directions and heights of flight, and behaviour with respect to the oil.

The specific methodology of the surveys will be determined by the extent of the contaminated area, the degree of success of attempts to burn the oil, and the ease with which oiled birds can be observed (if at all) from the air.

Timing of Study -- May and June.

Criteria for Initiation -- Observations would be initiated if aerial reconnaissance indicated the presence of oil-covered leads or surface pools of oil during the spring migration period. Because of the apparent attraction that surface pools of oil and oil-covered leads could hold for water birds, it would be useful to conduct this study whenever any such areas occur. Limited observations suggest that even a few small pools of oil could cause considerable bird mortality (Barry 1970; NORCOR 1975). If only a small amount of oil were present, the study would be scaled down accordingly.

Government Agency and Contact Persons

Agency: Canadian Wildlife Service
Department of Fisheries and Environment
10025 Jasper Avenue
Edmonton, Alberta
Telephone: (403) 425-6860

Contact: Dr. Dennis Surrendi, Acting Director

Personnel Requirements -- One (possibly two) experienced bird survey biologist would be required to conduct surveys, to analyze and interpret the data, and to write up the report. He should be accompanied by a native assistant during all surveys on or over the ice.

Equipment Requirements

On site in readiness -- none

On hand elsewhere -- Arctic winter survival gear

- 2 tape recorders) probably already
- spare batteries, tapes) on hand
- spotting telescope)
- blind

Logistic Support -- 100 hrs of helicopter (Bell 206) [estimated]

- 2 months accommodation for three persons (biologist, native assistant and pilot) at Tuktoyaktuk (depending on location of spill)
- Air fare: Edmonton-Tuktoyaktuk return (2 fares)
- Fuel caches at Komakuk and/or Sachs Harbour

Funds Required --

To prepare:	Survival gear	1,000
	Blind	100
	Miscellaneous	500
TOTAL		1,600
To implement:	Helicopter	33,700
	Air fare	836
	Accommodation	9,900
	Fuel caches	2,000
	Native guide	4,500
TOTAL		50,936

Priority -- Second level

Relationship to Other Studies -- The implementation and the extent of this study will depend on information from the Aerial Reconnaissance study (1A) and the study on ice movement (1C). In the event of a very large contaminated area of ice, the results of the study recording the presence of oil on the ice surface (2D) will be important to the interpretation of results from this study. The study on the effects of oil on whales during spring (12A) would be conducted in conjunction with this study.

9B. Mortality of Moulting Sea Ducks

During July and August, tens of thousands of diving ducks (predominantly scoters and Oldsquaw) are known to congregate along the Beaufort Sea coast, particularly in bays and lagoons, in order to undergo their annual wing moult (Searing *et al.* 1975). They are flightless at this time and are thus particularly vulnerable to oil spills. In the event of a major oil spill in the Beaufort Sea during this period, oil could be blown into coastal areas where it could cause substantial mortality to these birds.

Objectives

1) To determine the numbers, species, and distribution of water birds (particularly diving ducks) present in coastal areas before (if possible) and after an oil spill reaches these areas.
2) To determine the species and numbers of dead and oiled birds relative to the species and numbers of birds that could potentially have encountered the oil.
3) To assess the responses of the birds to the oil.
4) To determine the extent of utilization of the carcasses of oiled birds by scavengers (e.g. foxes, gulls).

Methods -- Aerial surveys would be conducted of the coastline in threatened areas in order to establish the species, numbers and distribution of sea ducks both before (if possible) and after any oil reaches the threatened areas. These surveys should be designed to obtain total counts of birds in the coastal areas and should be initiated as soon as possible after the spill occurs. The surveys should be conducted at weekly intervals, particularly in those coastal areas where the threat of oil-contamination is high.

Ground surveys of the numbers of dead birds along beaches (beached bird surveys) would also be conducted immediately after the oil reaches the coast and at weekly intervals thereafter. The following information would be recorded during the beached bird surveys: species, numbers, location, and condition of oiled birds; evidence of scavengers; and quantity and location of oil (e.g. on the beach, in the water, etc.). By marking dead birds during each beached bird survey (e.g. removing a wing) and by repeating the surveys, information could be obtained on the removal of dead birds by scavengers. Comparative information on normal mortality could be obtained by surveying a similar but uncontaminated area.

Timing of Study -- Mid-July to mid-September.

Criteria for Initiation -- This study should be initiated almost immediately after any major oil spill during July and August that will possibly result in oil reaching coastal areas.

Government Agency and Contact Person

Agency: Canadian Wildlife Service
Department of Fisheries and Environment
10025 Jasper Avenue
Edmonton, Alberta
Telephone: (403) 425-6860

Contact: Dr. Dennis Surrendi, Acting Director

Personnel Requirements -- Two biologists experienced in conducting aerial surveys of water birds and familiar with conducting beached bird surveys would be required during the late summer if there were a threat of oil reaching coastal areas.

Equipment Requirements

On site in readiness -- none

On hand elsewhere -- tape recorders (2)
- spare batteries, tapes
(see study 9A)

Logistic Support -- 50 hr fixed-wing aircraft (Cessna 185) for aerial surveys

- 10 hr helicopter (Bell 206) for transportation to survey sites for beached bird surveys. This could be done in conjunction with studies 4B or 6
- Accommodation for two months (two people) at Tuktoyaktuk
- Air fare: Edmonton-Tuktoyaktuk return (4 fares)

Funds Required -- To prepare: none

To implement:	Aircraft	10,870
	Air fare	1,672
	Accommodation	6,600
TOTAL		19,142

Priority -- Second level

Relationship to Other Studies -- The implementation of this study will depend on the results of study 1A on the Movement of Oil. The results of the studies on Oil in the Coastal Zone (4B) and on Effects of Oil on Coastal Ecosystems (6) will provide important information for interpreting the results of the aerial and beached bird surveys.

9C. Mortality of Birds in Offshore Open Waters

By the time of the open-water period in the southern Beaufort Sea (sometime in July), many (perhaps most) birds will have moved inland to nest. Those birds that remain on or return to the open water offshore will apparently occur in very low densities (Searing *et al*. 1975). It is also possible that clean-up activities during an oil spill will frighten birds away from the contaminated areas. The mortality to birds in offshore areas is thus expected to be small. Moreover, any offshore bird mortality due to oil will be difficult to measure because the birds may sink and because dead birds on the water are difficult to see both from aircraft and from ships (Hay 1976). An offshore study would thus be able to measure only the species and numbers of birds that were present in affected and unaffected areas. Little direct information could be obtained on actual bird mortality in these areas. A study is briefly described below for an offshore area but it is not considered a high priority study.

Objectives -- To determine the species and numbers of water birds in oiled and unoiled offshore areas.

Methods -- Standard aerial survey techniques for birds would be used to determine the species and numbers of birds on transects through the area affected by the oil spill and through adjacent unaffected areas. Surveys would be flown at weekly intervals during the open-water period for the duration of the spill. Comparisons of densities between the areas should indicate whether the birds are avoiding the contaminated area.

Timing of Study -- Open-water period.

Criteria for Initiation -- This study would only be considered if aerial reconnaissance observations indicated the presence of large numbers of water birds offshore in or near contaminated areas.

Government Agency and Contact Person

Agency: Canadian Wildlife Service
Department of Fisheries and Environment
10025 Jasper Avenue
Edmonton, Alberta
Telephone: (403) 425-6860

Contact: Dr. Dennis Surrendi, Acting Director

Personnel Requirements -- Two experienced aerial survey biologists would be required for this study.

Equipment Requirements

On site in readiness -- none

On hand elsewhere -- tape recorders (3)
- spare batteries, tapes (already on hand)

Logistic Support -- 60 hrs Cessna 337 with positioning system
- Accommodation for 1-1/2 months at Tuktoyaktuk (two observers and pilot)
- Air fare: Edmonton-Tuktoyaktuk return (4)

Funds Required -- To prepare: none

To implement:	Cessna 337	11,520
	Accommodation	7,425
	Air fare	1,672
TOTAL		20,617

Priority -- Fourth level

Relationship to Other Studies -- The implementation and survey design of this study would depend on information obtained during the Aerial Reconnaissance study (1A). The study could be conducted by the same personnel and at the same time as study 9B Mortality to Moulting Sea Ducks.

9D. Effects of Storm Surges on Birds

Storm surges that carry oil inland to contaminate tundra, lakes, and delta areas could cause mortality to birds that nest or feed in these areas. Most major storm surges occur in late September or October when most birds have left the Beaufort Sea area. However, the occurrence of a storm surge in July or August, in combination with a major oil spill, could result in mortality to breeding birds, to young, or to staging or migrating birds that were present in the affected areas. It may be difficult, however, to assess directly the magnitude of any such mortality. Lightly oiled birds will probably hide in vegetation; heavily oiled dead birds will probably be mixed with oil or oiled vegetation where they will be difficult to see. Scavengers will probably remove some of the oiled birds.

Moulting birds and broods of water birds would be particularly sensitive to oil contamination because they are flightless and hence unable to escape from the oil. The mortality to these birds could be measured indirectly by conducting surveys in the contaminated area and in a similar control area. Comparisons between the two areas would provide a crude measure of the impact on young and on moulting birds.

A storm surge in late September or October will not directly affect birds, but the oil deposited in nesting areas could create a problem for birds during the next breeding season. If a storm surge were to contaminate an extensive area of nesting habitat, a study should be implemented the next year to determine the impact on nesting birds.

Objectives -- To assess the impact on broods of water birds and on moulting water birds from oil contamination caused by a storm surge.

Methods -- Immediately after the storm surge aerial surveys by helicopter would be made of a portion of the contaminated area and of a similar control area in order to determine the numbers of broods, the numbers of moulting birds and the numbers of oiled birds visible. A second survey would be conducted one week later.

Timing of Study -- July to early September.

Criteria for Initiation -- Any storm surge that carries oil inland during the period from July to early September. After early September, the results of study 4B Oil in the Coastal Zone would be used to determine the need for a study during the nesting season of the next year.

Government Agency and Contact Person

Agency: Canadian Wildlife Service
Department of Fisheries and Environment
10025 Jasper Avenue
Edmonton, Alberta
Telephone: (403) 425-6860

Contact: Dr. Dennis Surrendi, Acting Director

Personnel Requirements -- An experienced waterfowl survey biologist would be required for the surveys.

Equipment Requirements

On site in readiness -- None

On hand elsewhere -- tape recorders (2)
- batteries, tapes (already available)

Logistic Requirements -- 15 hrs helicopter (Bell 206)
- Accommodation in Tuktoyaktuk for 2 weeks (1 person)
- Air fare: Edmonton-Tuktoyaktuk return (1 fare)

Funds Required -- To prepare: None

To implement:	Helicopter	5,055
	Accommodation	770
	Air fare	418
TOTAL		6,243

Priority -- Second level

Relationship to Other Studies -- The implementation of this study would depend on the results of study 1A Aerial Reconnaissance. The results of the study 4B on Oil in the Coastal Zone would be necessary for the interpretation of the results of this study.

10. Effects of Oil on Seals

During the open water season it is very probable that bearded and ringed seals (the two principal species of seals in the Beaufort Sea) will avoid any spills and will suffer little or no mortality caused by the oil.

In the winter months the response and susceptability of seals to oil spills could be quite different. Bearded seals and subadult ringed seals tend to occur largely in the leads and polynias in the transition zone off the Tuktoyaktuk Peninsula and off Banks Island (Stirling *et al.* 1975b). Bearded seals also pup in these areas. If extensive areas of the transition zone are contaminated with oil (as suggested by Milne and Smiley 1976), these animals will possibly be incapable of avoiding the oil. Because winter is probably a very stressful period for seals, any prolonged contact with oil by seals could cause substantial mortality (*cf.* Smith and Geraci 1975).

During the winter a large portion of the adult ringed seal population occurs in the fast ice zone off the Tuktoyaktuk Peninsula, off Banks Island, and in the Amundsen Gulf. Pupping also occurs in these areas. Contamination of large portions of this habitat (considered to be highly unlikely) could have effects on the survival of both adult ringed seals and pups.

10A. Spring Distribution and Numbers of Seals

Objectives -- To determine the numbers and distribution of bearded and ringed seals with respect to the oil-contaminated and uncontaminated areas of the Beaufort Sea.

Methods -- Aerial surveys along a transect grid would be conducted during the spring break-up period in the same manner as the surveys conducted before, during, and subsequent to the Beaufort Sea project (Stirling *et al.* 1975b).

Timing of Study -- Approximately 1 June to 21 June.

Criteria for Initiation -- This study would only be useful with respect to the effects of an oil spill on seals provided that extensive areas were contaminated with oil and provided that baseline studies had been conducted in the year previous to the spill.

Government Agency and Contact Persons

Agency: Canadian Wildlife Service
Department of Fisheries and Environment
10025 Jasper Avenue
Edmonton, Alberta
T5J 1S6
Telephone: (403) 425-6860

Contact: Dr. Dennis Surrendi, Acting Director

Scientist: Dr. Ian Stirling

Personnel Requirements -- Two experienced marine mammal survey biologists would be required to conduct surveys, analyse the data, and prepare the report. During surveys these people should be accompanied by a native assistant familiar with survival and travel on the ice.

Equipment Requirements -- Required equipment (tape recorders, etc.) is presently available.

Logistic Support -- 80 hr fixed-wing aircraft (Cessna 337) with positioning system

- fuel cache at Komakuk
- fuel cache at Sachs Harbour
- accommodation for two people
  - 1 week Inuvik
  - 1 week Tuktoyaktuk
  - 1 week Sachs Harbour
- air fares: Edmonton-Inuvik return (2)

Fuel caches for this study should be established at the same time as those for the polar bear study (11), since the criteria for implementation are similar for both studies.

Funds Required --	To prepare:	None	
	To implement:	aircraft	15,360
		fuel cache	2,000
		accommodation	2,310
		air fares	680
		native assistant	1,575
	TOTAL		21,925

Priority -- Second level.

Relationship to Other Studies -- The implementation of this study is highly dependent on the results of the aerial reconnaissance study (1A) and the ice-tracking study (1C). The interpretation of the results of this study will be aided by the results of the polar bear survey (11), and of the study on the effects of oil on seals in the transition zone (10C).

10B. Effects on Seals in the Fast Ice Zone

Objectives

1) To compare densities of ringed seal lairs in an oil-contaminated area with densities in a similar but uncontaminated area.
2) To record any oil contamination of lairs and of pups in birth lairs.

Methods -- A helicopter would be used to reach offshore areas and an oversnow machine to reach nearshore areas. Seal lairs would be found through use of a trained dog, and by sight if the lair had been opened by a predator. Any oiled seal pups found dead would be necropsied to establish cause of death.

Timing of Study -- Late March to early May.

Criteria for Initiation -- Unless an extensive area of fast ice is oiled, it is unlikely that the data would meaningfully show any differences between oiled and unoiled areas. This study should, therefore, only be considered if an extensive area in the fast ice zone were contaminated with oil.

Government Agency and Contact Person

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Research Scientists: Dr. Thomas G. Smith
Arctic Biological Station

and

Dr. Joseph R. Geraci
Department of Pathology
University of Guelph
Guelph, Ontario
Telephone: (519) 824-4120 Ext. 3112

Personnel Requirements -- One biologist and a native assistant would be required to carry out the lair searches. They should be accompanied by a person experienced in conducting post-mortem examinations of dead seals. The biologist and pathologist would be required to analyze data and prepare the report.

Equipment Requirements -- Complete equipment requirements for this study are presently available at Holman and at Cape Parry.

Logistic Support -- 80 hr helicopter (Bell 206) for offshore searches

- 5 hr fixed-wing aircraft (Twin Otter) for transporting equipment from Cape Parry to Tuktoyaktuk
- accommodation for 2 months at Tuktoyaktuk (3 people)
- air fare: Montreal-Tuktoyaktuk return (1)
  Toronto-Tuktoyaktuk return (1)

Funds Required -- To prepare: None

To implement:	helicopter	26,960
	aircraft	2,125
	air fare	1,516
	accommodation	9,900
	native assistant	3,375
TOTAL		43,876

Priority -- Second level.

Relationship to Other Studies -- The implementation of this study is dependent on knowing the extent of the contaminated area (1A). The interpretation of the results of this study would be greatly aided by a photo record of oil when it comes to the surface of the ice in spring (2D), and by the results of the polar bear study (11).

10C. Effects on Seals in the Transition Zone

Objectives -- To compare the physical condition of seals in a contaminated area with that of seals in an oil-free area.

Methods -- Seals would be collected at varying distances from the spill. They would be examined for external oiling and ingestion of oil and would be necropsied to determine their physical condition. During collecting trips, incidental observations should be made on seal behaviour.

Timing of Study -- March and April.

Criteria for Initiation -- As with the lair searches, this study would only yield sufficient quantitative data if an extensive area were contaminated with oil. It should only be undertaken if a blowout were to occur in the transition zone and if extensive areas of this zone were contaminated.

Government Agency and Contact Person

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Research Scientists: Dr. Thomas G. Smith
Arctic Biological Station

and

Dr. Joseph R. Geraci
Department of Pathology
University of Guelph
Guelph, Ontario
Telephone: (519) 824-4120 Ext. 3112

Personnel Requirements -- This study would require a biologist experienced in collecting seals, a pathologist, and probably two native assistants. The pathologist would be required to carry out the tissue analysis and to prepare the report.

Equipment Requirements -- All equipment required for the field portion of this study is presently available at Cape Parry. Facilities and equipment for the preparation and examination of tissue samples are available at the University of Guelph.

Logistic Support -- 50 hr helicopter (Bell 205)

- transportation of field equipment from Cape Parry to Tuktoyaktuk (Twin Otter)
- air fare: Montreal-Tuktoyaktuk return (1)
  Guelph-Tuktoyaktuk return (1)
- accommodation for probably one month at Tuktoyaktuk (4 people)

Funds Required -- To prepare: None

To implement:	helicopter	38,300
	transportation	1,700
	air fare	1,516
	accommodation	6,600
	native assistants	6,000
	tissue preparation	200
TOTAL		54,316

Priority -- Third level.

Relationship to Other Studies -- The implementation of this study will depend on the results of studies on the movement of oil under ice (1A, 1C). The results of this study will assist in the interpretation of the studies on the distribution and numbers of seals (10A) and of polar bears (11).

11. Effects of Oil on Polar Bears

Polar Bears are not randomly distributed over the winter ice of the Beaufort Sea. They tend to concentrate in ice habitats where seals are present and accessible (Stirling *et al.* 1975a). The three most important habitats, in approximate order of importance, are the following:

1) areas in the transition zone where movement of ice caused by winds and sea currents has been followed by refreezing to create intermittent lanes or patches of refrozen young ice that are bare or only slightly drifted with snow;
2) edges of large floes in the transition zone where there are large leads (1 km), small leads (open or refrozen), and pressure ridges that are not heavily drifted with snow; and
3) stable flat ice areas (in the fast ice zone) that are interspersed with pressure ridges that have not moved for a long time and that are drifted with snow suitable for seal lairs.

Oil contamination of an extensive area of these habitat types (particularly the first two) could substantially alter the numbers and distribution of seals and thus their accessability to polar bears. This could cause a decline in polar bear populations.

If the number of seals available to polar bears were to decrease substantially, there could be a noticeable increase in the number of dangerous encounters between polar bears and the men working on the Beaufort Sea ice.

Objectives

1) To assess the distribution of polar bears with respect to oil-contaminated areas.
2) To record the presence of any oiled bears and the degree of oiling.

Methods -- The same methods of surveying and tagging polar bears that were conducted before and during the Beaufort Sea project (Stirling *et al.* 1975a) and that have been continued in 1976 should be repeated. A meaningful assessment of the effects of an oil spill on polar bear populations will be highly dependent on the conducting of baseline population studies in the year previous to the spill.

Timing of Study -- Late March to mid-May.

Criteria for Initiation -- This study would be conducted if extensive areas in the transition zone or the fast ice zone become contaminated with oil. The determination of whether the oiled area is extensive will depend on the ice zone, the location of the spill, and the relative amount of unoiled seal habitat available.

Government Agency and Contact Persons

Agency: Canadian Wildlife Service
Department of Fisheries and Environment
10025 Jasper Avenue
Edmonton, Alberta
Telephone: (403) 425-6860

Contact: Dr. Dennis Surrendi, Acting Director

Research Scientist: Dr. Ian Stirling.

Personnel Requirements -- Two experienced polar bear survey biologists would be required to conduct the surveys, to analyze the data, and to prepare the report. These people should be accompanied by a native assistant familiar with survival and travel on ice.

Equipment Requirements -- The equipment required (tranquilizer guns, tape recorders, winter survival gear, etc.) is already available.

Logistic Support -- 80 hr of helicopter (Bell 206)

- accommodation for approximately two months at Tuktoyaktuk (3 people)
- Air fare: Edmonton-Tuktoyaktuk return (2)
- Fuel caches at Komakuk and Sachs Harbour

Funds Required -- To prepare: None

To implement:	helicopter	26,960
	fuel caches	2,000
	air fare	836
	accommodation	9,900
	native assistant	3,150
TOTAL		42,846

Priority -- Second level.

Relationship to Other Studies -- Results of the studies on Radio Tracking of Oil Under Ice (1C) and Winter Aerial Reconnaissance (1A) are critical to determining the need for this study. The results of the studies on the effects of oil on seals (10A, 10B, 10C) would assist in the interpretation of the results from the study on polar bears.

12. Effects of Oil on Whales

12A. Effects on Whales During Spring

In May and June bowhead and beluga whales migrate eastward into the Beaufort Sea apparently along the network of leads and open water areas that are 200-300 km offshore in the transition zone (M. Fraker, pers. comm.). The destination of these whales during spring is the large open water area that forms in the southeastern Beaufort Sea during May and June. Extensive oil contamination of leads and polynias in the transition zone could delay the annual spring migration of bowheads and belugas into this area, if the animals were to avoid the oil rather than swim through it. The effects on the whales of such a delay are unknown.

Objectives -- To monitor the migration behaviour of beluga and bowhead whales if oil-covered leads and polynias are present along their spring migration route.

Methods -- This study would be combined with the study on the effects of oil on migrating birds. Observations would be made both aerially and from the ice on the reaction of whales to oil-covered leads and on the subsequent movement of the whales and on apparent effects of the oil on the whales that swim through it.

Timing of Study -- May and early June.

Criteria for Initiation -- This study would be implemented only if extensive contamination of the transition zone were to occur along the migration route of the whales.

Government Agency and Contact Person

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Personnel Requirements -- A marine mammalogist would be required to carry out this study; he would accompany the avian biologist and guide. This person would also be required to analyze and summarize the results of the study.

Equipment Requirements

On site in readiness: None

On hand elsewhere: tape recorder, batteries, tapes (probably already available)

Logistic Support -- helicopter support provided by the study of mortality to migrating birds (9A)

- air fares: Montreal-Tuktoyaktuk return (1)
- accommodation for 1 1/2 months (one person)

Funds Required --	To prepare:	None	
	To implement:	air fare	768
		accommodation	2,475
	TOTAL		3,243.

Priority -- Second level.

Relationship to Other Studies -- If implemented as determined by the results of studies 1A and 1C this study would be carried out in conjunction with study 9A on bird mortality during spring migration. If the results of this study indicate effects such as the whales turning back, the study on the calving and fall migration of beluga (12B) will become necessary.

12B. Effects on Whales During Summer

In July and early August, beluga whales move into the warm river waters of Kugmallit Bay and Shallow Bay and remain in these areas until late August. The importance of these areas to belugas is not yet clearly understood (M. Fraker, pers. comm.); calving apparently occurs before the whales actually arrive in these areas. Oil contamination could delay the movement of belugas from the Amundsen Gulf area into the Mackenzie Delta area until the break-up of the ice was almost complete. The significance of such a delay is unknown.

If there is considerable boat traffic associated with the clean-up activities, particularly in shallow coastal waters, this traffic could delay the westward migration of belugas and bowheads out of the Beaufort Sea.

Objectives

1) To determine the effects on the movement of belugas into the Mackenzie Delta area that would result from the blocking of their migration routes by oil contamination.
2) To determine the effects of extensive boat activity on the westward migration of belugas and bowheads out of the Beaufort Sea in late summer and early fall.

Methods -- This study would require that fixed aerial survey routes be flown systematically and that the positions and numbers of all whales sighted be recorded. It would also require information on the distribution of oil and on the activities of boats in the area.

Timing of Study -- Late July to early September.

Criteria for Initiation -- This study would be implemented only if

1) the spring migration of whales were to be delayed by oil blocking their normal migration route, or
2) oil contamination were to occur in the access routes used by belugas to reach the Mackenzie Delta area, or

3) extensive boat activity were to occur across the migration routes used by whales to leave the Beaufort Sea in late summer.

Government Agency and Contact Person

Agency: Arctic Biological Station
Department of Fisheries and Environment
Box 400, Ste. Anne de Bellevue
Quebec H9X 3L6
Telephone: (514) 457-3660

Contact: Dr. A.W. Mansfield, Head

Personnel Requirements -- This study would require an experienced marine mammal survey biologist to conduct the study, analyze the data, and prepare the report.

Equipment Requirements

On site in readiness -- None

On hand elsewhere -- tape recorder, batteries, tapes

Logistic Support -- 150 hr twin-engine fixed-wing aircraft (Cessna 337) with positioning system
- air fare: Montreal-Tuktoyaktuk return (1)
- accommodation for 2 months at Tuktoyaktuk (1 person)

Funds Required -- To prepare: None

To implement:	aircraft	28,800
	air fare	768
	accommodation	3,300
TOTAL		32,868

Priority -- Second level.

Relationship to Other Studies -- The implementation of this study will depend on the results of the Aerial Reconnaissance study (1A) and on the results of the study on spring migration of whales into the Beaufort Sea (12A).

13. Effects of Oil on Human Utilization of Wildlife

Hunting, trapping and fishing are important activities of the native peoples in the Beaufort Sea area. They provide domestic income (from domestic or subsistence use of wildlife), cash income (from commercial uses), and recreation (Brackel 1977). Wildlife that are the focus of these activities include fish, seals, polar bears, whales, arctic fox and (in the Mackenzie Delta) muskrat.

The utilization of wildlife could be affected by an oil spill in the following three ways:

1) A spill could cause a reduction in the availability of wildlife by causing changes in their numbers and/or distributions. This effect would be reflected in a lowered rate of return per unit of effort expended in hunting, trapping or fishing.
2) Clean-up activities could provide alternative employment and thus reduce the level of effort expended in hunting, trapping or fishing.
3) Spilled oil could reduce the usability of wildlife (e.g., tainting of fish, oiling of furbearers).

The effects of an oil spill on the numbers and distributions of animals have been addressed by other studies in this report. The results of these studies will be important to the interpretation of the following study to monitor the effects of a spill on the utilization of wildlife by the inhabitants of affected areas.

Objectives

1) To assess the effect of a spill on the level of effort expended in hunting, trapping and fishing and on the rate of return per unit of effort.
2) To assess the effect of a spill on the usability of wildlife resources.

Methods -- The methods that would be employed in a study such as this have not been defined and would probably vary considerably depending on the size, location, and timing of a spill and on the extent of available baseline information. Accordingly, no attempt has been made to define personnel, equipment, logistical, and funding requirements.

Timing of Study -- This study would be carried out for the duration of the spill and would probably be continued on a longer-term basis.

Criteria for Initiation -- Any large spill.

Government Agency and Contact Person

Agency: Environmental Management Section
Fish and Wildlife Service
N.W.T. Government
Yellowknife, N.W.T.
Telephone: (403) 873-7411

Contact: Dr. N. Simmons

and

Agency: Pipeline Co-ordination Division
Northern Economic Planning Branch
Department of Indian and Northern Affairs
400 Laurier Ave., W.
Ottawa K1A 0H4
Telephone: (613) 992-2998

Contact: Mr. D. Bissett

Priority -- Second level

Relationship to Other Studies -- The interpretation of this study will be greatly assisted by the results of nearly all the biological studies and particularly by studies 10A, 10B, 10C, 11, 12A and 12B.

SUMMARY OF SCIENTIFIC STUDIES

This report delineates 30 scientific studies that would possibly be conducted in the event of an oil spill in the Beaufort Sea. These studies have been outlined for the purpose of monitoring the oil spill and its impact. Fifteen of the studies are concerned with determining the behaviour and fate of the spilled oil; fifteen are concerned with determining the immediate biological impact of the oil. In addition to determining the immediate fate or impact of the oil, some of the studies collect baseline information that would be invaluable for monitoring the long-term impact or fate of the spilled oil. The knowledge gained from conducting these studies would greatly increase our understanding and hence predictive capabilities concerning oil in Arctic marine environments.

Table 1 lists the 30 studies and the priorities for implementation of each of the studies. The priorities have been listed as first, second, third, or fourth level. First level studies are those studies that are prerequisites for the successful implementation of the plan. Second level studies are those studies that will adequately and convincingly measure immediate impacts of the oil spill, that will provide adequate information to improve predictive capabilities with regard to oil spills, or that are critical to long-term studies on the recovery rate of impacted areas. Third level studies are those studies that would assist in improving predictive capabilities or measuring impacts, but that would probably be severely limited in the amount of data that could be collected because of logistical difficulties. Fourth level studies are studies that are useful but less critical than the higher priority studies in meeting the objectives of the plan.

Table 1 also lists the relationships between the studies. Prerequisite studies for a given study are those studies that must be conducted in order to determine the need for the given study. Necessary complementary studies for a given study are those studies that must be conducted in conjunction with the given study to ensure that the results of the given study are meaningful. Optional complementary studies are those studies whose results would assist in, but are not crucial to, the interpretation of the results of the

TABLE 1. Priorities of Studies and Relationships Between Studies.

STUDY	PRIORITY LEVEL	PREREQUISITE STUDIES[1]	NECESSARY COMPLEMENTARY STUDIES[2]	OPTIONAL COMPLEMENTARY STUDIES[3]	DEPENDENT STUDIES[4]	PRE-SPILL STUDIES REQUIRED	LONG-TERM STUDIES REQUIRED
1. Monitoring the Movement of Oil							
A. Aerial Reconnaissance	1	-	1B	2A	*	-	-
B. Radio Tracking of Surface Oil	1	-	1A	2A	1A,2A,4C,4D,4E	-	-
C. Radio Tracking of Oil Under Ice	1	-	-	1A,2C,2D	†	-	-
D. Satellite Reconnaissance	-						
2. Factors Affecting Movement of Oil							
A. Effects of Surface Currents and Wind	2	-	1A,1B	-	1A,1B,4C	Desirable	-
B. Effects of Subsurface Currents	3	-	1A,4A	-	4A,8	-	-
C. Effects of Under-Ice Currents	3	-	1C,2D,4A	-	1C,2D,4A,7,8,	-	-
D. Effects of Under-Ice Topography	2	1A	1C,2C	-	1C,2C,7,9A,10B	-	-
3. Monitoring of the Blowout Plume							
A. Measurement of Plume Profile	4	-	-	1A	-	-	-
B. Time Lapse Photographic Record	-						
4. Deposition and Decomposition of Oil							
A. Oil in the Water Column	3	-	2B,2C	1A,1C,4C,4D	2B,2C,4C,4D,4E,7,8	-	-
B. Oil in the Coastal Zone	2	1A	-	4D,4E	4C,4D,6,9B,9D	-	Necessary
C. Oil in Sediment-Laden Waters	3	1A	4B	1B,2A,4A	4A,6	-	Necessary
D. Chemical Weathering of Oil	2	-	1A,1B,1C	4A,4B,4E	4A,4B,4E,6,7	-	-
E. Microbial Decomposition of Oil	2	-	1A,1B	4A,4D	4B,4D,6	-	Necessary
5. Toxicity of Spilled Oil	2	-	-	-	6,7,8	Desirable	-
6. Effects of Oil on Coastal Ecosystems	2	1A	4B	4C,4D,4E,5	8,9B,13	-	Necessary
7. Effects on Under-Ice Flora and Fauna	2	1C	2D	2C,4A,4D,5	8,13	-	-
8. Effects on Plankton and Fish Populations	3	1A,1C	2B,2C,4A,5	6,7	13	-	Possible
9. Effects of Oil on Water Birds							
A. Mortality During Spring Migration	2	1A,1C	2D	-	13	-	-
B. Mortality to Moulting Sea Ducks	2	1A		4B,6	13	-	-
C. Mortality in Offshore Open Waters	4	1A	-	-	13	-	-
D. Effects of Storm Surges on Birds	2	1A	4B	-	13	-	Possible
10. Effects of Oil on Seals							
A. Spring Distribution and Numbers	2	1A,1C		10C,11	10C,11,13	Necessary	Possible
B. Effects in the Fast Ice Zone	2	1A	2D	11	11,13	-	-
C. Effects in the Transition Zone	3	1A,1C	-	10A,11	10A,11,13	-	-
11. Effects of Oil on Polar Bears	2	1A,1C	-	10A,10B,10C	10A,10B,10C,13	Necessary	Possible
12. Effects of Oil on Whales							
A. Effects on Whales During Spring	2	1A,1C	-	-	12B,13	-	-
B. Effects on Whales During Summer	2	1A,12A	-	-	13	-	-
13. Effects on Human Utilization of Wildlife	2	-	10A,10B,10C, 11,12A,12B	6,7,8,9A, 9B,9C,9D	-	-	Possible

[1]Studies that must be conducted to determine the need for the given study.

[2]Studies that must be conducted in conjunction with the given study to ensure meaningful results.

[3]Studies whose results would assist in (but are not critical to) the interpretation of the results of the given study.

[4]Studies that depend on or would be assisted by the results of the given study.

*1B,1C,2A,2B,2D,3A,4A,4B,4C,4D,4E,6,8,9A,9B,9C,9D,10A,10B,10C,11,12A,12B.

†2C,2D,4A,4D,7,8,9A,10A,10C,11,12A.

given study. Dependent studies are those studies that depend on or would be assisted by the results of the given study. From these relationships it is possible to see which studies must be implemented before a given study is considered for implementation and also which studies would be affected if a given study is not to be implemented.

Table 1 also lists the studies for which pre-spill studies are desirable or necessary. The pre-spill studies that are desirable are those that would help in the planning of countermeasure activities. The studies for which pre-spill studies are considered necessary are those studies that should only be implemented provided a pre-spill study was conducted during the year prior to the spill. Table 1 also lists those studies that it is necessary or possible to conduct on a long-term basis in order to monitor the long-term impact or fate of the oil.

Table 2 gives the timing during which each of the studies would operate. It also lists the major logistical requirements for each study. Table 3 lists the types of oil spill conditions under which each of the studies would operate. The information from Tables 2 and 3 should help to determine under what conditions each program would be implemented and how each program might be co-ordinated with other programs to facilitate the sharing of the limited logistical support that will be available.

Table 4 lists the funding necessary to prepare and to implement each of the studies. Funds necessary to prepare a study are those expenditures that should be made prior to any oil spill if the given study will potentially be implemented in the event of an oil spill. Costs are very difficult to estimate realistically because many factors cannot be determined until the conditions of the oil spill are known. The costs of a given study as listed in Table 4 may consequently be under or over the actual costs that will be required if the study is implemented.

With a few exceptions, the studies have each been presented as a separate unit with separate logistical and funding requirements. This has been done so that each study could be evaluated separately. Some of the studies could be conducted co-operatively, sharing logistical support and personnel requirements (particularly technicians and assistants). Considerable savings could be instituted by organizing the studies to be as co-operative as is

TABLE 2. Timing[1] and Major Logistical Requirements of Scientific Studies.

STUDY NUMBER[2]	DEEP WATER VESSEL	NEARSHORE VESSEL	FIXED-WING AIRCRAFT	HELICOPTER	CCRS AIRCRAFT	TIMING (JLY AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN)
1A			x	x	x	JLY–OCT --Reduced Intensity-- NOV–APR; MAY–JUN
1B			x			JLY–OCT
1C				x		NOV–JUN
1D						JLY–JUN
2A			x			JLY–OCT
2B	x					JLY–OCT
2C				x		NOV; FEB–MAY
2D					x	MAY–JUN
3A	x					JLY–OCT; DEC–MAY
3B						N/A[3]
4A	x			x		JLY–OCT; NOV; FEB–MAY
4B		x		x	x	JLY–OCT
4C		x				JLY–SEP
4D	x			x		JLY–JUN
4E	x	x		x		JLY–OCT
5						N/A
6				x		JLY–OCT -----Reduced Intensity----- NOV–JUN
7				x		MAR–MAY
8	x			x		JLY–OCT; MAR–MAY
9A				x		MAY–JUN
9B			x	x		JLY–AUG
9C			x			JLY–AUG
9D				x		JLY–AUG
10A			x			JUN
10B				x		MAR–MAY
10C				x		MAR–APR
11				x		MAR–MAY
12A				x		MAY–JUN
12B			x			JLY–AUG
13						JLY–JUN

[1]Assuming open-water period mid-July to late October, ice cover mid-November to end of June.

[2]See Table 1 for study names.

[3]N/A not applicable.

TABLE 3. Oil Spill Conditions[1] Necessary for the Implementation of the Studies.

STUDY	OPEN WATER			ICE COVER	
	OFFSHORE	RIVER PLUME	ONSHORE	TRANSITION	FAST ICE
1. Monitoring the Movement of Oil					
A. Aerial Reconnaissance	A	A	A	A	A
B. Radio Tracking of Surface Oil	A	A	A		
C. Radio Tracking of Oil Under Ice				A	A[2]
D. Satellite Reconnaissance					
2. Factors Affecting Movement of Oil					
A. Effects of Surface Currents and Wind	A	A			
B. Effects of Subsurface Currents	L	L			
C. Effects of Under-Ice Currents				L	L
D. Effects of Under-Ice Topography				L	L
3. Monitoring of the Blowout Plume					
A. Measurement of Plume Profile	L[3]	L[3]		L[3]	L[3]
B. Time Lapse Photographic Record					
4. Deposition and Decomposition of Oil					
A. Oil in the Water Column	L	L		L	L
B. Oil in the Coastal Zone			A		
C. Oil in Sediment-Laden Waters		A			
D. Chemical Weathering of Oil	A	A	A	A	A
E. Microbial Decomposition of Oil	A	A	A		
5. Toxicity of Spilled Oil	L	L	L	L	L
6. Effects of Oil on Coastal Ecosystems			L		
7. Effects on Under-Ice Flora and Fauna				L	L
8. Effects on Plankton and Fish Populations	L			L	L
9. Effects of Oil on Water Birds					
A. Mortality During Spring Migration				A	A
B. Mortality of Moulting Sea Ducks			A		
C. Mortality in Offshore Open Waters	L				
D. Effects of Storm Surges on Birds			L[4]		
10. Effects of Oil on Seals					
A. Spring Distribution and Numbers				L	L
B. Effects in the Fast Ice Zone					L
C. Effects in the Transition Zone				L	
11. Effects of Oil on Polar Bears				L	L
12. Effects of Oil on Whales					
A. Effects on Whales During Spring				L	
B. Effects on Whales During Summer		L			
13. Effects on Human Utilization of Wildlife	L	L	L	L	L

[1]A - any spill for which the response plan is to be implemented.
L - large spill

[2]optional

[3]blowout only

[4]storm surge inland

TABLE 4. Funds Required to Prepare and Implement Scientific Studies.

PRIORITY		STUDY	FUNDS REQUIRED TO PREPARE	FUNDS REQUIRED TO IMPLEMENT
1	1A	Aerial Reconnaissance	$ 4,003	$208,358
	1B	Radio Tracking of Surface Oil	23,450	
	1C	Radio Tracking of Oil Under Ice	45,250	375
	TOTAL		$72,703	$208,733
2	2A	Effects of Surface Currents and Winds	$11,000	$ 11,005
	2D	Effects of Under-Ice Topography		6,600*
	4B	Oil in the Coastal Zone	700	34,048
	4D	Chemical Weathering of Oil	2,700	17,945
	4E	Microbial Decomposition of Oil		5,518
	5	Toxicity of Spilled Oil	7,000	17,200
	6	Effects of Oil on Coastal Ecosystems	27,550	71,673
	7	Effects of Oil on Under-Ice Flora and Fauna	29,735	45,743
	9A	Bird Mortality During Spring Migration	1,600	50,936
	9B	Mortality to Moulting Sea Ducks		19,142
	9D	Effects of Storm Surges on Birds		6,243
	10A	Spring Distribution and Numbers of Birds		21,925
	10B	Effects on Seals in the Fast Ice Zone		43,876
	11	Effects of Oil on Polar Bears		42,846
	12A	Effects on Whales During Spring		3,243
	12B	Effects on Whales During Summer		32,868
	13	Effects on Human Utilization of Wildlife		†
	TOTAL		$80,285	$430,811
3	2B	Effects of Subsurface Currents		$ 9,340
	2C	Effects of Under-Ice Currents		25,910
	4A	Oil in the Water Column	$ 8,500	41,600
	4C	Oil in Sediment-Laden Waters	500	12,888
	8	Effects of Oil on Plankton and Fish Populations		7,554
	10C	Effects on Seals in the Transition Zone		54,316
	TOTAL		$ 9,000	$151,608
4	3A	Measurement of Plume Profile		$ 13,328
	9C	Mortality of Birds in Offshore Open Waters		20,617
	TOTAL			$ 33,945

*Plus costs of CCRS aircraft.

†Cost estimate not made.

feasible. It may also be possible to share some logistical arrangements with the countermeasure activities and hence institute further savings.

ESTABLISHMENT OF A FUNCTIONAL SCIENTIFIC RESPONSE PLAN

The second phase in the development of a functional oil spill scientific response plan for the Beaufort Sea can only be carried out once the present study has been completed. This phase will lead to a functional response plan and will include the following tasks:

1) the identification of a scientific co-ordinator (and an alternate) for the plan;
2) the decisions as to which of the studies described in this report will be incorporated into the scientific response plan;
3) the decisions as to which of the studies in the scientific response plan will share logistical or personnel requirements;
4) the formal assignment of responsibilities for various studies to specific government agencies and persons, or to other institutions;
5) the designation or purchase of the scientific equipment that is required to be in readiness;
6) the establishment of procedures for the expenditure of funds that will be required to implement the studies; and,
7) the merging of the scientific response plan with the countermeasures plan.

None of the above tasks was a part of the present contracted study. These tasks can only be carried out by government personnel. The present study has, however, identified government agencies and, where possible, individuals that would most logically be responsible for the various scientific studies.

In terms of the scientific response to an oil spill in the Beaufort Sea, it is crucial that a scientific co-ordinator be designated to be responsible for the scientific response plan. He would be responsible for the establishment of the functional plan and the maintenance of the plan in a state of current readiness. He should maintain a current knowledge of the type and scope of all scientific studies routinely being carried out in the Beaufort Sea area in order that these studies could be incorporated wherever appropriate into the scientific response plan in the event of an oil spill.

During an oil spill, the scientific co-ordinator would be responsible for determining if and when scientific studies are required, determining whether the necessary logistic support for required studies is available (in collaboration with the On-Scene-Co-ordinator [OSC]), and mobilizing scientists responsible for the implementation of those studies that are necessary and feasible.

To be effective, the scientific co-ordinator should be a member of the government observation team that would work with industry during smaller spills; in a national or international emergency this person should be a member of the government response team and should work at the OSC headquarters.

Without a scientific co-ordinator most of the benefits that could be obtained from a scientific response plan will be lost.

GUIDELINES FOR THE CONDUCT OF SCIENTIFIC STUDIES

In the event of a major oil spill in the Beaufort Sea, considerable public attention will be focused on the area and a major influx of people into the area will occur. The potential for serious accidents will be high because of the frenzy of activity and the presence of new people in the area. Logistical support will be in short supply. In order to retain a reasonable semblance of order during a major oil spill in the Beaufort Sea and in order to ensure that studies attain the goals of the scientific response plan it is recommended that scientific studies adhere fairly rigidly to the following guidelines:

1) oil spill countermeasures should have first priority unless specific instructions to the contrary are received from the scientific co-ordinator;
2) for safety reasons, all scientists conducting winter studies in offshore areas should be accompanied by a native assistant who is familiar with survival and travel on the ice;
3) wherever possible, studies should be conducted by investigators who have had considerable previous experience in the Beaufort Sea area;
4) wherever possible, studies should use methods similar or comparable to those used during the Beaufort Sea project; and,
5) scientific studies should adhere to the guidelines developed by the Advisory Committee on Northern Development and contained in the government publication <u>Guidelines for Scientific Activities in Northern Canada</u> (Appendix 4).

LITERATURE CITED

Barry, T.W. 1968. Observations on natural mortality and native use of eider ducks along the Beaufort Sea coast. Can. Field-Nat. 82:140-144.

Barry, T.W. 1970. Likely effects of oil in the Canadian Arctic. Mar. Poll. Bull. 1:73-74.

Brackel, W.D. 1977. Socio-economic importance of marine wildlife utilization. Beaufort Sea Technical Report No. 32. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 91 p.

Bunch, J.N., and R.C. Harland. 1976. Biodegradation of crude petroleum by the indigenous microbial flora of the Beaufort Sea. Beaufort Sea Technical Report No. 10. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 52 p.

Elson, B.M. 1975. Seasat faces multiple sensor challenges. Aviation and Space Technology (December 8):42-47.

Gower, J.F.R. 1975. Uses of aircraft and balloon photography in studying coastal areas. Pacific Marine Science Report 75-8. Institute of Ocean Sciences, Victoria, B.C. Unpublished Ms. 17 p.

Hay, K.G. (ed.). 1976. Guidelines for assessing environmental impact of oil spills. Deliberations of Montauk Workshop, February, 1976. Unpublished Ms.

Herlinveaux, R.H., and B.R. de Lange Boom. 1975. Physical oceanography of the southeastern Beaufort Sea. Beaufort Sea Technical Report No. 18. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 97 p.

Kolpack, R.L. (ed.). 1971. Physical, chemical and geological studies. Volume II. *In*: Biological and Oceanographic Survey of the Santa Barbara Channel Oil Spill 1969--1970. Allan Hancock Foundation, University of Southern California.

La Roche, G., R. Eisler, and C.M. Tarzwell. 1970. Bioassay procedures for oil and oil dispersant toxicity evaluation. Journal Water Pollution Control Fed., Washington, D.C. 42(11):1982-1989.

Logan, W.J., D.E. Thornton, and S.L. Ross. 1976. A review of oil spill countermeasures. Beaufort Sea Technical Report No. 31. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C.

MacNeill, M.R., and J.F. Garrett. 1975. Open water surface currents. Beaufort Sea Technical Report No. 17. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 113 p.

Mattson, J.S., and E.I. Chan. 1976. Report on NOAA-USCG oil spill trajectory effort at Key Largo, Florida, 20-22 May 1976. Environmental Data Service, National Oceanic and Atmospheric Administration, 3300 Whitehaven Street N.W., Washington, D.C. Unpublished Ms.

Milne, A.R., and B.D. Smiley. 1976. Offshore drilling for oil in the Beaufort Sea: a preliminary environmental assessment. Beaufort Sea Technical Report No. 39. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 43 p.

NORCOR Engineering and Research Ltd. 1975. The interaction of crude oil with Arctic sea ice. Beaufort Sea Technical Report No. 27. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 145 p.

O'Rourke, C. 1977. Oil spill clean-up in the Beaufort Sea. Spill Technology Newsletter 1(6):12-36.

Percy, J.A., and T.C. Mullin. 1975. Effects of crude oils on Arctic marine invertebrates. Beaufort Sea Technical Report No. 11. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 167 p.

Richardson, W.J., M.R. Morrell, and S.R. Johnson. 1975. Bird migration along the Beaufort Sea coast: Radar and visual observations in 1975. Beaufort Sea Technical Report No. 3c. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 131 p.

Scott, B.F. 1975. Investigations of the weathering of a selected crude oil in a cold environment, p. 514-525. *In*: Water Quality Parameters. ASTM STP 573. American Society for Testing and Materials, Philadelphia, Pa.

Searing, G.F., E. Kuyt, W.J. Richardson, and T.W. Barry. 1975. Seabirds of the southeastern Beaufort Sea: aircraft and ground observations in 1972 and 1974. Beaufort Sea Technical Report No. 3b. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 257 p.

Smith, T.G., and J.R. Geraci. 1975. Effect of contact and ingestion of crude oil on ringed seals. Beaufort Sea Technical Report No. 5. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 66 p.

Stirling, I., D.Andriashek, P. Latour, and W. Calvert. 1975a. Distribution and abundance of polar bears in the eastern Beaufort Sea. Beaufort Sea Technical Report No. 2. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 59 p.

Stirling, I., R. Archibald, and D. DeMaster. 1975b. Distribution and abundance of seals in the eastern Beaufort Sea. Beaufort Sea Technical Report No. 1. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 58 p.

Topham, D.R. 1975. Hydrodynamics of an oilwell blowout. Beaufort Sea Technical Report No. 33. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 52 p.

Wong, C.S., W.J. Cretney, R.W. Macdonald and P. Christensen. 1976. Hydrocarbon levels in the marine environment of the southern Beaufort Sea. Beaufort Sea Technical Report No. 38. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 113 p.

A P P E N D I C E S

APPENDIX 1. Major Support Facilities and Equipment That Would Probably Be Available for Use in the Beaufort Sea Area.

Inuvik Research Laboratory, Inuvik

Facilities: laboratory space and various equipment;

accommodation not available but such facilities may be added in 1977.

Contact: Dr. C.P. Lewis
Inuvik Research Laboratory
Inuvik, N.W.T.

Telephone (403) 979-3838

Polar Continental Shelf Project, Tuktoyaktuk

Facilities: accommodation for up to 60 people ($30/day);

3200 ft gravel air strip;

well-equipped garage for mechanical repairs;

radio-communication facilities;

22 ft inboard-outboard with 160 hp engine;

several inflatable rubber rafts.

Contact: Mr. George Hobson
Science Technology Branch
Energy Mines and Resources
Ottawa, Ontario

Telephone (613) 996-3388

Vessels

This is probably the one type of logistic support that will not be readily available for scientific studies. There are at least two government vessels that will be or could be present in the Beaufort Sea over the next few years -- Department of Transport vessel Nahidic and Energy Mines and Resources (EMR) vessel Ross MacKay.

Nahidic -- This vessel is a 200 ft dual draught vessel with a beam of 50 ft. In offshore waters it has a draft of 6 1/2 ft, which is sufficient for operation of this vessel in this area. In the event of an oil spill, however, this vessel will be committed to oil spill countermeasures and is unlikely to be available for scientific studies.

Contact: Mr. H.R. Dubinsky, Area Manager
Department of Transport
Hay River, N.W.T.

Telephone (403) 874-2406

Ross MacKay -- This is a 40 ft scientific observation vessel used for geophysical survey work. It could be available for scientific studies but it is one that would be restricted to use in nearshore waters only (inside the 10m depth contour line). It does not have lab facilities on board for chemical oceanographic work although there would be room for some equipment.

Contact: Mr. L. Collett, Head
Dr. W.J. Scott, Acting Head (in 1977)
Terrain Geophysics Program
Resource Geophysics and Geochemistry Division
Department of Energy Mines and Resources
Ottawa, Ontario

Telephone (613) 593-6780

Charter Aircraft

An in-depth description of aircraft and facilities available in the Beaufort Sea area was published by Canadian Petroleum in September 1976. This description has been reproduced and attached at the end of this appendix for the convenience of the reader.

CCRS Aircraft

Canada Centre for Remote Sensing presently has a fleet of three aircraft that contain equipment that would be particularly useful during an oil spill. Moreover, a commitment has been made to make these aircraft available immediately in the event of an oil spill.

The aircraft consist of a Falcon jet and two Dakotas. Each of these aircraft have on board standard 9X9 R/C cameras for aerial photography, two-channel IR line scanners, and a closed-circuit video system (B&W). In September 1977, a Convair 580 will be added to the fleet and will contain, in addition to the above types of equipment, a laser flow sensor and a colour closed-circuit video system.

Normal operating costs charged for these aircraft are $1100/hr on a basis of flying time, or in the case when specific areas are being photographed, $18/line mile plus consumables.

Contact: Mr. Ernest McLaren, Head
Airborne Operations Section
Canada Centre for Remote Sensing
Department of Energy Mines and Resources
Ottawa, Ontario.

Telephone (613) 998-3101 office
(613) 737-4199 home

Positioning Systems

VLF/Omega Radio Navigation System

The VLF/Omega navigation system uses as reference a combination of any two or more U.S. Navy-operated very-low-frequency (VLF) communication stations, of which there are eight in the world, and Omega navigation systems signals. The radio signals from these stations are in the very low range (10-24 kHz) and as such have worldwide range. The receiver units used on aircraft contain a minicomputer that utilizes cross-bearings from the VLF stations to pinpoint the exact location of the aircraft in terms of latitude and longitude. The accuracy is apparently within 3/10 mi.

Department of Energy Mines and Resources has one such unit that is installed on Twin Otters chartered for departmental research in the Arctic. Most aircraft charter companys also have these receiver units in some of their aircraft (usually the twin-engine aircraft).

Decca Lambda Navigational System

This system is owned and operated by Energy, Mines and Resources and functions in a similar manner to the system described above. It consists of three transmitting towers that can be set up for any area desired. Receiving units are available off-the-shelf from EMR in Ottawa and can be used on boats, aircraft, and ground vehicles.

During the Beaufort Sea Project these transmitting towers were set up at Herschel Island, Pullen Island, and Atkinson Point. In 1977 this system will be in the Amundsen Gulf area; it will perhaps be in the Beaufort Sea area again in 1978. If the system were required in the Beaufort Sea to support scientific studies, approximately three weeks would be required to dismantle the towers from their current locations and reassemble them in the Beaufort Sea area.

Contact:
(for both types of
positioning systems)

Mr. George Hobson, Director
Polar Continental Shelf Project
Science Technology Branch
Energy, Mines and Resources
Ottawa, Ontario

Telephone (613) 996-3388

Aircraft for the Explorer:

Today, aircraft have replaced the dog-team and canoe as the mainstay of remote air transportation for resource development jobs which require getting crews and equipment in and out quickly over Canada's thousands of miles of mountains, forests, and tundra.

The helicopter, with its potential of dropping loads passengers and cargo into thick bush, muskeg, or mountainside, has made enormous strides in the past couple of decades as the personal "cayuse" of the working geologist and geophysicst.

As well as a means of transportation, the aircraft can also mount such survey tools as cameras, mangetometers, or radar, to overview the enormous stretches of our virgin land still only partially explored.

In surveying the field of remote area transportation, **Canadian Petroleum** has provided an information package intended to be a permanent reference source for everyone involved in organizing exploration, drilling, or development activities in Canada's north.

The two main components of the package are a map showing all known airstrips in the regions of Canada above the Arctic Circle, not only those currently operated by the Ministry of Transport, but the over 100 others developed in the past decade of Arctic exploration mainly by Canada's oil and gas exploration teams.

While not all of these strips are currently usable, they provide a basis for today's northern explorer to see what sites for landing strips have already been developed in what areas, and to relate them, via the latitude and longitude references given, to the areas in which he is interested. He can also tell, from the description of the strip, whether it will be adequate, or what further development it would require, to service the activity he is planning.

He can then contact the original developer of the strip as to its history, present condition, and what arrangements he would need to make for its use.

The second part of the package comprises the tables on the reverse of the map, indicating the actual experience by air charter companies, of the performance of the various aircraft and helicopters composing their fleets.

To compile this information, **Canadian Petroleum** circulated questionaires to companies known to be in the aircraft charter business. The great majority of the companies in this field (some 28) participated in this survey. In all, they represent a combined fleet of 168 fixed wing aircraft, single and multi-engine, and 267 helicopters. A complete listing of participating companies, their equipment is given on page 34.

These operators reported the actual speed, payload, range, and fuel capacities and runway requirements of their wide range of operating aircraft, ranging from four engine Hercules to light reconnaissance aircraft. The data has been organized with an eye to actual use. We differentiate, for instance, between helicopter airspeed with internal load and sling load.

The main value of the tables is that they represent an industry composite of experience with actual aircraft in use, rather than a manufacturers' specification based on prototype tests.

To our knowledge, such a body of information on availabilities and capabilities of aircraft for charter in Canada has never been provided in one place in a simple, easy-to-use format.

The information package has been produced in four page fold - out form, so that you can conveniently detach it either for filing or wall display. We hope it will be of use to you.

It is only the first in a series of reference materials for oil and gas explorers, field operating staff, pipeliners, and processors, which **Canadian Petroleum** will be bringing you from time to time.

H.C.M.

Fixed Wing Data

AIRCRAFT TYPE	NORMAL CRUISE SPEED M.P.H.	MAXIMUM PAYLOAD 100 MILE MISSION (200 mi. ret.)	MAXIMUM PAYLOAD 500 MILE MISSION (1000 mi. ret.)	MAX. ENDURANCE HOURS	PASS SEATS	FUEL ** IMP. GALLONS CAPACITY	FUEL ** IMP. GALLONS CONSUMPTION	MINIMUM RUNWAY LENGTH	UNDER CARRIAGE W-Wheels S-Skiis F-Floats	ENGINES T. TURBINE R. RECIP. J-JET
Lockheed Hercules	340	52,000 lbs.	52,000 lbs.	12	N/A	8,000	600 per hr.	5,000'	W	4 T
Lockheed Electra	380	26,000 lbs.	26,000 lbs.	8	70 - 94	5,400	600 per hr.	5,000'	W	4 T
Boeing 727	520	42,500	42,500 lbs.	7	118	6,000	800 per hr.	6,000'	W	3 J
Boeing 737	480	30,000 lbs.	30,000 lbs.	6	117	4,000	600 per hr.	5,000'	W	2 J
Boeing 707	545	70,000 lbs.	63,000 lbs.	15	182	19,864	1,279 per hr.	5,000'	W	4 J
YS-11	260	11,500 lbs.	6,000 lbs.	5	46	1,560	275 per hr.	3,600'	W	2 T
HS 748	260	11,000 lbs.	7,000 lbs	6	48	1,400	230 per hr.	4,000'	W	2 T
F-27	280	11,000 lbs.	7,000 lbs.	5	40	1,100	200 per hr.	4,000'	W	2 T
DC-6	250	26,000 lbs.	17,000 lbs.	14	88	4,600	320 per hr.	5,000'	W	4 R
DC-3	160	7,000 lbs.	4,000 lbs.	7	28	670	85 per hr.	3,500'	WS	2 R
Bristol Freighter	155	10,500 lbs.	5,500 lbs.	11	44	1,172	110 per hr.	3,000	W	2 R
Twin/Otter	165	3000-3800 lbs.	*	4½	17-20	315 - 360	65-75 per hr.	1,200'	WSF	2 T
Single Otter	115	2,300 lbs.		6	10	178	28 per hr.	2,000'	WSF	1 R
Turbo Beaver	140	1,400 lbs.		5	8	155	30 per hr.	1,500'	WSF	1 T
Std. Beaver	120	1,200 lbs.		5	6	115	21 per hr.	1,500'	WSF	1 R
MU-2	300	1,600 lbs.		4½	6	305	66 per hr.	2,800'	W	2 T
Piper Navajo	200	1,200 lbs.	600 lbs.	4	7-8	158	36 per hr.	1,500'	W	2 R
Piper Cheyenne	280	2,400 lbs.	1,200 lbs.	5½	6	320	55 per hr.	2,500'	W	2 T
Piper Aztec	185	1,200 lbs.	600 lbs.	5	5	117	22 per hr.	1,500'	W	2 R
Piper Seneca II	190	900 lbs.		4	6	80	20 per hr.	2,000'	W	2 R
Cessna 402	210	1,700 lbs.	800 lbs.	5½	8-9	175	30 per hr.	2,500'	W	2 R
Cessna 310 L	200	1,100 lbs.	*	4½	5	116	24 per hr.	2,000'	W	2 R
Cessna 337	165	1,100		6	5	133	20 per hr.	2,000'	W	2 R
Cessna 185	150	650 lbs.		4	3	65	15 per hr.	1,000'	WSF	1 R
Travel Air	180	800 lbs.		5	4	85	15 per hr.	2,500'	W	2 R
King Air	265	2,195 lbs.	600 lbs.	5	8	304	60 per hr.	1,500'	W	2 T
Queen Air										
Lear Jet 35	525	3,000 lbs.	2,100 lbs.	6	8	775	120 per hr.	5,000'	W	2 J
DeHavilland 125 1A	360	1,100 lbs.	1,100 lbs.	3½	6	1,025	275 per hr.	5,000'	W	2 J

—* Range under 1000 mi. **Jet & Turbine operators use JP 1 and 4. Piston engines use 100&130 Avgas.

Aircraft Data Charts:

These charts are presented as a general information guide only. The data was compiled from information provided by many aircraft operators in Canada.

There can be a wide variation in different models of the same type of aircraft and those noted do not necessarily coincide with the manufacturer's specification. Compensation for temperature altitude must also be made.

Endurance rather than range in miles has been used because of the great difference that exist if IFR (Instrumental Flight) rather than VRF (Visual Flight) rules are being followed, what weather conditions and alternatives exist.

For detailed information contact the appropriate operator listed.

On aircraft that can be equipped with floats, a reduction of 10% to 15% in cruising speed is averaged.

Helicopter Data

AIRCRAFT TYPE	CRUISE SPEED M.P.H.	GROSS WEIGHT lbs.	OPERATIONAL EMPTY WEIGHT INCLUDES PILOT AND 20 min RESERVE FUEL	MAXIMUM LIFT lbs.	MAXIMUM PAYLOAD 25 mile Mission (50 mi. return)	MAXIMUM PAYLOAD 50 mile Mission (100 mi. return)	PASS SEATS	FUEL IMP. GALLONS ** CAPACITY	FUEL IMP. GALLONS ** CONSUMPTION PER HOUR	ENDURANCE HOURS NO RESERVE	ENGINES T. TURBINE R. RECIP. S. SUPER-charged	HOVERING CEILING Gross Weight ISA IGE	HOVERING CEILING Gross Weight ISA OGE
AEROSPATIALE													
ALOUETTE II	95	3,650	2,300	1,350	1.238	1,100	4	125	31	4	1T	5.000'	2,700'
LAMA	110	5,070	2,640	2,430	2,250	2,080	4	125	45	2.6	1T	9,000'	5,000'
ALOUETTE III	100	4,850	2,800	2,050	1,875	1,700	6	125	45	2.7	1T	7,000'	5,000'
GAZELLE	150	3,970	2,400	1,570	1,470	1,370	4	125	35	3	1T	9,000'	7,000'
PUMA	160	16,300	8,950	7,350	6,950	6,550	20	340/496	140	2.4/3.5	2T	7,500'	6,200'
BELL 206L	130	4,000	2,513	1,487	1,400	1,310	6	81 gal	28 gph	2.6	1T	6,400 ft.	1,200 ft
47G4A	75	2950	2,100	850	770	690	2	46	15	2.8	1R	4,500'	3,000'
47G3B-1/2	75	2,950	2,200	750	670	590	2	46	15	2.8	1RS	8,000	6,000'
47 AJ2	85	2,850	2,150	700	640	580	3	39	15	2.4	1RS		
206B	120	3,350	1,950	1,400	1320	1240	4	62	22	2.5	1T	7,000'	—
204B	110	9,500	5,200	4,000	3,500	3,300	10	200	65-70	2.7	1T	5,000	—
205A	120	10,500	5,770	4,730	4475	4,200	14	180	75-80	2.3	1T	6,500	700
212	125	11,200	6,400	4,800	4,520	4,250	14	180	85-90	2	2T	11,000'	—
214	160	16,000	8,000	8,000	7,630	7,260	15	180	130	1.2	1T	8,400'	SL
BOEING													
105C	140	5,070	3,050	2,020	1,890	1,760	4	127	45	2.8	2T	7,800'	5,000
HILLER													
12E *	80	3,100	1,900	1,000	945	885	2	38	16	2.1	1R	6,000	4,000
FH1100	100	2750	1,870	880	780	680	4	56	19	2.5	1T	8,500'	5,500'
HUGHES 500C	140	2,550	1,320	1,230	1,174	1,118	4	51	20	2.5	1T	—	—
SIKORSKY													
S55T	90	7,200	4,600	2,600	2,400	2,000	11	140	43	3	1T	7,500	5,500'
S58	110	12,700	8,730	3,860	3,800	3,265	14	220	75-80	2.7	1R	32,000	1,000'
S58T	115	13,000	8,000	5,000	4,700	4,400	16	235	85-90	2.3	2T	10,000'	8,000'
S61N	140	19,000	12,600	6,400	6,000	5,650	28-32	535	130	4.1	2T	8,700	3,800'
S61L	140	19,000	11,000	8,000	7,475	7,050	28 - 32	535	130	4.1	2T	—	—
S64E	100	42,000	22,000	20,000	18,500	17,000	—	1,120	335	3	2T	—	—

*higher gross weight possible if sling load check with operators.

Some helicopters have a higher gross weight if load is on the sling. Data on this chart lists the greatest permissable. Exception is Hughes 500C where an additional 450 lbs is approved on sling operation.

Helicopters equipped for IFR (Instrumental Flight) have additional equipment and systems on board reducing the payload. Check with operators of Bell 212, Sikorski S 58T and S 61 series for details.

Use of floats usually increased empty weight and reduces airspeed and on some models reduces the gross weight allowable, e.g. Bell 206.

Payloads over mission distances on chart is calculated at normal cruise speed. Sling load speeds vary between 50 - 90 mph, so payload over the mission distances would be reduced by the extra fuel required for the additional flying time necessary.

This data has been compiled from charter operators in Canada. There are often variations between models of the same machine due to special equipment on board for different operating environments. The figures are averages and do not necessarily coincide with manufacture specification.

Remote area aircraft charter operators

Fixed wing

Co. Name	Address	Operating Base(s)	Region Served	(No.) & Type of A/C Op.
Arctic Air	Box 5570, Stn. L Edmonton, Alta.	Fort Nelson, B.C.	Northwest Canada	(1) DC-3, (2) Aztec PA23, (1) Navajo PA 31, (1) Cessna 185. Total: 5
Athabasca Airways	Box 100, Prince Albert Sask.	Prince Albert, Lac La Ronge, Buffalo Narrows, Sask.	Northern Sask. Northern Man. NWT	Twin Otters, Single Otters, DHC Beavers. Total: 26
Chinook Air	Hangar 57, Calgary Int'l Airport	Calgary	Northern Canada	(2) Piper Aztec, (1) Beech B90 (1) Learjet 35 (1) DeHavilland 125. Total: 5
Contact Airways	Box 5175, For McMurray, Alta.	Fort McMurray, Alta.	Northern & Central Canada	(3) C-185, (3) Aztec, (1) Navajo, (1) Dornier, (1) C-337, (1) DC-3. Total: 10
Gateway Aviation	Municipal Airport, Edmonton	Calgary, Edmonton, Norman Wells, NWT, Inuvik, Fort Smith, Yellowknife.	Western & Arctic Canada	(1) Cessna 185, (1) DH Beaver, (1) Aztec, (X) DH Otter, TWIN Total: 20, DC3, HS748
International Jet Air (NW Div)	PO Box 380, Stn. B., Calgary, Alt.	Calgary, Edmonton	Western Canada and NWT	(1) Lockheed Electra L-188
Ken Borek Air Ltd.	1249 - 38th Ave N.E. Calgary, Alta.	Resolute Bay, Inuvik, Frobisher Bal (all NWT) & Dawson Creek, B.C.	B.C., Arctic Islands	(6) DHC - 6 Twin Otter, (2) DHC-2 Beaver, (3) DC-3 Douglas, (1) Cessna 150, (1) Cessna 172, (1) Cessna 185. Total: 13
Norcanair	Box 850, Prince Albert, Sask.	Prince Albert, La Ronge, Uranium City, Stony Rapids, Sask.	Prairie Provs. & NWT	Bristol Freighter, F-27, DC-3 Single Otter, Std. Beaver, Piper Aztec, Cessna 185. Total: 30
Nordair	Box 4000, Dorval, Que.	Montreal, Toronto, Frobisher Bay	Arctic & Eastern Canada	(1) DC8 61CF, (6) B737 (3) Lockheed 188 Electras, (3) FH227. Total: 13
Northwest Territorial Airways	Box 9000, Northwest Hanger, Yellowknife, N.W.T.	Yellowknife	Western Canada & NWT	(2) DC-6 A/B. (4) DC-3 Pax-Freighter, (1) DC-3 Executive. Total: 7.
Pacific Western Airlines	9th Floor, Edmonton Inn Tower, Edmonton	Edmonton, Stanstead, England	Canada & Europe	(4) Hercules L100-20, (2) B727, (12) B737, (2) CV640. Total: 20
Transair	Winnipeg Int'l Airport, Winnipeg, Man	Winnipeg, Toronto	Manitoba, NWT, Yukon, NW Ontario (to Toronto)	(1) Boeing 707/351C, (3) Boeing 737/200C, (2) Fokker F-28, (2) Nihon YS-11, (3) DHC Twin Otter, (2) HS Argosy. Total: 16.
Transnorth Turbo Air	Box 4338 Whitehorse, Y.T.	Whitehorse, Mayo, Ross River, Dawson Y.T.	Yukon, NWT, Northern B.C.	(1) DHC6, (1) C402, (1) PA34 200 T, (2) B95, (1) DHC3. (2) Turbo Beaver, (1) DHC2. (1) C185E. Total: 10.
Wardair X Canada	Box 610, Yellowknife, NWT	Yellowknife	Northern Canada	(1) Bristol Freighter, (6) Twin Otter, (1) MU-2. Total: 8.

Helicopters

Co. Name	Address	Operating Base(s)	Region Served	(No.) & Type of A/C Op.
Agro Copter Enterprises	3926 - 4th St. N.W. Calgary, Alberta	Red Deer, Springbank Whitecourt	Alberta, NWT, YUKON B.C.	(3) Hiller 12E (Bell & Hughes machines leased as required).
Alpine Helicopters	Bldg. #13, McCall Field, Calgary	Calgary, Hinton, Alta., Kelowna, Burns Lake, McKenzie, B.C., Norman Wells, NWT	All of Canada	(6) Bell G3B-1, (6) Bell 206B, (2) S55T (1) Bell 204B. Total: 15.
Associated Helicopters	#10 Hangar, Industrial Airport Edmonton, or 309 - 603 - 7th Ave. S.W. Calgary, Alta.	Edmonton, Ft. McMurray, Norman Wells, Inuvik	Western & Northern Canada	Bell 212, Bell 204, Bell 206. Toal: 24.
Athabasca	see under "Fixed Wing" Listing			Bell 206B, S55T, Bel 47. Total: 12.
Canwest Aviation	#4 Hangar, Int'l Airport, Calgary	Calgary & Hay River, NWT	Western & Northern Canada	(3) Allouette III Gazelle
Highland Helicopters	424 Agar Dr. Vancouver Int'l Airport, B.C.	Vancouver, Chetwynd Nelson, Quesnel, Williams Lake, Kamloops Castlegar, Agassiz, B.C.	Western Canada	(3) Bell 206 A, (9) Bell 206 B. Total: 12.
Klondike Helicopters	#3 Hangar, Calgary Int'l Airport, Calgary	Calgary, Resolute Bay, NWT	All of Canada	(2) Bell 205A-1, (2) Sikorsky S-58,)10) Bell 206 B, (2) FH - 1100, (2) Bell G-2. Total: 18.
Nahanni Helicopters	4193-104 St. Delta, B.C.	Vancouver, Fort Simpson NWT	Canada	(2) Bell 205A-1 (1) Hughes 500 C (1) S-58, (1) S-55T. Total: 5
Okanagan Helicopters	493 Agar Dr., Int'l Airport South, Vancouver, B.C.	21 Western Canada bases, five summer bases in north, one eastern base plus 3 subsidiaries*** and bases in Bangkok, Los Angeles, Surinam, and Singapore	Canada and abroad	(81) Bell 206 Jet Ranger, (15) Alouette II, (5) Bell 205A, (7) Bell 212 (IFR) (6) Sikorsky S58T, (1) S-55 (1) S61L (IFR). (4) S61N (IFR). Total: 130.
Shirley Helicopters	#3 Hangar, Municipal Airport Edmonton, Alta.	Edmonton, Inuvik	Canada	(2) Bell46GZ, (2) Bell 47 G3B1. (2) Hiller UH12E (2) Bell 206A, (6) Bell 206B, (5) Gazelle S4341G, (2) Alouette II, (2) Hughes 500C. Total: 23.
Transair	see under "fixed wing" listing			(11) Bell 206
United Helicopters	206-2003 McKnight Blvd. N.E., Calgary	Calgary, Vancouver, Fort Smith, Norman Wells, NWT	Northern & Western Canada	(7) Hughes 500C, (5) Bell 47. Total: 12.
Vancouver Is. Helicopters	Box 2095 Sidney, B.C.	Victoria, Port Hardy, Prince Rupert, Stewart, Terrace, B.C.	B.C. and Yukon Terr.	(6) Bell 206 B, (5) Bell 47. Total: 11.

Landing Strip Co-ordinates

	NAME	LOCATION	ELEV.	RUNWAY HEADING	RUNWAY DIMENSIONS	DEVELOPER
1	ABLE CREEK	73°25'N 120°05'W	433	093-273	5500 x 50	PAN
2	ALERT	82°31'N 62°17'W	95	048-228	5500 x 200	*MOT
3	ALLISON RIVER	75°12'N 99°25'W	680	035-215	5000 x 200	SUN
4	AMAGUK	69°36'30"N 130°58'W	SL	030-210	5000 x 150	ELF
5	APOLLO	75°33'N 111°52'W	607	068-248	7500 x 200	PAN
6	MUND RINGNESS	78°19'N 96°16'30"W	210	176-356	5000 x 150	PAN
7	BAR HARBOUR	74°17'N 123°54'30"W	160	126-306	5000 x 200	PAN
8	BENT HORN	76°19'30"N 104°06'W	100	088-268	5000 x 200	PAN
9	BIG RIVER RIVER	72°24'N 122°35'W	331	127-307	5200 x 200	
10	BORDEN IS.	78°33'N 110°55'W	100	030-210	6000 x 170	PAN
11	BJORNE PENINSULA	77°26'N 85°48'W	45	159-339	5000 x 150	PAN
12	BROCK ISLAND	77°51'N 114°08'W	45	159-339	5050 x 200	PAN
13	BROUGHTEN ISLAND	67°33'N 64°02'W	20	049-229	3500 x 100	*MOT
14	BYRON BAY	68°45'N 109°04'W	302	058-238	4500 x 100	*MOT
15	CAMBRIDGE BAY	69°06'N 105°08'W	90	127-307	5000 x 150	MOT
15	CAPE DYER	66°36'N 61°35'W	1288	020-200	5000 x 150	*MOT
17	CAPE FLEETWOOD	76°32'30"N 103°34'W	10	092-272	5000 x 200	PANARCTIC
18	CAPE HOOPER	66°28'N 66°50'W	68	102-282	3000 x 100	MOT
19	CAPE ISACHSEN	79°17'N 105°18'W	10	166-346	6100 x 250	PAN
20	CAPE NOREM	77°27'N 110°55'W	100	140-320	6600 x 150	ELF
21	CAPE OBRIEN	77°29'N 95°23'W	SL	090-270	5000 x 150	SUN
22	CAPE PARRY	70°10'N 124°42'W	57	037-217	5000 x 150	*MOT
23	CAPE YOUNG	68°56'N 116°56'W	52	126-306	4660 x 150	*MOT
24	CASTEL BAY	74°07'N 120°50'W	494	142-322	5300 x 200	PAN
25	CHAD CREEK	76°26'32"N 109°59'32"W	162	14[illegible]-328	5000 x 200	PAN
26	CLINTON POINT	69°35'N 120°44'W	45	161-341	4500 x 100	*MOT
27	CORNWALLIS	75°09'N 94°45'W	625	256-076	5500 x 150	PAN
28	CROOKED LAKE	72°35'N 98°15'W	200	105-285	5000 x 150	KERR MAGE
29	DEPOT POINT	79°24'N 86°07'W	350	036-216	5000 x 200	PAN
30	DEWAR LAKES	68°37'N 71°07W	504	023-203	4000 x 100	MOT
31	DOME CROCKER	80°06'N 98°57'W	10	154-334	5000 x 200	DOME
32	DOME SUTHERLAND	77°44'30"N 102°11'30"W	100	098-276	5000 x 200	DOME
33	DOME WALLIS	77°53'N 102°22'W	20	012-192	5000 x 200	DOME
34	DRAKE POINT	76°28'N 108°40'W	150	030-210	5000 x 200	PANARCTIC
35	DRAKE THREE	76°23'N 108°16'W	10	115-295	5000 x 200	PANARCTIC
36	DUMBELL	78°27'N 99°56'W	150	175-355	5000 x 200	PAN ARCTIC
37	DUNDAS PENINSULA	74°39'N 113°23'W	789	107-287	5400 x 200	PANARCTIC
38	DYER BAY	76°08'N 121°48'W	80	098-278	6000 x 200	PANARCTIC
39	EAST AMUND	76°19'N 95°10'W	20	143-323 158-336	5300 x 200 5100 x 160	PHEONIX
40	ELDRIGE BAY	75°59'N 109°31'W	20	011-191	5200 x 200	PAN
41	EMERALD ISLAND	76°44'N 113°40'W	17	142-322	5000 x 200	PB OIL & GAS
42	EUREKA	79°59'N 85°49'W	256	108-288	5200 x 200	MOT
43	FOSHEIM	79°39'N 84°47'W	2350	005-185	6000 x 200	PANARCTIC
44	FREEMANS COVE	75°06'N 97°53'W	50	173-353	5300 x 200	SUN
45	GARNIER BAY	73°41'N 90°37'W	1218	080-260	3500 x 100	PANARCTIC
46	GLADMAN POINT	68°40'N 97°48'W	46	138-318	4700 x 100	*MOT
47	GRAHAM ISLAND	77°20'N 90°51'W	80	055-235	5000 x 200	PAN
48	GRIFFEN INLET	72°02'N 91°57'W	780	036-216	6300 x 200	I.O.L.
49	HALFMOON BAY	75°54'N 101°30'W	700	040-220	5000 x 200	PAN
50	HALL BEACH	68°47'N 81°15'W	26	124-304	5000 x 150	*MOT
51	HECLA	76°22'N 110°21'W	10	052-232	5400 x 200	PAN
52	HELICOPTER BAY	78°42'N 100°58'W	140	050-230	5700 x 200	PAN
53	HOLMAN ISLAND	70°44'N 117°40'W	20	105-285	3000 x 150	CO-OP
54	HOODOO RIVER	78°15'N 99°48'W	60	072-252	5000 x 200	I.O.L.
55	INTREPID BAY	76°56'N 116°15'W	238	040-220	5800 x 200	PAN
56	INUVIK	68°16'N 133°29'W	223	040-220	6000 x 150	MOT
57	ISACHSEN	78°47'N 103°33'W	198	048-228	4800 x 150	*MOT
58	JAMESON BAY	76°33'N 116°53'W	40	150-330	5000 x 200	BP OTG
59	JENNY LIND	68°39'N 101°44'W	60	099-279	4500 x 100	*MOT
60	JOHNSON POINT	72°40'N 118°31'W	30	054-234	5500 x 200	ELF
61	KING CHRISTIAN ISLAND	77°45'N 101°02'W	100	009-189	5400 x 150	SUN
62	KING POINT	75°30'N 108°50'W	45	150-330	5800 x 200	TEXACO
63	KIMAKUK	69°36'N 140°11'W	24	090-270	3500 x 100	*MOT
64	KRISTOFFER BAY	78°16'N 102°27'W	SL	042-222	5000 x 200	PAN
65	LADY FRANKLIN	68°29'N 113°13'W	52	089-269	4500 x 100	MOT
66	LONG POINT	76°11'N 112°35'W	79	092-272	6000 x 200	PANARCTIC
67	LONGSTUFF BLUFF	68°50'N 75°17'W	47	142-322	4000 x 100	MOT
68	LOUISE	78°47'N 103°22'W	10	199-019	5800 x 200	PAN
69	MALLOCH DOME	78°13'N 101°03'W	40	171-351	6000 x 200	PAN
70	MACKER INLET	68°21'N 85°45'W	114	072-252	3800 x 100	*MOT
71	MEIGHAN ISLAND	80°02'N 100°00'W	SL	112-292	5000 x 200	PAN
72	MIDDLE FIORD	79°55'N 95°08'W	662	123-303	5500 x 200	DRILL ARCTIC
73	MOKKO FIORD	79°03'N 87°15'W	SL	017-197	8745 x 200	PAN
74	MOULD BAY	76°14'N 119°20'W	40	092-272	5400 x 200	*MOT
75	NANUK	73°05'N 123°23'W	450	105-285	5000 x 150	ELF
76	NICHOLSON PENINSULA	69°57'N 128°54'W	SL	142-322	3550 x 100	MOT
77	NOICE PENINSULA	78°17'N 104°16'W	45	175-355	5100 x 200	PAN ARCTIC
78	OKSE BAY	77°06'N 88°25'W	10	046-226	5000 x 200	PANARCTIC
79	PAT BAY	77°26'N 105°27'W	134	166-346	5000 x 200	PANARCTIC
80	PEDDER	75°34'N 118°52'W	10	132-312	5000 x 200	PANARCTIC
81	PELLY BAY	68°26'N 89°36'W	318	156-336	3500 x 100	MOT
82	PELLY MISSION	68°31'N 89°48'W	100	048-150	5000 x 150	CO-OP
83	POLLUX	79°10'N 104°59'W	175	179-359	5000 x 200	PAN
84	PRINCE OF WALES	73°35'40"N 98°23'W	190 180	132-312 132-312	5200 x 200 5200 x 200	PAN PAN
85	PYM POINT	76°24'N 104°191'W	20	060-240	5000 x 200	PAN
86	RAT STRIP	64°06'18"N 134°30'58"W	25	073-253	7000 x 200	PAN
87	REA POINT	75°22'N 105°44'W	50	153-333	6300 x 200	PANARCTIC
88	RESOLUTE BAY	74°43'N 94°57'W	220	167-347 104-284	6500 x 150 4000 - 150	MOT MOT
89	ROMULUS LAKE	79°52'N 84°34'W	475	172-352	5000 x 200	PAN
90	RUSSELL ISLAND	73°53'N 98°13'W	500	135-315	5000 x 200	SUN OIL
91	SACHS HARBOUR	72°00'N 125°16'W	281	084-264	4000 x 150	MOT
92	SANDY POINT	76°25'N 115°18'W	75	090-270	5000 x 150	PANARCTIC
93	SATELLITE BAY	77°17'N 116°57'W	50	137-317	5200 x 200	BP O.G.
94	SEA OTTER	72°31'N 125°12'W	SL	115-295	5600 x 250	PAN
95	SHADOW "J"	78°58'N 118°45'W	250	165-345	5200 x 200	PAN
96	SHEPHERD BAY	68°46'N 93°25'W	139	027-207	4500 x 100	*MOT
97	SHEPHERD BAY	76°05'N 108°30'W	40	090-270	5000 x 200	PANARCTIC
98	SHINGLE POINT	68°56'N 137°14'W	123	130-310	3780 x 100	*MOT
99	SKY BATTLE BAY	77°14'N 105°06'W	100	100 x 260	5400 x 200	SUNOIL
100	SOUTH AMUND	77°49'N 98°55'W	10	135-315	6000 x 25	PAN
101	SOUTH SABINE	75°25'N 109°59'W	525	148-328	5000 x 200	PAN
102	SPENCE BAY	69°32'N 93°31'W	SL	040-220	5000 x 150	CO-OP
103	THOR ISLAND	78°08'N 103°15'W	170	141-321	5000 x 200	PANARCTIC
104	TUKTOVAKTUK	69°26'N 133°02'W	15	126-306	3522 x 100	MOT
105	TWO CRATERS	70°20'N 92°15'W	SL	042-222	5200 x 200	I.O.L.
106	UPLUK	69°20'N 135°21'W	SL	090-270	5000 x 200	PAN
107	VANIER ISLAND	76°08'N 104°02'W	565	071-251	5300 x 200	BP O.G.
106	VICTORIA	72°44'N 117°20'W	680	015-195	5200 x 200	MURPHY OIL
109	WILKINS STRAIT	77°58'N 111°15'W	60	148-328	5000 x 150	ELF
110	WINTER HARBOUR	74°48'N 110°30'W	75	360-180	1800 x 100	BAWDEN DRILLING
111	WEST AMUND	78°23'N 97°54'W	58	023-283	5000 x 150	PANARCTIC
112	YOUNG BAY	72°36'N 97°06'W	10	023-203	6000 x 200	PAN
113	YOUNG INLET	75°20'N 96°42'W	700	155-335	5400 x 200	SUN
114	ZUES	75°46'30"N 113°37'W	132	095-275	5000 x 200	PAN

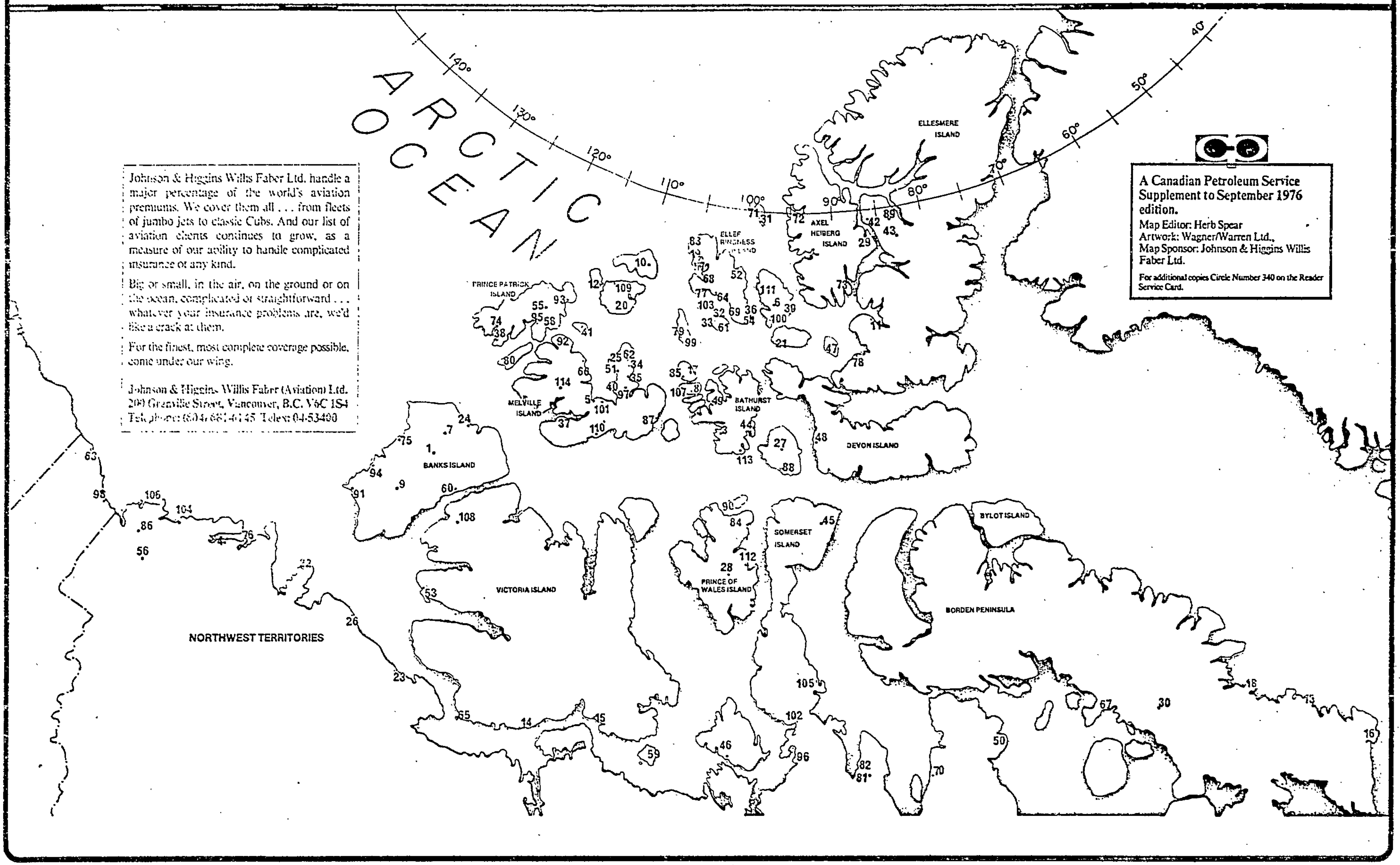
NOTE

There are or have been airstrips at these locations.

This information is a guide only & there is no suggestion that all or any of these are useable without close inspection.

*Prior permission is required from DND - unsupported activities only.

Remote Area Landing Strips in Canada's North



Johnson & Higgins Willis Faber Ltd. handle a major percentage of the world's aviation premiums. We cover them all . . . from fleets of jumbo jets to classic Cubs. And our list of aviation clients continues to grow, as a measure of our ability to handle complicated insurance of any kind.

Big or small, in the air, on the ground or on the ocean, complicated or straightforward . . . whatever your insurance problems are, we'd like a crack at them.

For the finest, most complete coverage possible, come under our wing.

Johnson & Higgins Willis Faber (Aviation) Ltd.
209 Granville Street, Vancouver, B.C. V6C 1S4
Telephone: (604) 681-4145 Telex: 04-53400

A Canadian Petroleum Service Supplement to September 1976 edition.

Map Editor: Herb Spear
Artwork: Wagner/Warren Ltd.,
Map Sponsor: Johnson & Higgins Willis Faber Ltd.

For additional copies Circle Number 340 on the Reader Service Card.

APPENDIX 2. Costing Assumptions Used to Prepare Implementation Costs.

Air Fares	
Edmonton-Tuktoyaktuk return	$ 418.00
Edmonton-Inuvik return	340.00
Montreal-Tuktoyaktuk return	768.00
Montreal-Inuvik return	690.00
Ottawa-Tuktoyaktuk return	756.00
Toronto-Tuktoyaktuk return	748.00
Victoria-Tuktoyaktuk return	560.00
Winnipeg-Tuktoyaktuk return	592.00

Air Charter	Per Hour
Cessna 185	$ 150.00
Cessna 337	192.00
Twin Otter	425.00
Bell 206 (including fuel @ $22/hr)	337.00
Bell 205 (including fuel @ $66/hr)	766.00
CCRS aircraft	1100.00

Accommodation	Per Day
Inuvik and Tuktoyaktuk	$ 55.00
Field subsistence	17.50
Native Assistant	75.00

Vessels

The assumption was made that there would be no costs of vessels charged directly to the scientific response.

APPENDIX 3. Details of The Orion Slick-Tracking Device.

Manufacturer:	Orion Electronics Limited Saulnierville, Nova Scotia Phone: (902) 769-3059	
Size:	10" diameter	
Color:	Fluorescent orange	
Transmission:	Pulsed signal on:	(1) 150.8150 kHz
		(2) 150.8300 kHz
		(3) 150.8450 kHz
		(4) 150.8600 kHz
		(5) 150.8750 kHz
		(6) 150.8900 kHz
Range:	Depending on antenna -- from a boat, 10 miles; from an aircraft, at least 20 miles.	
Deployment:	Dropable from aircraft up to 100 feet	

Adjustable to suit several different oil types

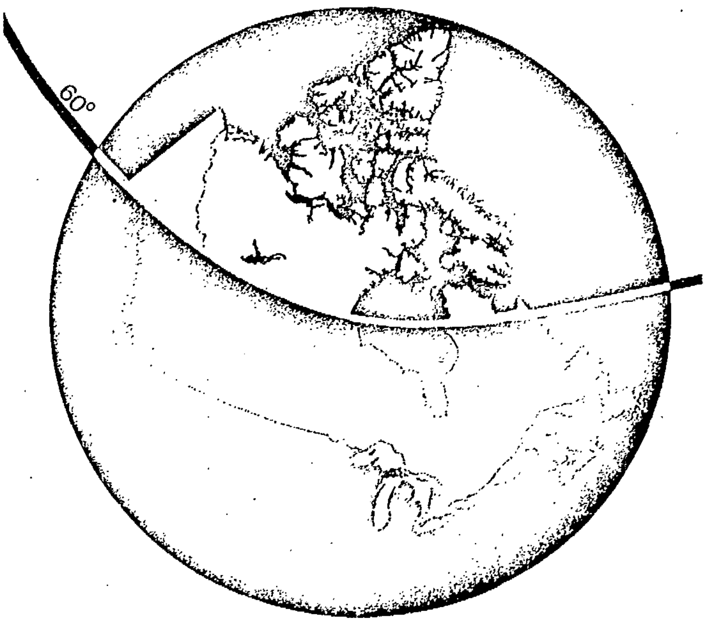
Battery Life:	New units - estimated 2 weeks
Unit cost:	$220 (volume discounts available)
Antenna:	Portable unit for use in aircraft--available June or July 1977--estimated cost $600-700.

APPENDIX 4. Guidelines for Scientific Activities in Northern Canada.

These guidelines have been prepared by the Advisory Committee on Northern Development, Department of Indian and Northern Affairs (Catalogue No. R2-47/1976). The guidelines have been reproduced here for the convenience of the reader.

Advisory Committee
Northern Development

Comité consultatif
mise en valeur du Nord



Guidelines for Scientific Activities in Northern Canada

Introduction

This pamphlet contains Guidelines for Scientific Activities in Northern Canada. These Guidelines were developed by the concerned Federal agencies in the Advisory Committee on Northern Development as a follow-up to a review of federally sponsored northern research conducted in the early 1970's. The need for such guidelines arose from the Government's objectives for northern Canada and the recognized need for a concerted approach in directing research and scientific effort towards acquiring scientific knowledge in support of northern plans and programs. These guidelines receive support of, and are adhered to by, Federal departments and agencies responsible for northern research; they are thus helping to ensure that Canada's limited professional and financial resources are used effectively in support of northern objectives. Moreover, implementation of the Guidelines enhances Canadian participation in international scientific activities in the North.

Your support of the Guidelines is greatly appreciated and adherence to the Guidelines by the scientific community at large will contribute significantly to the achievement of Canada's objectives in the North.

Warren Allmand

Federal government science policy can be considered under three headings; policies for the support of science, policies for the application of scientific and technological resources, and science in public policy. Northern science involves all three of these areas.

Under the heading of support of science are included all those research and data gathering activities that are aimed at the achievement of knowledge of the physical and social environments. Such knowledge is basic to Canada's ability to define and deal with the social and economic needs of the northern residents, to manage northern resources, to determine man's impact on the environment, and to maintain sovereignty and control in the North.

Government application of science in the North can be classified as follows:

1. To contribute to the political, social and economic development, and to support the administration of health and social programs and services.
2. To support the development and administration of regulatory activities in areas such as resources management, maintenance of environmental standards, and arctic waters pollution.
3. To provide science-based support services in resources management and in the transportation, communications and administrative infrastructure.
4. To provide a capability in highly technical areas related to defence and sovereignty.

The term science in policy describes the whole process whereby scientific knowledge and methodology contribute to the development of national strategy. This is of particular importance in relation to the North where a very careful and systematic assessment of development proposals is required to determine impacts and long term effects on the sensitive social and environmental conditions that exist.

Three fields of science dominate the Federal Government's concern in the North: human and social sciences; ecology and geosciences. Scientific activities related to government programs invariably demand an interdisciplinary approach. The sociological aspects of northern science are of particular concern because the government has stated that its primary objective in the North is "to provide for a higher standard of living, quality of life and equality of opportunities for northern residents by methods which are compatible with their own preferences and aspirations".

The following guidelines apply:

1. In conducting scientific activities in the North, the native people must be encouraged to participate to the greatest extent possible. In scientific activities related to the people, this involvement is essential in nearly every case if the research is to be meaningful and of maximum benefit to the northern people. Every effort should be made to provide opportunities for the native people to become involved in research programs and in the uses of science and technology.
2. In research affecting the native people, there should be prior consultation leading to informed agreement, participation in the conduct of the research itself, and feed-back of results to northern communities concerned. It is the inhabitant's perception of his environment that influences his decisions. His perception of the environment therefore, as well as its physical properties, is an important element of research programs.
3. Scientific activities sponsored or supported by Federal or Territorial governments should be treated as tools or services to help in the attainment of the national goals for the North. They are not ends in themselves and can only be justified if they support one or more national objectives.
4. It is essential that in northern science programs of a multidisciplinary nature, all relevant sources of expertise are involved in the planning and implementation phases and in the analysis of results.
5. In accordance with the government policy, scientists from the academic community and industry should be involved to the maximum extent practicable in government sponsored or supported scientific activities. Wherever appropriate, the scientific programs should be carried out "by contract" with universities, non-government scientific institutions, industry, or individuals.
6. Every effort should be made to ensure that the scientific concerns are taken fully into account in the design and phasing of northern programs. Where overriding considerations force the introduction of such programs before adequate scientific assessment is possible, the promoters should be made aware of any known deficiencies in scientific knowledge, and the implications thereof.
7. In the design and implementation of programs, provision should be made for scientific evaluation of progress in relation to objectives, and to assess impacts and effects of program activities in order to undertake any necessary adjustments.
8. To ensure that the lessons of experience and the results of research already completed are recorded and available for use, and to guard against repetition of research, all useful scientific and technical information acquired from programs should be adequately reported and fed into tne appropriate scientific information service.
9. All scientific programs sponsored or supported by the Federal or Territorial governments should be reviewed at regular intervals by the Advisory Committee on Northern Development through the Committee on Science and Technology to ensure that activities remain in keeping with the original purposes of the studies and their objectives. The scientific activities undertaken to meet defined needs must remain the responsibility of the accountable department or agency.

10. The amount of effort which the Federal Government devotes to increasing and broadening its information base in northern science should take into account estimated future demands of northern development. As far as possible, government research in the North should progress at a steady pace rather than on a crash basis in response to crisis demands.
11. The design of Canada's northern observational networks should be the object of careful study, in order that they yield the most useful and general data, especially in relation to variations of site and habitat. Present networks often emphasize cheap operation because of existing settlements and communications rather than good sampling principles.
12. With Canadian sovereignty extending over such a large northern region which contains many features of special scientific interest, it is important that Canada should play a significant role in international arctic research. From the government's point of view, the emphasis should be on programs aimed at the achievement of Canadian objectives; however, there will be occasions when the international scientific community wishes to pursue research projects in Canada which do not rate as priority items for the Federal and Territorial governments. In such cases, Canada not only has some obligation to assist them but may also stand to gain from the contribution made to the pool of international knowledge and the leverage which such co-operative action provides in obtaining reciprocal information of direct value to Canada from other countries.
13. Where the Federal Government initiates international co-operative scientific activities in the Canadian North, the following principles should apply:
a) the Canadian contribution should be defined in terms of Canadian objectives;
b) the leadership in co-ordinating such activities in Canada and their effective control should be provided by Canada;
c) Canada should receive all data and all analytical results.
14. Where the initiative for co-operative international programs comes from other countries and the objectives are not priority items for Canada, the following principles should apply:
a) government logistic support of international scientific programs should not be considered a substitute for scientific involvement;
b) the need for the program and the reason for conducting it in Canada should be stated to the satisfaction of Canadian authorities;
c)there should be Canadian scientific participation in any significant scientific investigation in the Canadian North;
d) non-government sources, primarily universities and scientific institutions, should be invited to participate;
e) Canada should receive all data and all analytical results.

Published under authority of the
Hon. Warren Allmand,
Minister of Indian and Northern Affairs,
Ottawa, 1976.
QS-8126-000-BB-A1

Catalogue No. R2-47/1976

Environment Canada Environnement Canada

CONTRACTOR REPORT SERIES.

GC 1 C45 No.77-2 Scientific studies to be conducted in response to an oil spill in the Beaufort Sea 4007660