ENVIRONMENTAL OVERVIEW BEAUFORT SEA DEVELOPMENT

WORKING DRAFT

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DOME PETROLEUM LIMITED

DOME

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INTRODUCTION

The possible production of hydrocarbons from Dome interest lands in the Beaufort Sea, and their subsequent transportation to southern markets via the Northwest Passage, represents one of the most significant industrial efforts facing Canada in the decade of the 1980's. The proposed development poses not only difficult physical and engineering problems, but tremendous environmental, socio-economic and other challenges as well.

Dome Petroleum Limited recognizes the significance of its role in meeting the challenges, and firmly believes that with the assistance and cooperation of all concerned, the Beaufort Sea hydrocarbon resources can be developed in a timely manner, while affording optimal protection to the environmental and other important values of the region.

In order to initiate and promote early communications between the company, government and the public, Dome has prepared a preliminary overview of future development possibilities under consideration, and has attempted to identify the key environmental issues, possible implications and mitigative measures which may be associated with such a development scenario. This document will serve to introduce

i) the possible nature, magnitude, timing and location of development in the Beaufort Sea.

ii) a broad overview of the major environmental elements comprising the development area.

iii) the currently perceived major environmental issues, possible implications and mitigative measures, and areas which may require further assessment.

This document represents the first step in a many-step program envisaged by Dome which will lead to an acceptable development project. These steps can be divided into a preliminary cycle, a main cycle, and an operational cycle. A cycle consists of a series of steps including concept design, environmental and socio-economic assessments, public and Government discussions, and finally recommendations for mitigative measures to optimize the project benefits which are then fed back to Dome Petroleum for implementation at the completion of each cycle (Figure 1-1).

The approximate duration and activities included within each cycle are summarized in Figure 1-2. It is important to note that the preliminary cycle is really a planning period intended to make use of existing data to develop project concepts and assess key issues before the exploration program determines that a full-scale development project is warranted.

The project status is currently perceived to be in the formative stages of the preliminary impact cycle. This environmental overview will be followed by several more submissions intended to examine in detail the major environmental issues identified herein or developed as a result of continuing discussions with government and the public. Upon completion of the preliminary cycle, the results obtained will be summarized and used in the development of the main cycle program design, which in turn is intended to produce an acceptable system.

BEAUFORT SEA DEVELOPMENT PROJECT

ACTIVITY CYCLE TOWARD ACCEPTABLE DEVELOPMENT

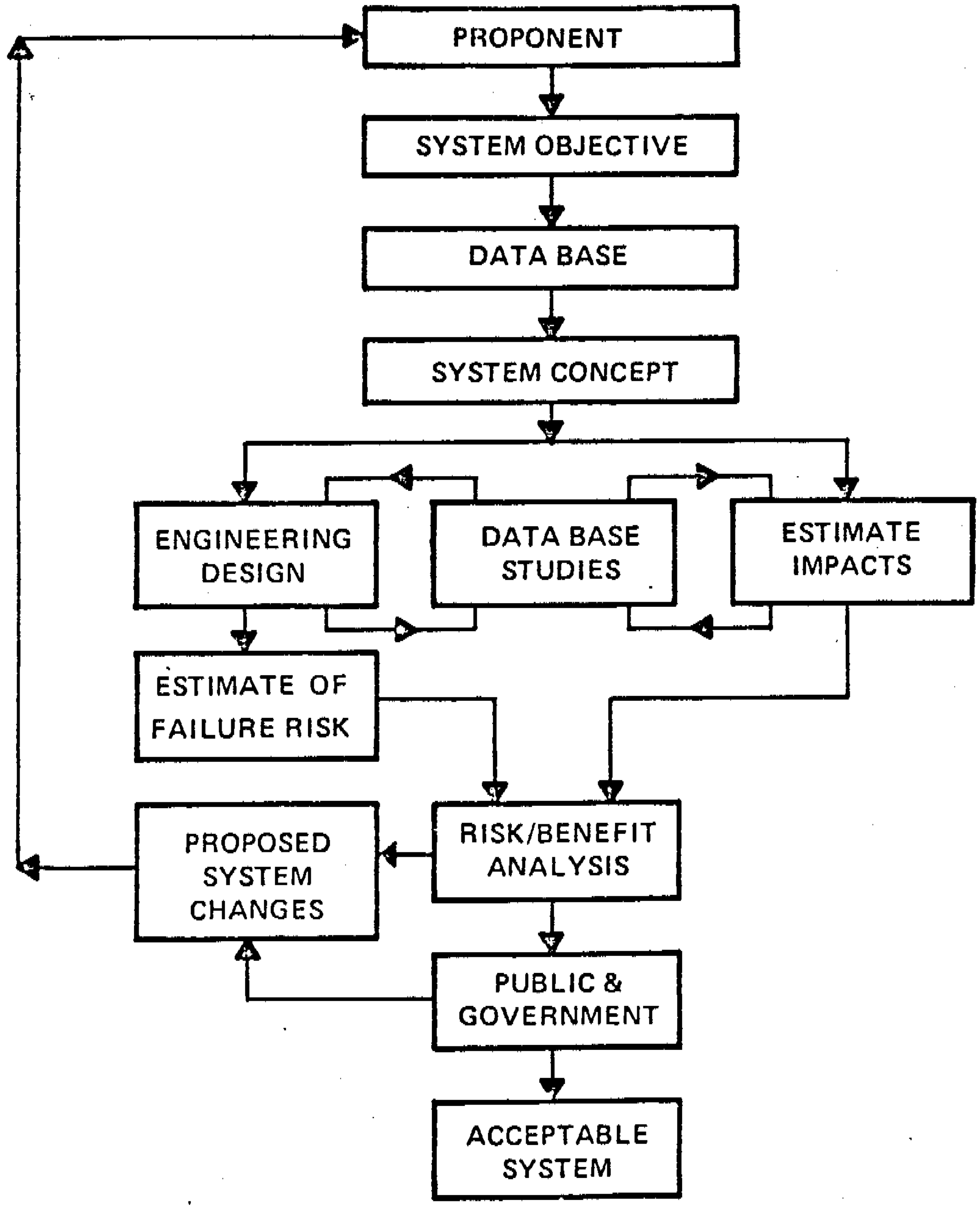


FIGURE 1-1

ACTIVITIES OF DEVELOPMENT CYCLES

CYCLE	APPROXIMATE DURATION	ENVIRONMENTAL IMPACT ACTIVITIES	TECHNICAL ACTIVITIES	DECISION & APPROVAL ACTIVITIES
PRELIMINARY CYCLE	1-2 years	- Review of existing data base - Estimate key environmental issues and impacts - Develop mitigative measures - Design main Environmental Impact Cycle Study	- Develop design Criteria - Develop system concepts	- Project likely but not officially proposed - Informal liaison with public & Government
MAIN CYCLE	4-6 years	- Intensive field programs to fill essential data gaps - Analysis of data to verify and expand upon issues and impacts identified in preliminary cycle - Develop mitigative measures	- Detailed engineering design - Construction and placement of facilities	- Project officially proposed by Dome - Conditional approval of Government at start of main cycle - Formal public and Government liaison programs.
OPERATIONAL CYCLE	15-30 years	- Field program to monitor environmental effects - Continuous development of mitigative measures	- Production - Development of new geological structures	- Final Government approval - Continuous public and Government liaison

FIGURE 1-2

Background

The Mackenzie Delta and Beaufort Sea areas of Canada have all the essential geological attributes for the generation and accumulation of major oil and gas reserves (Figure 1-3). The Geological Survey of Canada has estimated potential reserves of oil and OEG (oil equivalent of gas) for this area totalling 95 billion barrels, as compared to current proven reserves in southern Canada of 18 billion barrels (oil and OEG).

Dome Petroleum Limited has a working interest in approximately nine million gross acres of the offshore Beaufort region. Since the commencement of exploratory offshore drilling in the Beaufort Sea, a total of 16 wells have been drilled by Dome's subsidiary, Canadian Marine Drilling Ltd. (Canmar). Two substantial oil discoveries have been made to date; namely, Nektoralik and Kopanoar. The latter well indicated a flow rate in excess of 12,000 barrels per day of sweet oil from a sand zone in excess of 250 net feet. A step-out well two and one-half miles northwest is currently being drilled on this structure to help determine the size of the reserve. In addition, two gas discoveries have been confirmed so far; namely, Ukalerk and Tingmiark.

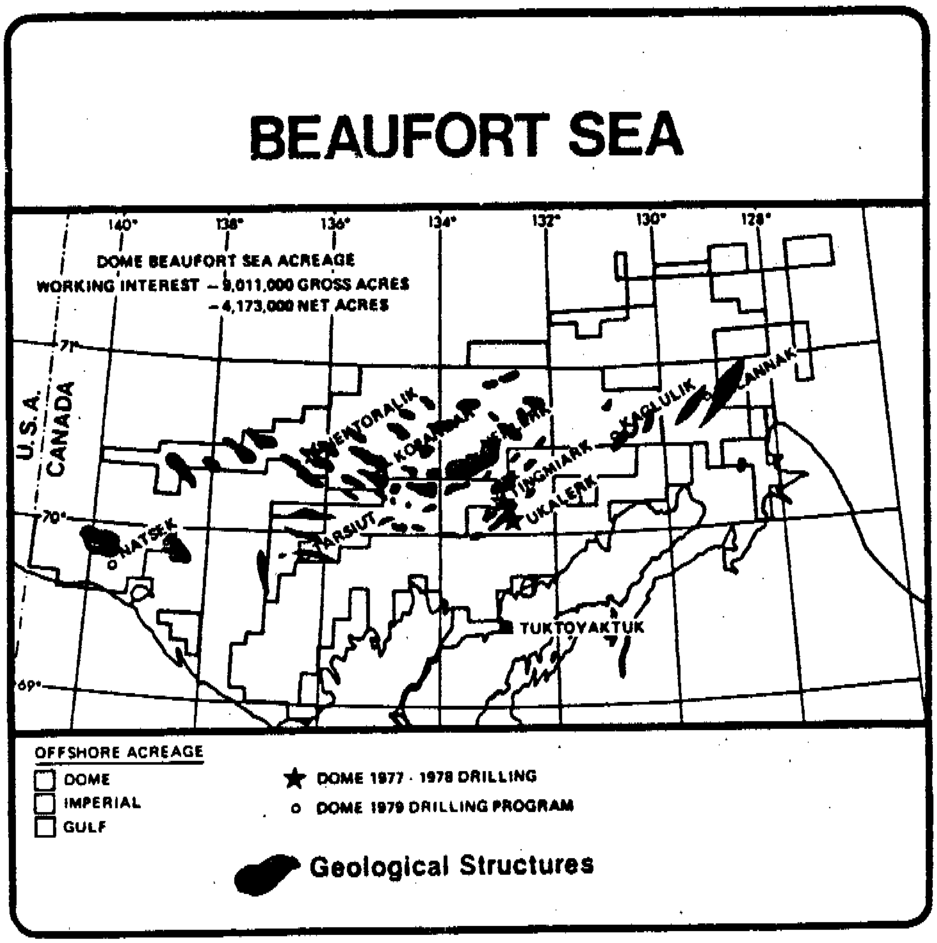

BEAUFORT SEA
DOME BEAUFORT SEA ACREAGE
WORKING INTEREST – 9,011,000 GROSS ACRES
– 4,173,000 NET ACRES
140°
138°
136°
134°
132°
130°
128°
71°
70°
69°
U.S.A.
CANADA
NATSEK
TUKTOYAKTUK
UKALERK
OFFSHORE ACREAGE
DOME
IMPERIAL
GULF
DOME 1977 - 1978 DRILLING
DOME 1979 DRILLING PROGRAM
Geological Structures

FIGURE 1-3

Most recently, with the onset of winter, testing operations were suspended at two new sites, Nerlerk and Tarsiut, with resumption scheduled for the 1980 season.

At Nerlerk, testing of two lower zones recovered non-commercial oil and water with extensive oil-stained reservoir sand sections remaining to be tested. The Nerlerk structure is the largest structure mapped in the Beaufort Sea, and the Company regards the presence of oil in the Nerlerk well as highly significant.

After four years of experience with first generation arctic offshore drilling systems in the Beaufort Sea, and having extended the capability of these systems to a five month drilling season in 1979, the Company can now visualize second generation marine drilling technologies which would permit year round operation. In addition, on the basis of exploratory drilling results to date, the Company is continuing to project the year 1985 as the target date for the initial production and movement of Beaufort oil to southern markets.

Development Need

Petroleum and natural gas continue to supply 45.7% and 18.6% respectively of the total Canadian demands for energy. Despite renewed interest in, and the utilization of alternative energy sources, and the application of conservation measures, etc., the Canadian demand for oil has been forecast by the National Energy Board to increase at a minimum rate of 2.0% into the foreseeable future (Figure 1-4).

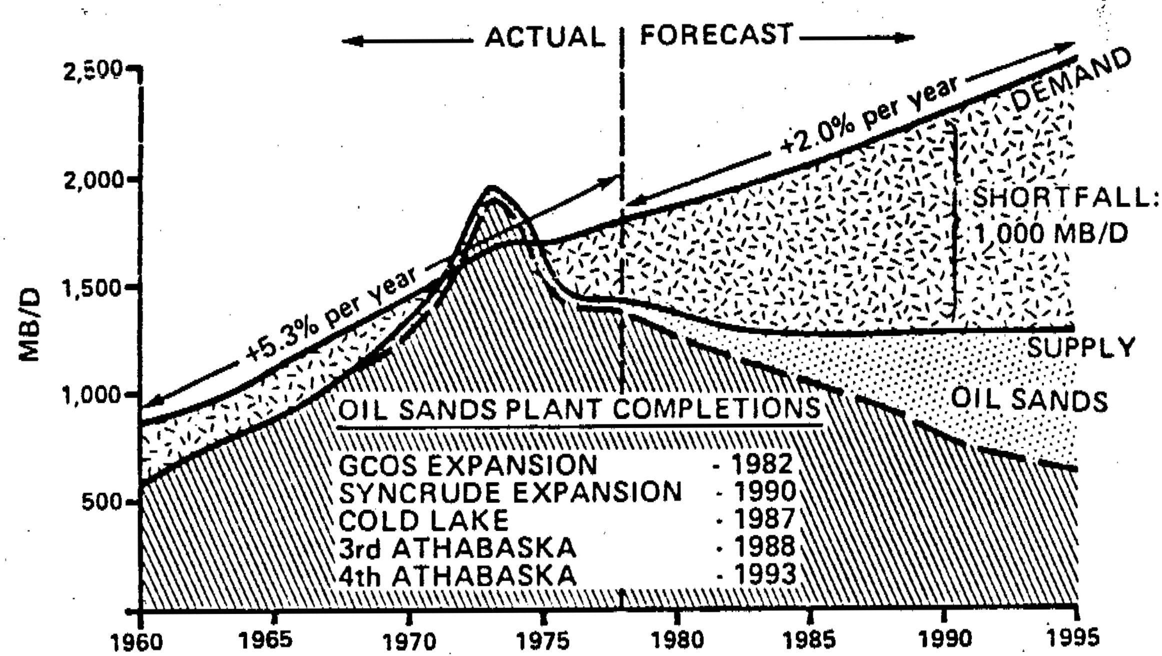


FIGURE 1-4 CANADIAN DEMAND FOR OIL

Currently, over 40% of the North American continents domestic crude oil needs are being imported from "politically insecure" countries at an annual cost of approximately $50 billion. Canada and the United States of America are becoming increasingly dependent on these foreign offshore sources to meet their growing crude oil requirements, much to the detriment of our balance of payments.

Unlike most of the other developed countries of the western world, Canada, and to a lesser extent, the U.S., have the proven and potential hydrocarbon reserves to satisfy national energy requirements for many decades to come. However, in order to accomplish energy self-sufficiency, the great undeveloped potential of the arctic offshore areas, and particularly the Beaufort Sea, must be developed and produced efficiently and in a timely manner.

Development Description

The overview report outlines a possible scenario for the development of Dome interest lands in the Beaufort Sea over the next fifteen to twenty years. A summary of this possible scenario follows.

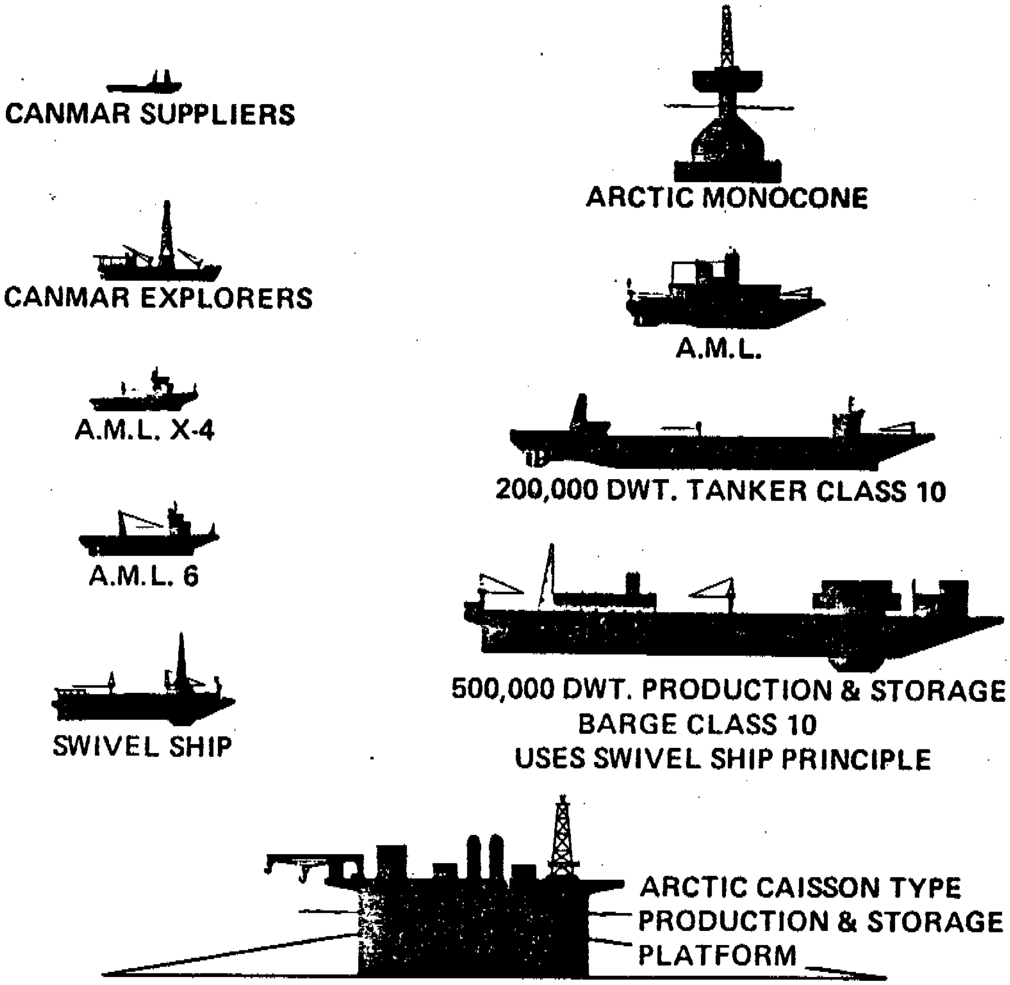
The geographic area of the development is illustrated in Figure 1-5. The scenario begins with the discovery of the first commercial oilfield during the period 79/80, with subsequent discoveries leading to the development of ten to twelve offshore oilfields, containing approximately 16 billion barrels of recoverable reserves, by the year 2000. Projected expenditures (in 1979 dollars) may reach $40 billion by 1990. These expenditures include $4 billion for exploration

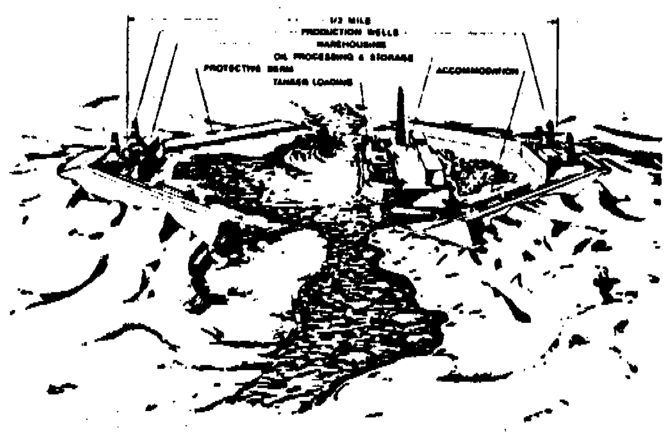
exploration, $25 billion for oil development and a further $10-15 billion for gas development.

The development and production phases will, for the most part, employ conventional technology, modified where appropriate, to accommodate the arctic environment (Figure 1-6). At the present time the most favorable concept for the initial production system is an Arctic Production Loading Basin (APLB). Such a facility, which combines an offshore artificial harbour and loading terminal with production capabilities, would be specific to the Kopanoar location (60 metres water depth) but would not necessarily be appropriate for other sites.

Eventually a combination of bottom founded caissons, platforms variations of man-made islands, and some subsea completions will form the basis for the full development of the hydrocarbon resources of the Beaufort Sea. One to three structures will be required for the average oilfield, with each development facility accommodating 40-60 wells. Average production per well is expected to be in the order of 5-10 thousand barrels per day, with associated gas of approximately 800 cubic feet per barrel. Some of the wells could be utilized for water injection, for pressure maintenance, and/or for injection of associated gas. A total of 24 production platforms are projected, reaching peak production of three million barrels of oil and 1.8 billion cubic feet of gas per day by 1999.

The production/drilling platforms are envisaged to be totally self-contained, having in addition to the drilling rigs: living accommodation; processing facilities for separating oil, water and gas; power generation facilities; gas compression facilities; oil pumping facilities; and all the





ARCTIC PRODUCTION AND LOADING BASIN
(APLB)

FIGURE 1-6

support facilities required for the drilling and production operation.

In addition, the platforms may be equipped for crude oil storage up to a capacity of three million barrels, either in the base of the structure, or through the use of subsea storage tanks. Alternatively, and in particular for discoveries close to shore, underwater pipelines for both oil and gas could carry the production to a shorebased facility for separation of oil, water and gas.

During at least the early development/production years, solution gas would be re-injected and all oil would be transported via Class 10 icebreaker tankers through the eastern and/or western Northwest Passage to southern markets. Tankers could be loaded directly at the offshore production platforms, or at a shorebased terminal. The capacity of each tanker will be in the order of 1.$ million barrels, and two tankers would be required per 80,000 barrels per day of field production. Production from the initial field would be serviced by two tankers, cumulating to between 10 and 20 tankers at the peak of tanker utilization.

The icebreaker tankers would be supported by one or more Class 10 icebreakers. These icebreakers would serve to ensure that breakout routes would be open through particularly difficult sections of the Northwest Passage, and where necessary, would be used to push the icebreaker tankers through these areas.

Once economic threshold limits were achieved, pipeline transportation of the oil and gas to southern markets would become desirable. It is anticipated, however, that the pipeline(s) would continue to be supplemented by tankers.

Substantial shorebased facilities may be required to support the development components anticipated for Dome's offshore Beaufort interest lands. The final determination of harbour and shorebase needs, functions, sites and facilities will be dependent on the nature, location, magnitude and timing of offshore discoveries, as well as the types of development technology employed.

Over the short term (1980-81), the administrative, support, and supply services provided by Inuvik and Tuktoyaktuk, combined with the winter moorage capabilities of McKinley Bay and Wise Bay/Summers Harbour, should be sufficient for the Company's needs.

For the medium term (1982-86), shorebased needs are projected to include all of those provided at the aforementioned sites, but at increased levels of activity. In addition, there will be the need to establish at least one 10-metre draft harbour capable of supporting year round drilling activities, and an area of 17-metre draft (potentially at the same location) to permit refueling, mooring, and dry-docking of vessels such as Class 6 icebreakers and Arctic Drilling Barges (ADB's).

Over the long term (1985-2000+), in addition to those requirements previously described, the area of 17-metre draft harbour available would have to be incrementally increased to accommodate a larger fleet of deep draft vessels requiring refueling, mooring and possibly dry-docking for maintenance purposes. The vessels that may have to be serviced at this time could include Class 10 icebreakers, icebreaker tankers, and arctic drilling or production barges. The deep draft site could also be utilized for the assembly of production, processing, storage and other facilities transported in from the south.

The bulk of construction for the drilling, production, storage, transportation and other facilities to be used in the Beaufort Sea would be undertaken in the south. The various modules would be transported to the north, where they would be assembled and installed.

All of the various components outlined in this scenario require manpower. Making certain assumptions on the number of personnel required per activity, one can estimate that by the year 2000 (when 24 production platforms may be operating) approximately 4,200 offshore and 1,000 onshore permanent jobs would be provided. Assuming 24 hour per day operations, and applying actual experience on the number of people required per job, the total number of offshore personnel employed could reach 13,500, while in the order of 3,000 personnel could be required for onshore support activities.

Environmental Setting

Beaufort Sea

The Canadian Beaufort Sea is located north of the Yukon Territory and the northwestern part of the Northwest Territories, and west of Banks Island and Prince Patrick Island. The Beaufort Sea is bordered by the Chukchi Sea to the west, the Arctic Ocean to the north, and Amundsen Gulf and M'Clure Strait to the east.

The proposed development area has a polar continental climate characterized by long cold winters and short cool summers. The Beaufort Sea is ice-covered for about eight months of the year. Spring breakup generally occurs during May or June and freezes again in September or October. Ice in the Beaufort Sea can be divided into three major zones. These zones are the polar pack, the landfast ice, and the transition zone which separates them.

The polar pack consists mostly of multi-year floe ice which moves westward across the Beaufort Sea as part of a circulation pattern called the Beaufort Gyre. The landfast ice grows outward from the shore during the fall and early winter. Between the pack edge and the landfast ice is a transition zone of deforming, sporadically moving, heavily ridged and irregular ice.

The largest persistent feature of circulation in the Beaufort Sea is the Beaufort Gyre, whose southern boundary lies at the northern edge of Dome interest lands during summer. This eddy is huge, extending as far as the North Pole, and is associated with a clockwise circulation. Mean speeds in the southern Beaufort Sea are of the order of 4 cm/sec, but a large variability exists.

The dominant marine feature of the nearshore south Beaufort Sea is the estuarine area resulting from fresh water and sediments discharged by the Mackenzie River. Over the centuries, sediment deposition from this turbid outflow has generated a wide shallow coastal shelf extending north and east of the Mackenzie Delta. Approximately 13.5×10^6 metric tons of suspended matter are contributed annually from this source.

Generally, the coastal zone of the Beaufort Sea is both recent and dynamic in character. Shore materials are not hardened into rock-like formations and often contain ground ice which melts when exposed by wave erosion during the open water season.

There are some 25 species of mammals in the Beaufort region, of which 14 are considered to be marine species. Of these, the beluga and bowhead whales, ringed and bearded seals, polar bear and arctic fox are considered to be the most important.

Terrestrial mammals such as the migratory Porcupine caribou herd and reindeer use portions of the coastal zone on a seasonal basis and are among the more important animals frequenting this region.

Over a hundred species of birds have been recorded in the Beaufort Sea/NE Chukchi Sea portion of the study area. Of these, approximately 35 species are major users of the marine and coastal regions. They include loons, brant, sea ducks, phalaropes, jaegers, gulls, terns, murres and guillemots. Others, such as swans, geese (other than brant), dabbling ducks and shorebirds (other than phalaropes), are abundant in coastal terrestrial areas.

Approximately two-thirds of the birds nesting on the coasts of the Beaufort Sea and Arctic Islands migrate through the great plains and the Mackenzie Valley, while the rest follow the coast of Alaska, Yukon and Northwest Territories. Open water leads in the ice are important sites for breeding and nesting stops during migration. Most bird species arrive in June or July and leave in August or September.

The Mackenzie estuary, bays, lagoons, and coastal margins are regions most important for spawning, feeding, migratory, and over-wintering cycles of the 38 species of marine, anadromous and freshwater fish found in the Beaufort Sea.

Northwest Passage

In order to transport Beaufort hydrocarbons to southern markets, the Northwest Passage appears to be the most appropriate route. Tankers would traverse Prince of Wales Strait, Viscount Melville Sound, Barrow Strait, Lancaster Sound, the south end of Baffin Bay and Davis Strait.

A reasonable baseline of environmental information is available for all the above marine environments except Prince of Wales Strait and Viscount Melville Sound.

The dominant element of the arctic marine environment throughout the length of the Northwest Passage is the presence of sea ice cover, which may be found along most of the route for between 6 to 12 months of the year. Further, the timing of sea ice formation and subsequent breakup regulates to a considerable extent the activities and concentrations of permanent and migratory biological populations.

The only widely distributed permanent mammal populations are the ringed seal, arctic fox, and polar bear. Other mammals occupy the Northwest Passage on a seasonal basis. These species include walruses and bearded seals in the winter, and harp seals, beluga, narwhal, and bowhead whales in the summer.

In the eastern Arctic, over 80 species of birds have been recorded in the Parry Channel/Baffin Bay/Davis Strait area, of which 35 species regularly use the marine system. The distribution of birds is uneven through this large area. Approximately 19 species commonly use the waters of Parry Channel with most individuals being found in Lancaster Sound and eastern Barrow Strait. The numbers of species increase to the south in Baffin Strait and Davis Strait; 31 species commonly use the waters of western Davis Strait. The number of individuals using Davis Strait is very large since virtually all of the sea-associated birds in the High Arctic migrate through or winter in Davis Strait.

Approximately thirty species of marine fish are thought to inhabit the interior sections of the Northwest Passage, with greater numbers of species present in the more open water environment towards the eastern end of the passage.

Environmental Issues

This report has identified a number of important environmental issues which will have to be addressed and resolved as development of the Beaufort Sea proceeds. This section serves to identify and summarize the major issues perceived; attempts to describe the degree of impacts which may be anticipated; and outlines some measures for mitigating major concerns. Clearly, the views expressed and the mitigation measures proposed are not intended to fully resolve the environmental issues addressed. They are meant to express the proponent's preliminary views. These will form the basis for future deliberations, resulting, where appropriate, in additional evaluations, studies, etc. Table 1 summarizes the issues discussed in the report.

TABLE 1

SUMMARY OF ENVIRONMENTAL ISSUES AND MAJOR IMPACTS

ENVIRONMENTAL ISSUES	IMPORTANCE	GEOGRAPHICAL EXTENT	IMPACTS
1) Major Oil Spill	High	Broad	Significant impacts could be anticipated, particularly with respect to seabirds, under ice biota, shoreline and ice edge habitats, marine mammals and benthic communities. Degree of impact would vary depending upon many factors, but not expected to be permanent.
2) Industrial Land Use	Moderate	Local	Localized disturbance to terrestrial habitat, possible interference with migratory patterns, particularly mammals.
3) Chronic Pollution			
a) Drilling Fluids	Moderate	Local)	Localized smothering and disturbance to benthic and planktonic communities.
b) Produced Fluids	Low	Local)	
c) Rig Wash Water	Low	Local)	
d) BOP Control Fluids	Low	Local)	
e) Sewage	Moderate	Local)	The cumulative effects of all chronic pollution could have significant environmental repercussions if left unchecked.
f) Cooling Water	Low	Local)	
g) Ballast Water	Low	Local)	
h) Minor Oil Spills	Low	Local)	
Cumulative Chronic Pollution	High	Local)	
4) Other Issues a) Ice Breaking	Low	Broad	Minor linear effects in comparison to natural ice variations. Some disturbance to marine mammals. Possibly beneficial to feeding and nesting marine birds.
b) Presence of Artificial Structures	Low	Local	Localized implications for ice cover, water circulation, current regimes, coastal and biotic processes.
c) Effects of Dredging	Low to Moderate	Local	Temporary increase in turbidity, minor reduction in dissolved oxygen, and localized changes in vertical salinity/temperature structure. Some effect on seabirds, zooplankton, as well as localized removal and burial of bottom flora and fauna.
d) Aircraft Disturbance	Low	Local	Overflights may cause disturbance to birds, marine and terrestrial mammals.
e) Noise	Low	Local	Localized disturbance from production facilities. Vessel activity may affect the behavior of marine mammals.
f) Solid Waste	Low	Local	Localized impacts only; for example, emissions associated with incineration, and land alteration associated with landfill.
g) Air Emissions	Low	Local	Localized ice fog and possible interaction between air emissions and atmospheric conditions.
h) Gas Blowout	Low	Local	Negligible environmental impact anticipated. Human health and safety of primary concern.

Major Oil Spills

The continuing risks associated with possible major oil spills in the Arctic remains one of the primary environmental/social concerns. Such a spill could result from an uncontrolled oil blowout, tanker accident, ruptured pipeline, or storage tank. A tanker accident could theoretically occur anywhere along the marine route from the Beaufort to southern markets, although the risk would be greater in areas constrained by geography, difficult ice conditions, or increased traffic concentrations.

In addressing the threat of major oil spills, prevention will form the initial basis for reducing the chances of a significant spill occurring. To this end studies have been and are being undertaken to analyze the causes of past oil spills during exploration, production and transportation phases, in order to permit the design and incorporation of the best possible equipment and/or operational features into Dome's future development components.

The advent of second generation drilling equipment will significantly extend the drilling season, an important consideration with respect to relief well drilling capabilities, should the need arise. The proper design of permanent facilities such as artificial islands, arctic production/loading atolls and caisson platforms should further enhance capabilities to control the possible release of oil to the environment from blowouts. The risk of pipeline and oil storage tank ruptures occurring will be minimized by the incorporation of approved design, placement and protection features. Underwater pipelines will be located to avoid geological hazards, ice scour and other problems as identified. Offshore oil storage tanks will generally be positioned below the depth of ice scour, or may be enclosed within the platform which it serves.

Likewise, the arctic class tankers to be used for transportation of oil will be the most technologically advanced vessels operating in the world at the time, and will be designed to reduce the possible risk of occurrence and magnitude of oil spills. Amongst their features, the tankers will be double-bottomed, will have compartmentalized oil storage, and will have completely segregated ballast systems. In addition to the preventive measures employed in tanker design and construction, the traffic controls, whether shipboard, satellite, or shorebased, will be the most sophisticated available. All of these measures should assist in reducing the risks of a major oil spill occurring.

In spite of the preventative measures employed, the risk of spills remains and must be planned for. Pre-planning involves emergency preparedness through organization, machinery and manpower. In this regard, during exploratory drilling in the Beaufort, oil spill contingency plans have been prepared, personnel have been trained, and a large inventory of equipment is immediately available in the region to respond to oil spills.

Assuming a spill occurs, the first line of defense will be to contain the spill, thereby localizing the problem. Present containment techniques include the deployment of booms and the use of ice edges, when appropriate, with subsequent removal of oil or *in situ* burning. For the future, and with particular reference to subsea blowouts, underwater containment systems are being evaluated.

If containment proves only partially or perhaps totally unsuccessful in limiting the spread of oil and it moves out to sea, measures to be employed in open water could include burning, mechanical recovery, and chemical dispersants.

Mechanical recovery systems already available in the region include containment of oil in offshore booms with recovery by skimming devices. The use of chemical dispersants requires government approval and further investigation in order to determine the effectiveness of dispersants on fresh, weathered, and emulsified oil in arctic environments.

If oil approaches nearshore areas, steps will have to be taken in an attempt to protect the most critical shore zone habitats. The delineation of particularly sensitive areas such as lagoons, marshes, etc. will permit the appropriate deployment of booms, deflectors, the construction of temporary dams, etc., to reduce the possibility of oil contaminating these most critical areas.

Notwithstanding all the preventive measures incorporated into the design and construction of arctic development components, and the suitability of countermeasure tools which may be available to control and reduce the magnitude of accidents, there may be significant losses of oil to the environment, with subsequent, possibly significant environmental repercussions.

Birds in general, but particularly seabirds, would probably be the most severely affected species in the event of a major oil spill, regardless of the location. Thousands, or in some areas, perhaps tens of thousands of birds could be killed. It is generally agreed that the seabird populations so affected would probably recover over time, although the rate and extent of recovery would vary with numerous factors, many of which currently remain unknown.

Marine mammals such as seals and whales and their habitat are the next most likely candidates to be significantly affected by an oil spill. For the southeastern Beaufort Sea, it has been estimated that perhaps 30% or more of the sub-adult and adolescent seal populations could encounter oil in the event of an oil blowout. Unfortunately the behavioral responses of marine mammals to oil and the possible effects of oil on these animals are poorly known. Likewise, it is not presently possible to predict the mortality which may be associated with oil/marine mammal encounters.

Reductions in seal populations, caused by oil-related stresses, could be reflected in subsequent decreases in the number of polar bears and white foxes, caused by emigration to marginal habitats elsewhere, and/or possibly due to reduced offspring survival. Nothwithstanding the data limitations, it is postulated that these populations can recover in time, if the critical leads and polynias used for feeding and breeding are not chronically polluted.

With respect to fish and fish habitat, it is generally felt that oil reaching nearshore regions, especially bays and estuarine areas, poses a greater concern to fish, food organisms and their habitat, than does oil in the offshore region. Oil reaching coastal margins could become incorporated into the sediments and marshes, to be re-released over extended periods of time (5-10 years). Through this process, possible deleterious effects of oil to the particularly significant nearshore communities could likewise continue for many years. Possible impacts could be expressed in several ways including direct mortality to fish and food organisms, the replacement of species, tainting, the concentration of hydrocarbons in the food chain, reduced breeding success, etc.

Offshore, oil trapped beneath the under-surface of ice may destroy exposed under-ice biota. The significance of the epontic life to the overall ecosystem is not well understood, although it is believed to represent an important component of the diet of some fish, seabirds and marine mammals. Oil on the water surface offshore would not be expected to have major effects upon the plankton, fish and benthos primarily due to the limited exposure they would receive and their generally ubiquitous distribution. However, should approved oil dispersants be applied in the offshore regions (presumably to afford protection to higher life forms) then oil and dispersant mixtures could exert greater influences on the organisms of the water column and benthic reaches.

In summary, it may be seen that predicting the definitive environmental implications which may be associated with major oil spills, remains a complex, significant problem. It is therefore evident that in order to reduce concern over this issue, every effort must be made to prevent major oil spills from occurring, followed by the application of the best possible counter- measures available, should they occur.

Industrial Land Use

The use of industrial lands will become increasingly important as the hydrocarbon reserves of the Beaufort region are developed. The Company's requirement for further industrial lands will be dependent on the degree of success during the exploratory program and on the final choice of functions to be carried out entirely offshore.

Industrial lands and associated activities will replace and alter natural habitats causing localized disturbance to flora and fauna. The impacts of these disturbances can be serious, particularly if significant amounts of unique wildlife habitat are destroyed, or if migratory routes are disrupted.

To date, land use required in support of Company activities has totalled less than 10 hectares, which is comparable to that used for support facilities in northern and western Alaskan exploration programs. From a regional perspective, the impacts of increased land use during the exploration phase have been small and localized. Issues which have arisen have been resolved or continue to be worked out by industry, government and the local population.

Site selection for new shore facilities such as deep draft harbours, service bases, treatment facilities, tank farms, marine terminals, and pipelines will have to minimize adverse environmental and social effects while satisfying basic industrial requirements.

It should be noted that physical and operational requirements will limit the alternatives for siting onshore facilities. For example, siting a marine terminal or deep draft harbour requires adequate water depth, safe navigation channels, maneuvering room, suitable level land and proximity to offshore rigs and production platforms. These requirements limit the coastal areas that could be used for such a facility. Once all potential alternatives are known, the final choice will be influenced by environmental, social, and economic criteria.

In the Beaufort region the impact of increased industrial land use can be minimized by:

1) concentrating new facilities at existing industrial sites

2) proper siting of new facilities
3) locating industrial facilities offshore

Chronic Pollution

Almost all components of the development scenario generate wastes at one time or another. They may be solid wastes produced during a construction and/or installation phase; liquid wastes associated with drilling, or sewage generated by all activities; or gaseous emissions released by machinery.

Following current practice, discharge and environmental monitoring programs will be undertaken by both the Company and the Government, in order to determine compliance with requirements and the environmental implications which may be associated with the releases. The results of these programs will determine the adequacy of the waste management practices employed at the time, and will form the basis for modification of these practices as necessary.

The following is a summary of eight major types of wastes emitted as by-products of the development activity, which could contribute to the generation of a chronic pollution problem if left unchecked.

1. Drilling Fluids and Formation Cuttings

Drilling fluids and formation cuttings represent one of the most significant offshore emissions. Assuming 1,200 wells may be drilled by the year 2000, approximately 15 million barrels of water based drilling wastes could be generated.

The principal environmental concerns associated with drilling fluids and formation cuttings have been the toxicity of the wastes, the effects of turbidity in the water column, possible smothering of bottom life, and the possible accumulation of contaminants in sediments and organisms.

All drilling fluids and cuttings will be discharged in accordance with regulatory requirements. Potential problems related to turbidity, toxicity and smothering would be expected to be localized and limited. Possible concerns over heavy metal concentrations in drilling fluids are best minimized by careful selection of mud components and the re-use of drilling mud at production platforms, wherever possible. Concurrent environmental monitoring programs will be required in order to ensure that problems, if they develop, are detected at an early stage, thereby permitting further remedial actions to be taken as necessary.

2) Produced Water

Produced water is formation water which is extracted in combination with oil and gas from production wells. Formation water is generally anaerobic and may contain higher chloride and dissolved mineral concentrations than seawater. Since the Beaufort basin fields are projected to be using water injection for pressure maintenance and to enhance oil recovery, a high percentage of produced water will be reinjected into the geological structures. Excess produced water will be discharged in accordance with regulatory requirements.

3) Rig Washwater

Rig washwater, as the name implies, is water used to wash down drilling equipment. It would likely also include detergents approved by regulatory agencies. Washwater on all rigs will be collected through an open drain system, treated to reduce oil concentrations to acceptable limits, and discharged to the sea.

4) BOP Control Fluids

Blowout preventers require a hydraulic fluid to operate. With the dilution the liquid will receive upon being released, the impacts which may be incurred by small discharges of the toxic fluid are considered short term, minor, and highly site specific.

5) Sewage

Domestic sewage will be generated by all activities. The volume of sewage produced will increase incrementally. If an estimated 13,500 personnel are employed in the region by the year 2000, then 4,000 m^3 (880,000 gallons) of sewage would be produced daily.

Environmental concerns associated with sewage disposal center around possible nutrient enrichment, oxygen depletion, and the introduction of pathogens. Adequate sewage treatment, combined with appropriate site selection for discharge of the treated wastes will ensure that none of the possible concerns develop into significant problems.

6) Process Cooling Water

Process cooling water is filtered seawater used as a cooling medium for regulating the temperature of industrial machinery. Process cooling water will be generated by all offshore platforms, shore bases and ships, with the most significant source being the drilling platforms. All cooling water discharges will require routine on-line monitoring in order to detect for the possible presence of oil, which in turn would activate remedial measures.

7) Ballast Water

All vessels require ballast (seawater) to maintain ship stability under varying sea and ice conditions. Ballast water tanks in icebreaker tankers will be segregated from the hydrocarbon storage tanks to ensure no contact with oil and only "approved" seawater will be used.

8) Minor Fuel Spills

Fuel spills could take many forms, including crude, Bunker C and diesel oil, hydraulic fluid, gasoline, kerosene, and residues. Releases to the environment could be approved/regulated discharges; chronic losses from leaking valves, machinery, etc;

or accidental minor spills associated with oil transfer and handling facilities.

The environmental implications of minor spills will naturally vary with the prevailing circumstances. Spills occurring in the vicinity of shore bases would probably be expected to have potentially greater environmental repercussions than offshore spills. Sea associated birds would likely represent the most significant component directly affected. The application of appropriate countermeasures such as booms, approved dispersants, scare tactics, and others should ensure that negative impacts associated with minor spills should themselves generally remain minor. More detailed specific projections will have to be developed for each major development component as they arise.

Cumulative Effects of Chronic Pollution

In reality, the activities will not occur in isolation and the combined effects of all activities could be important. Several possibilities exist.

1. The combined effects of several activities may be no greater than the effects of the single most severe activity.
2. The effects of the activities may be additive.
3. Several activities may act synergistically to produce effects that are much greater than the sum of the individual activity effects.

It has been demonstrated that populations of arctic animals can be stressed by unusually severe natural environmental conditions. For example, non-breeding seasons in arctic birds are common, and major population reductions of ringed seals, bearded seals and polar bears in the Beaufort Sea have been documented. Such naturally stressed populations may be more vulnerable to the effects of development. Natural stress may contribute significantly to the potential for cumulative and synergistic effects.

These are important considerations for the design of development components and for the development of mitigative measures.

Other Issues of Importance

Dredging

During the course of development there will be continuing requirements for dredging. Depending on the development activity and its location, the impact of dredging on the environment will vary. Table 2 summarizes the approximate quantities of dredged material which may be associated with the various Beaufort development components.

TABLE 2

Estimated Dredged Material Quantities per Facility

Type of Facility	Estimated Dredged Material per Facility (m^3)
1) Glory Hole	.04 - .05 million
2) Ballast for Caisson	.70 - .80 million
3) Pads/berms for Caissons	.76 - 3.8 million
4) Pipelines	.06 million m^3 per Km
5) New Harbour	2 - 6 million
6) Artificial Island	6 - 15 million
7) Arctic loading & production atoll	50 - 100 million

The major impacts associated with most dredging projects would be significant alterations to the bathymetry of the areas dredged. These in turn could have effects upon local water circulation patterns and water column properties such as temperature, salinity and dissolved oxygen values. Most impacts of dredging programs upon the biota of a given area would be limited in area and short term in duration.

Immediate losses of benthic fauna would be anticipated, generally followed by recolonization over a period of one to three years following cessation of dredging. Some fish may become entrained in suction-dredges, particularly in nearshore regions during periods of migration, rearing, etc. However, on the basis of experience gained to date, substantial losses would not be anticipated. Impacts of dredging programs upon marine mammals and birds would be expected to be limited to possible temporary avoidance or attraction reactions in some instances.

Ice Breaking

A number of physical and subsequent biological issues may be associated with ice breaking in the Northwest Passage and the Beaufort development area.

These include increased evidence of ice fog or sea fog and premature breakup of the ice edge. The presence of "artificial leads" will probably attract birds by providing feeding and resting habitat as the epontic algae community, ice associated amphipods and arctic cod may be exposed in overturned ice.

Some marine mammals, especially ringed seal pups, may be unable to avoid approaching icebreakers and will be killed or injured by collision. Others may be affected by disturbance. Whales that enter icebreaker tracks may become trapped. Artificial leads in the Northwest Passage area may delay the occasional inter-island movements of muskoxen and caribou.

Although definitive information on the possible effects of icebreaking traffic upon the physical and biological environment is generally lacking, the limited field observations made to date would suggest that most effects should be minor in nature and extent, particularly in comparison to natural seasonal and annual fluctuations in ice cover. The advent of Dome's Class 4 ice breaker provides a unique opportunity to examine possible concerns in a prototype operating made. These and other field programs to be carried out in conjunction with the Arctic Pilot Project and perhaps government icebreakers should substantially improve our knowledge base in this important area, and will assist in developing appropriate mitigative measures when warranted.

Artificial Structures

Artificial structures such as offshore platforms, nearshore breakwaters, docks, etc. will have localized implications for ice cover and water circulation, current regimes, sediment transport, and coastal erosion processes. The actual degree of impact will be dependent upon numerous site specific circumstances which will have to be examined in detail as particular plans for a given area are formalized.

Except for limited mortality of birds (especially migrating water birds) by collision with structures, the effects of the physical presence of artificial structures on birds and mammals will probably be minor, and generally indistinguishable from disturbance effects. During winter, assuming that offshore structures are in contact with the moving ice field, polar bears and foxes may be attracted to the operations areas. Proper garbage disposal should ensure that this potential problem will be minimized.

Underwater, structures may be expected to be colonized by attached fauna, macrophytic algae, and eventually by resident populations of algae-associated fish.

Aircraft Disturbance

Aircraft overflights may disturb birds and both marine and terrestrial mammals. Reactions to aircraft will depend on many variables including species, stages of life cycle, type of aircraft, their altitude and location.

Disturbance can be minimized by adherence to altitude guidelines and by routing aircraft away from sensitive areas. Monitoring programs should be able to determine the need for further mitigative measures.

Noise

Sounds will be generated from all activities, whether located onshore or offshore and may result in the exclusion of many of the mammals and birds normally frequenting these areas. Noises generated from such facilities should be restricted to small areas. Underwater, sounds from vessels may affect the behavior and movements of marine mammals. Monitoring of these concerns will assist in determining the possible significance.

The appropriate application of site selection criteria should ensure that most areas heavily utilized by birds and mammals will be avoided in the siting of new land facilities.

Solid Wastes

Solid wastes, whether scrap metal, other non-combustibles, or combustibles will be produced by all activities and require incineration or landfill. Emissions associated with incineration, and drainage associated with landfill operations will have to conform with applicable regulatory requirements.

Air Emissions

The primary air emissions will originate from internal combustion engine exhausts, incineration of garbage and the burning of formation gas.

The primary concerns associated with air emissions will be the formation of ice fog, and the interaction between fog and aerial pollutants. Concerns regarding atmospheric emissions will be greater at onshore locales than offshore at the drilling platforms. Nonetheless, the application of appropriate, Government approved emission controls, plus regular monitoring of the waste gases and receiving atmosphere should ensure that possible environmental implications remain highly localized if they occur at all.

Gas Blowout

In addition to the possible major oil spill, offshore drilling for oil brings with it the risk of a natural gas blowout. The hazards posed to human health and safety would be of greatest immediate concern. Natural gas blowouts would normally create very little impact on wildlife.

The potential for significant biological impacts from a gas blowout might be dramatically increased should the gas be accompanied by significant quantities of hydrogen sulfide. However, on the basis of exploration data generated to date, hydrogen sulfide is not anticipated to be present in the formations drilled.

Recommendations for Further Environmental Investigation

The overview document has served to identify several areas of environmental concern which will require further examination by either or both the proponent and government. Further investigations are required to fill continuing environmental baseline data gaps; to provide additional information essential to the development of environmental impact assessments; and through monitoring programs, to evaluate actual operations in order to ensure that satisfactory environmental protection is achieved.

Environmental Baseline Data Gaps

Environmental baseline data gaps exist in all disciplines of the environmental sciences. However, for the purpose of this overview, only those deemed to be of particular consequence are highlighted.

(1) In general, the meteorological, biological and physical oceanographic properties of Amundsen Gulf, Prince of Wales Strait and Viscount Melville Sound remain poorly understood. As a minimum, information sufficient to permit the development of adequate oil spill contingency plans will be required.

(2) The major mammal and bird species frequenting the Beaufort Region should be censused on a regular basis, in order to develop an improved understanding of natural population fluctuations, population densities, seasonal distributions, etc.

(3) Information is required on the biological significance of epontic life and arctic cod to the northern marine ecosystem.

(4) Additional chemical data are required for the Beaufort development area, to permit the adequate future assessment of possible changes which may result from development activities. In particular, improved baselines are required for the present levels of "contaminants" in the water column, sediments, and biological tissues.

(5) Site specific environmental baseline data such as the distribution and abundance of vegetation, fish, birds and mammals will be required within the possible areas of influence of proposed development components such as future shore base, quarry sites, transportation corridors, etc.

Environmental Impact Assessment Information

Although most of the technologies envisaged for the North are conventional, some have not yet been employed in the arctic. In addition, certain activities, such as ice-breaking, are unique to the arctic regions. Among the major issues which require continuing examination include:

(1) The biological/environmental repercussions which may result from significant oil spills, the application of dispersants, and clean-up technologies, etc., under arctic conditions. (AMOP will be addressing some of the issues associated with oil spills and dispersants in arctic locations.)

(2) The possible biological ramifications of year-round icebreaking activities. The advent of vessels such as the Kigoriak now provides the opportunity to examine these concerns in a "prototype" operating mode.

(3) The environmental effects of large scale dredging operations in the offshore Beaufort and/or in potentially significant nearshore areas.

Environmental Monitoring Programs

Environmental monitoring programs will have to be developed and instituted for all major activities and discharges pertaining to development of the Beaufort Sea resources. The primary objectives of these programs will be: to evaluate the possible degree of impact attributable to specific development components; and to ensure that possible chronic, cumulative impacts may be detected at an early stage, thereby permitting further remedial actions to be taken if necessary.

Included in this category of investigation will be the need to:

(1) assess the nature, quantity, distribution, fate and environmental implications which may be associated with all major effluent discharges, air emissions and solid waste management activities.

(2) evaluate the environmental effects which may result from human activities generally, including "mere presence effects", the effects of aircraft over-flights, vehicular traffic, noise, increased human presence, etc.

(3) monitor the actual effects (as opposed to predicted) which may be associated with substantial year-round icebreaking activities, major dredging and other construction projects, etc.

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2. DOME PETROLEUM - AN OVERVIEW

2 DOME PETROLEUM LIMITED - AN OVERVIEW

The Company

Dome Petroleum Limited, a Canadian public company, was formed in 1950 with $250,000 in equity and $7.7 million in debt.

From these modest beginnings, Dome has become one of the leading oil and gas exploration and production companies in Canada with a staff of over 2,000 and operations throughout North America. Current equity ownership varies between 52 and 60 per cent Canadian with approximately 12% owned by the employees.

Currently, Dome has asset values in excess of $4 billion, including over 500 million barrels of proven oil and oil equivalent of gas reserves, 50 million net acres of North American petroleum and natural gas rights, a working interest in over 4,500 producing oil and gas wells, over 4,600 miles of oil, gas, and product pipelines, varying interests in 52 large gas plants, a major offshore drilling company (Canadian Marine Drilling Ltd.), and other miscellaneous assets.

In addition, Dome owns 49% interest in TransCanada PipeLines, the only transporter of natural gas from Western Canada to Eastern Canadian and United States' consuming centres with annual revenue in excess of $2 billion. Finally, Dome Petroleum owns 39% interest in Dome Mines, Canada's largest gold producer, with interests in uranium, copper, and other base metals.

Frontier Work

Dome's involvement in frontier exploration dates back to 1959 when the Company first filed on permits in the Arctic Islands. Today the Company holds working interest in approximately 23 million acres of oil and gas rights, and gross royalties in an additional 14 million acres in the Arctic Islands.

In 1961 the Company drilled the first well in the High Arctic, Dome et al Winter Harbour No. 1 on Melville Island. Although this well was a dry hole, it demonstrated the feasibility of drilling on a year round basis in the Arctic Islands. Dome continues to hold 4.26% interest in Panarctic Oils Ltd. In the following years Dome participated in the drilling of eleven wildcat wells in the Arctic Islands, of which three were gas discoveries.

Offshore Exploration

In 1967 the Company filed on substantial acreage in the Beaufort Sea. Subsequently, Dome established Canadian Marine Drilling Ltd., specializing in offshore drilling in Arctic waters.

To date the Company has constructed a fleet of fourteen vessels consisting of four drillships, eight icebreaking supply ships, one icebreaker, three barges and a cargo/base vessel, with a total investment (including our supply base) of approximately $350 million. Based upon the availability of its drillships and its ability to carry out drilling operations in the Beaufort Sea, the Company has accumulated an acreage picture in the Beaufort Sea of approximately 9 million acres

Since the commencement of exploratory offshore drilling in the Beaufort Sea, Canmar has conducted drilling operations on 16 wells with 3 drilled to total depth and fully tested. Oil and gas have been found in all wells drilled with two substantial oil discoveries having been made to date; namely, Nektoralik and Kopanoar. The latter well indicated a flow rate in excess of 12,000 barrels per day of sweet oil from a sand zone in excess of 250 net feet. A step-out well two and one-half miles northwest is currently being drilled on this structure to help determine the size of the reserve. In addition, two gas discoveries have been made to date; namely, Ukalerk and Tingmiark.

Most recently, with the onset of winter, testing operations were suspended at two new sites, Nerlerk and Tarsiut, with resumption scheduled for the 1980 season.

At Nerlerk, testing of two lower zones recovered non-commercial oil and water with extensive oil-stained reservoir sand sections remaining to be tested. The Nerlerk structure is the largest structure mapped in the Beaufort Sea, and the Company regards the presence of oil in the Nerlerk well as highly significant.

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3. DEVELOPMENT SETTING

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3 DEVELOPMENT SETTING

THE NEED

Petroleum and natural gas continue to supply 45.7% and 18.6% respectively of the total Canadian demands for energy. Despite renewed interests in, and the utilization of alternative energy sources, and the application of conservation measures, etc., the Canadian demand for oil has been forecast by the National Energy Board to increase at a mimimum rate of 2.0% into the foreseeable future (Figure 3-1).

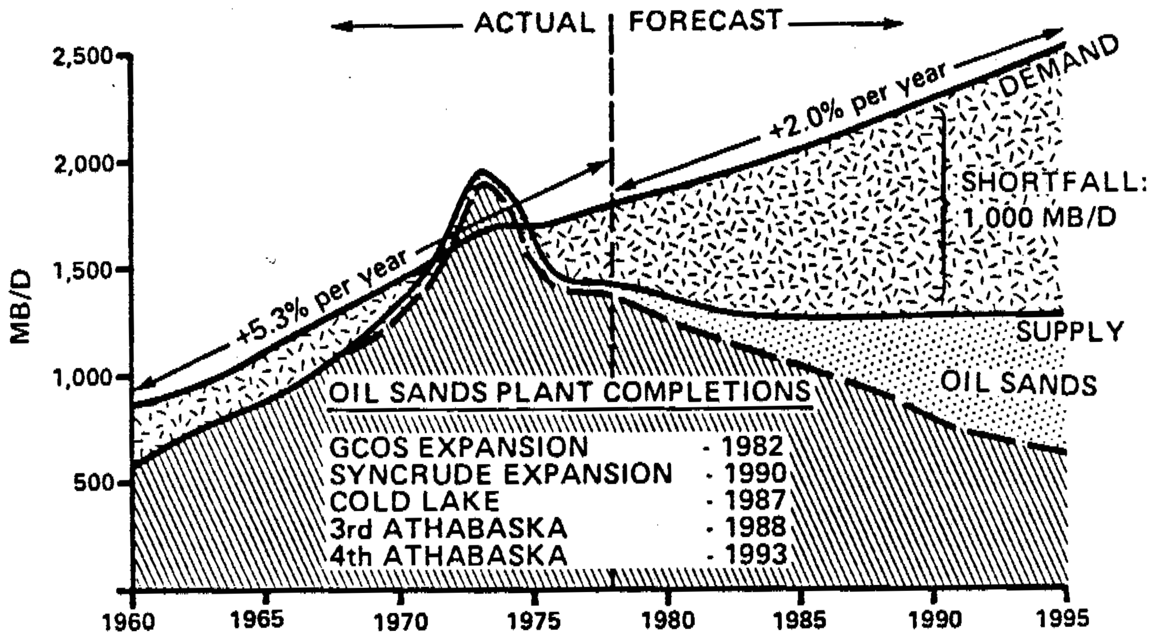


FIGURE 3-1 CANADIAN DEMAND FOR OIL

Currently, over 40% of the North American continent's crude oil needs are being imported from "politically insecure" countries at an annual cost of approximately $50 billion. Canada and the United States of America are becoming increasingly dependent on these foreign offshore sources to meet their growing crude oil requirements, much to the detriment of our balance of payments.

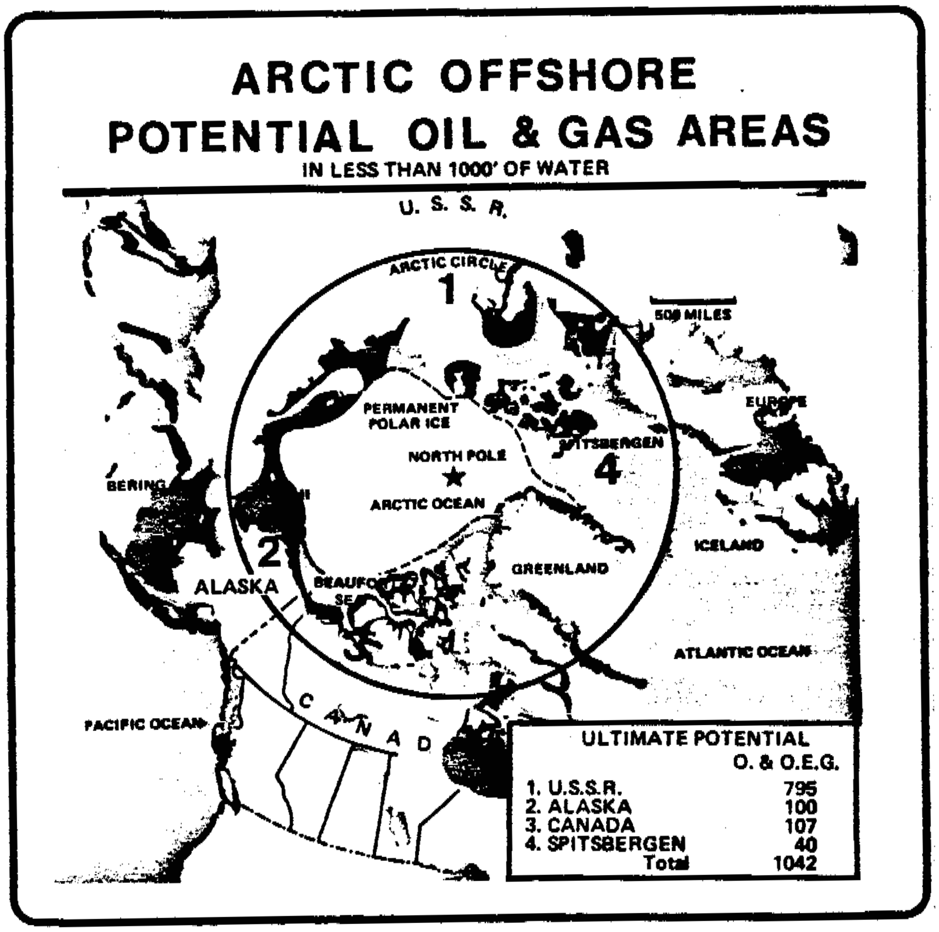
Despite conservation, Canada will consume over 35 billion barrels of oil and oil equivalent of gas (OEG) in the next 25 years, which is twice the current Canadian proven conventional reserves. During the same period, the U.S. will utilize over 372 billion barrels of oil and OEG, representing over five times the current U.S. proven conventional reserves.

Unlike most of the other developed countries of the western world, Canada and to a lesser extent the U.S., have the proven and potential hydrocarbon reserves to satisfy national energy requirements for many decades to come. However, in order to accomplish self sufficiency, the great undeveloped indigenous potentials of the Arctic offshore areas, and particularly the Beaufort Sea, must be developed and produced efficiently and in a timely manner.

OFFSHORE OIL AND GAS POTENTIAL

The potential for oil and gas north of the Arctic Circle is enormous. On a global basis, Figure 3-2 summarizes the Arctic offshore potential oil and gas areas in less than 1,000 feet of water, and the estimated reserves of oil and OEG's within the Arctic Circle.

FIGURE 3-2

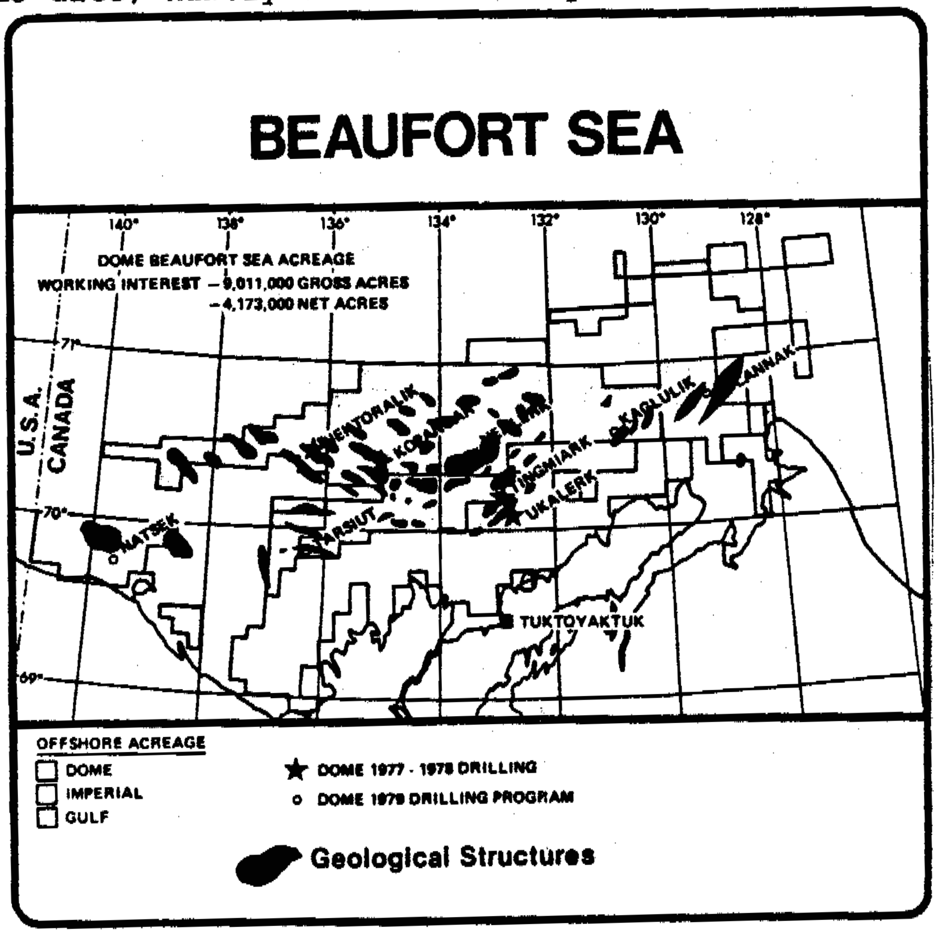


It should be noted that the estimated potential for the Russian Arctic areas is approximately 800 billion barrels of oil and OEG. These reserve estimates are becoming substantiated by major discoveries such as those made by Russia in the Kara Sea area of northwest Siberia, where one gas field alone has a proven and probable reserve of over 210 trillion cubic feet (as verified by representatives of the American

Association of Petroleum Geologists). Also shown are estimated potentials north of the Arctic Circle for Canada (107 billion barrels of oil and OEG), Alaska (100 billion) and northeast Greenland and Spitsbergen Islands (40 billion), for a total in excess of one trillion barrels of oil and OEG.

The Mackenzie Delta and Beaufort Sea areas of Canada have all of the essential geological attributes for the generation and accumulation of major oil and gas reserves. The Geological Survey of Canada has estimated maximum potential reserves of oil and OEG for this area totalling 95 billion barrels as compared to current proven reserves of oil and OEG of 18 billion barrels for southern Canada. Figure 3.3 shows the location of Dome's working interest in over 9 million gross acres and the sites of the Company's four oil and/or gas discoveries to date; namely Nektoralik, Kopanoar, Tingmiark and Ukalerk.

FIGURE 3-3

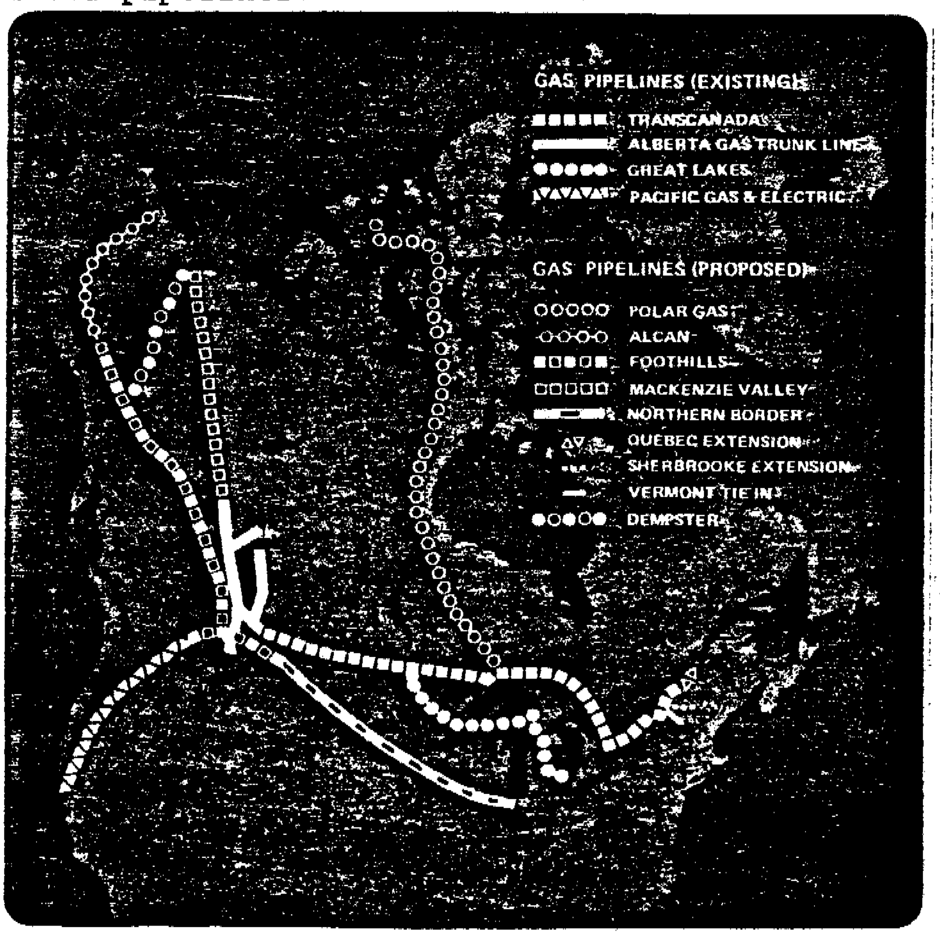


ASSOCIATED DEVELOPMENT

Directly associated with the development of the Beaufort Sea hydrocarbon resources will be the requirement to transport the products to market. Dome's economic studies indicate that, at least initially, oil should move out of the Beaufort by Arctic Class icebreaker tankers on a year round basis. The threshold of reserves required to initiate oil movement by tankers is approximately 1/10th of that required to finance a major pipeline, resulting in earlier cash flow and an ability to increment the facilities as reserves and markets grow.

Figure 3-4 illustrates existing and proposed gas pipelines in Canada. When oil production rates attain the necessary threshold level, one or more of the routes shown for potential gas lines could become likely candidates for the alignment of oil pipelines.

FIGURE 3-4



Because issues associated with the various pipeline proposals have been or are continuing to be examined through several different formal environmental review processes such as: Alaska Highway Gas Pipeline Project (EARP Panel); Dempster Pipeline Project (EARP Panel); Mackenzie Delta Gas Gathering System (EARP Panel); and the Polar Gas Project (EARP Panel) they will not be addressed to any great extent in this document. However general descriptions of current proposals and a review of their status will be made.

Alaska Highway Gas Pipeline Project (FEARO, 1979)

The proponent, Foothills Pipelines (South Yukon) Ltd. proposed the construction and operation of a buried gas transmission line to initially transport Alaska gas to U.S. markets in the lower 48 states. The proposed Yukon section of the line runs from Beaver Creek in the western corner of the Yukon, along the existing Alaska Highway for 512 miles to Watson Lake in the southeast Yukon. At its northern end the pipeline is proposed to connect to 732 miles of pipeline in Alaska, and at its southern end to 1,500 miles of proposed line in British Columbia, Alberta and Saskatchewan. The system will tie in at the 49th parallel with the U.S. system. The projected cost of the Beaver Creek to Watson Lake line is $1.24 billion (1976 dollars).

The current status of this project is that the Proponent has completed its assessment of the project. The Environmental report was transmitted to the Minister of the Environment and authorized for public release in September, 1979. After completion of the revised EIS, the Panel will reconvene the public technical hearings. Following the hearings, the Panel will report to the Federal Minister of the Environment on the adequacy of the environmental planning for the project.

Dempster Pipeline Project (FEARO, 1979)

The proponent, Foothills Pipelines (Yukon) Limited, proposed the construction and operation of a gas pipeline for transmission of Mackenzie Delta gas in the Northwest Territories to a point at or near Whitehorse in the Yukon Territory to link up with the projected Alaska Highway Gas Pipeline. The route will follow closely the Dempster Highway and the Klondike Highway.

The project was referred to the Federal Environmental Assessment Review Office in January, 1978. Formal guidelines for the preparation of an environmental impact statement have been issued publicly and are available from the Panel Secretary. The Panel will conduct a technical and public review of the environmental impact statement when produced by the proponent, and will subsequently make recommendations to the Minister of the Environment concerning the implementation of the project.

Mackenzie Delta Gas Gathering System (FEARO, 1979)

The proponents (Imperial Oil, Gulf Oil and Shell Oil) propose the construction and operation of three gas processing plants and transportation facilities by the above oil companies to supply a Dempster pipeline moving gas south to market in southern Canada. In the summer of 1977 these three projects were suspended. However, an environmental impact statement for the Imperial Oil plant (Taglu) has been prepared for review. The estimated cost of the Taglu development (Imperial Oil) is $500 million (1975 dollars).

The official request for Panel review was received in January, 1975, and the Panel was formed in the same month. Guidelines for the production of the environmental impact statement were issued to the initiator May, 1975. They are available to the public. The Taglu environmental impact statement will be distributed in the near future for technical review. In connection with the Dempster Pipeline Project, an overview will be submitted by the initiator to consolidate the description and mitigation of gas processing plant and pipeline impacts. The Panel will make arrangements for technical and public review of the Taglu environmental impact statement after which a report to the Minister will be prepared.

Polar Gas Project (FEARO, 1979)

The proponents (Polar Gas Consortium and Panarctic Gas Ltd.) propose the extraction and purification of gas from fields in the High Arctic, and the construction of a large diameter pipeline for natural gas transmission through the Northwest Territories and one or more provinces to a junction with an existing pipeline in southern Canada. The projected total cost for the pipeline component, south from Spence Bay ranges from $4.5 billion to $6.2 billion, the variation being a function of the route taken.

In addition, an alternate route, the "Y" line proposal, is now being considered by Polar Gas. It would involve piping natural gas reserves from the Arctic Islands with those from the Mackenzie Delta and the Beaufort Sea to southern Canada.

An official request for a Panel review was received in November 1975. A Federal Government Task Force was set up in February 1975 to produce draft EIS guidelines for an Environmental Assessment Panel. The Panel was formed in March 1976.

Guidelines for the preparation of an Environmental Impact Statement were finalized by the Panel and issued to the initiators for distribution to the proponents. The Environmental Impact Statement has been prepared and distributed to the Panel. Copies of the EIS have also been distributed to technical review agencies and the public strictly for information purposes.

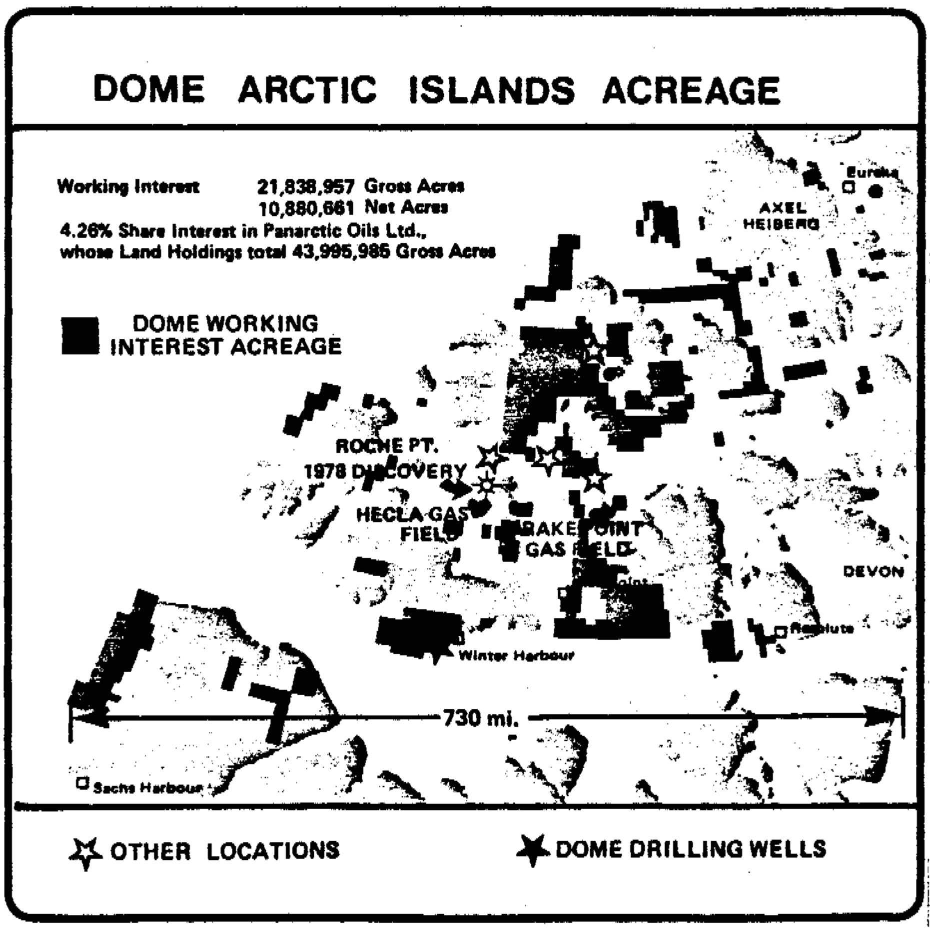
However, the review of the EIS for the "applied for" route is currently being held in abeyance, pending a decision by Polar Gas on route selection.

OTHER OIL AND GAS ACTIVITIES IN THE ARCTIC

In addition to the possible future development of oil and gas on Dome interest lands in the Beaufort Sea, Esso Resources and Gulf Canada in particular, are expected to have plans for their lease areas in the nearshore and onshore regions.

Beyond the Beaufort Sea area, Dome's land holdings in the Arctic Islands total 21.8 million gross acres and 10.8 million net acres, plus a 4.26% interest in Panarctic's 44 million gross acres (Figure 3-5).

FIGURE 3-5



To date, exploration drilling in this area has proven up an estimated 13 TCF of gas and a small oilfield. The results of a recently completed $45 offshore seismic program have indicated that the largest and most promising geological structures in this region are generally located between, rather than on the islands. Therefore, future testing will have to be carried out from ice islands or from drillships in landfast ice areas. The Geological Survey of Canada have estimated maximum potential reserves of oil and OEG for the Arctic Islands at 72 billion barrels.

Regarding the gas fields that have been discovered in the Arctic Islands, Petro-Canada is currently proposing to recover and transport these hydrocarbons to market under the terms of the Arctic Pilot Project. Referring to the FEARO (1979) report, this project would involve the construction of a small number of wellsite facilities in the Drake point area of Melville Island, a small gas plant, a pipeline to carry natural gas from the Drake Point area to Bridport Inlet on southern Melville Island, a liquid natural gas plant to process 250 million cubic feet per day of gas, a harbour facility at Bridport capable of year round operation, and icebreaking LNG carriers designed to operate between Bridport Inlet and the east coast on a year round basis.

Its current status under EARP is as follows. The project was referred for Panel consideration by both Petro-Canada and the Department of Indian and Northern Affairs in November 1977. An Environmental Statement has been prepared and has been circulated to government agencies for preview. The Panel received comments on the Environmental Statement in May, 1979. On the basis of these comments and its own review, the Panel issued "Draft Guidelines for Completion of the

Environmental Assessment" on June 15 and invited public and government agency comments on the guidelines by August 1. The final guidelines for completion of the environmental assessment were issued in early October. Public meetings to review the additional information to be provided by Petro-Canada are expected to be held in early 1980. The Panel will report its findings to the Minister of the Environment thereafter.

Finally, in the Eastern Arctic, several operators, including Norlands Petroleum, Petro-Canada, and a consortium (composed of Imperial Oil Ltd., Aquitaine Company of Canada Limited, and Canada-Cities Services Limited) have proposed and/or have initiated exploratory drilling programs in the Lancaster Sound, Baffin Bay, and Davis Strait areas, respectively.

In summary, it is apparent that large portions of the Canadian Arctic hold potential for hydrocarbon exploration and development activities, and in this respect all of the various proposals reviewed in this section may be considered to be associated in one way or another. The actual sequence of implementation will depend upon the economic matching of supply and market as well as the regulatory approvals for the necessary facilities and export permits, where applicable.

Dome's Beaufort Sea Production System Alternatives

The alternatives to be introduced herein form the basis of subsequent sections of the report. It is possible that many, or if appropriate, perhaps all of the alternatives to be discussed will be used at one time or another in the actual development of the Beaufort Sea hydrocarbon resources.

Drilling/Production Platforms

Within the next few years Dome anticipates being able to conduct drilling, whether for exploratory or production purposes, on a year round basis in the Beaufort Sea. Depending upon ice conditions, water depths, state-of-the-art technologies available as development proceeds, experience gained, and other factors, these activities may be undertaken through the use of artificial islands, offshore harbours (atolls), caisson and/or monocone platforms, floating drilling/production barges and/or subsea facilities.

Process/Storage Facilities for Produced Hydrocarbons

Processing facilities for oil produced offshore, and in time natural gas, could be located onshore or offshore. In the offshore mode, they may be placed on artificial islands or on platforms similar to those described for the drilling or production activities. Likewise, storage for the products could take place in association with any of these facilities. In addition, production could be stored underwater.

Bases of Operation/Harbours

Alternative locations for harbours, marine terminals and supply bases, are being considered. These alternatives are discussed further in the section dealing with land use.

Transportation of Produced Hydrocarbons

The Company proposes to transport hydrocarbons to market with Arctic Class icebreaker tankers, at least initially. Once economic threshold limits are achieved, it would become feasible to install and transport oil and gas to southern markets via pipeline. Nevertheless, current thinking is that even after the installation and operation of pipeline(s), transportation of the hydrocarbons would be supplemented with tanker service, possibly at a reduced rate.

Termination of Operations (Abandonment)

Oil and gas operations consist of 3 phases: exploration, development/production, and abandonment. The Company accepts the responsibility for providing adequate environmental protection during all phases of its Beaufort operations. This responsibility includes good abandonment planning and practice.

Post-abandonment environmental concerns will be identified, and control techniques and costs incorporated into the planning stage for new operations.

T A B L E   O F   C O N T E N T S

4. NATURE, MAGNITUDE, LOCATION AND TIMING OF DEVELOPMENT

L I S T   O F   F I G U R E S

L I S T   O F   T A B L E S

4 NATURE, MAGNITUDE, LOCATION AND TIMING OF DEVELOPMENT

The purpose of this section is to attempt to outline a possible scenario for the development of Dome interest lands in the Beaufort Sea over the next 15-20 years. Naturally, it must be appreciated that the scenario is a hypothetical projection, based on numerous assumptions.

By offering this view of the future, it is hoped that the reader is provided with a framework of future development possibilities. The accomplishment of this important objective should give a better perspective to subsequent submissions regarding specific development components, as they arise.

Exploration to date, although encouraging, has not progressed to the extent where Dome is ready to propose a final development scheme. The results of the exploration program, however, have been sufficiently positive to motivate Dome to enter into the early stages of design and planning for production and transportation facilities. Drilling and testing that will take place during the 1980 and 1981 drilling seasons should provide sufficient information to enable the Company to undertake commitments for detailed engineering design of these facilities. Successful delineation drilling will facilitate an increasing level of capital commitment leading to a full scale commitment by 1981 and the installation of permanent facilities by 1985.

THE SCENARIO

The scenario begins with the discovery of the first commercial oilfield during the period 79/80, with subsequent discoveries leading to the development of 10 to 12 offshore oilfields, containing approximately 16 billion barrels of recoverable reserves, by the year 2000 (Figure 4-1). Projected expenditures (in 1979 dollars) may reach $4 billion for exploration, $25 billion for oil development and a further $10-15 billion for gas development, up to the year 1990 (Figure 4-2).

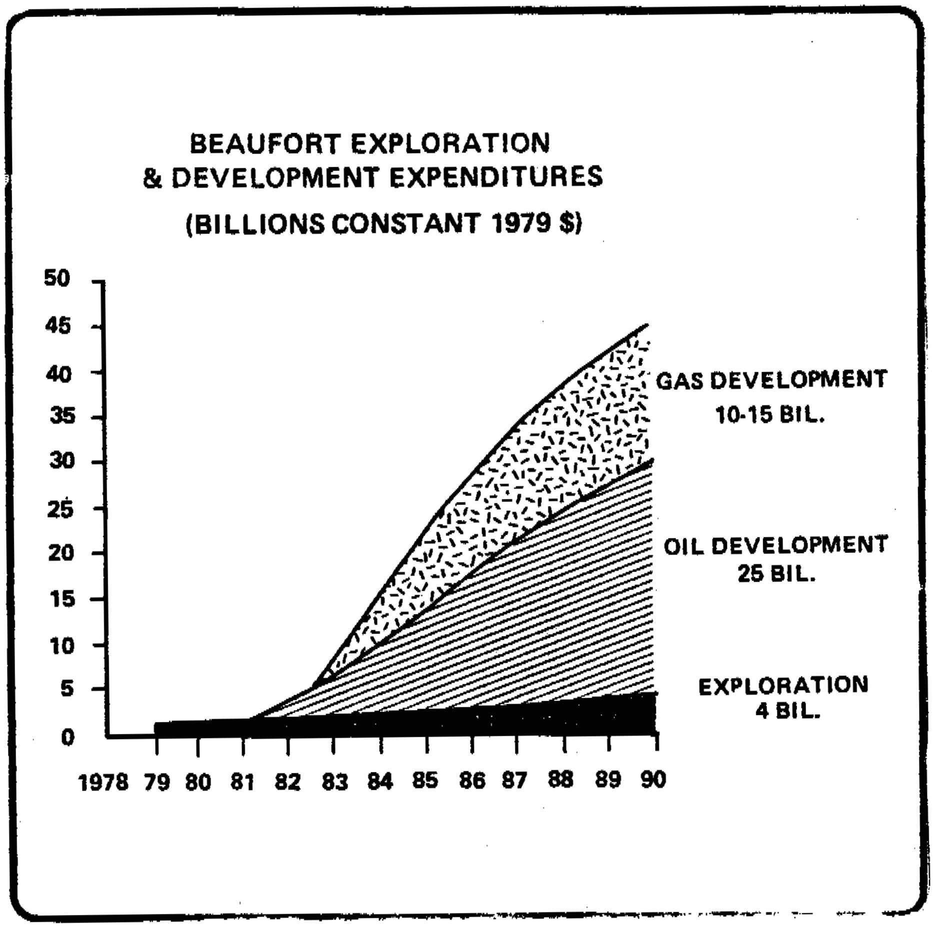


FIGURE 4-2

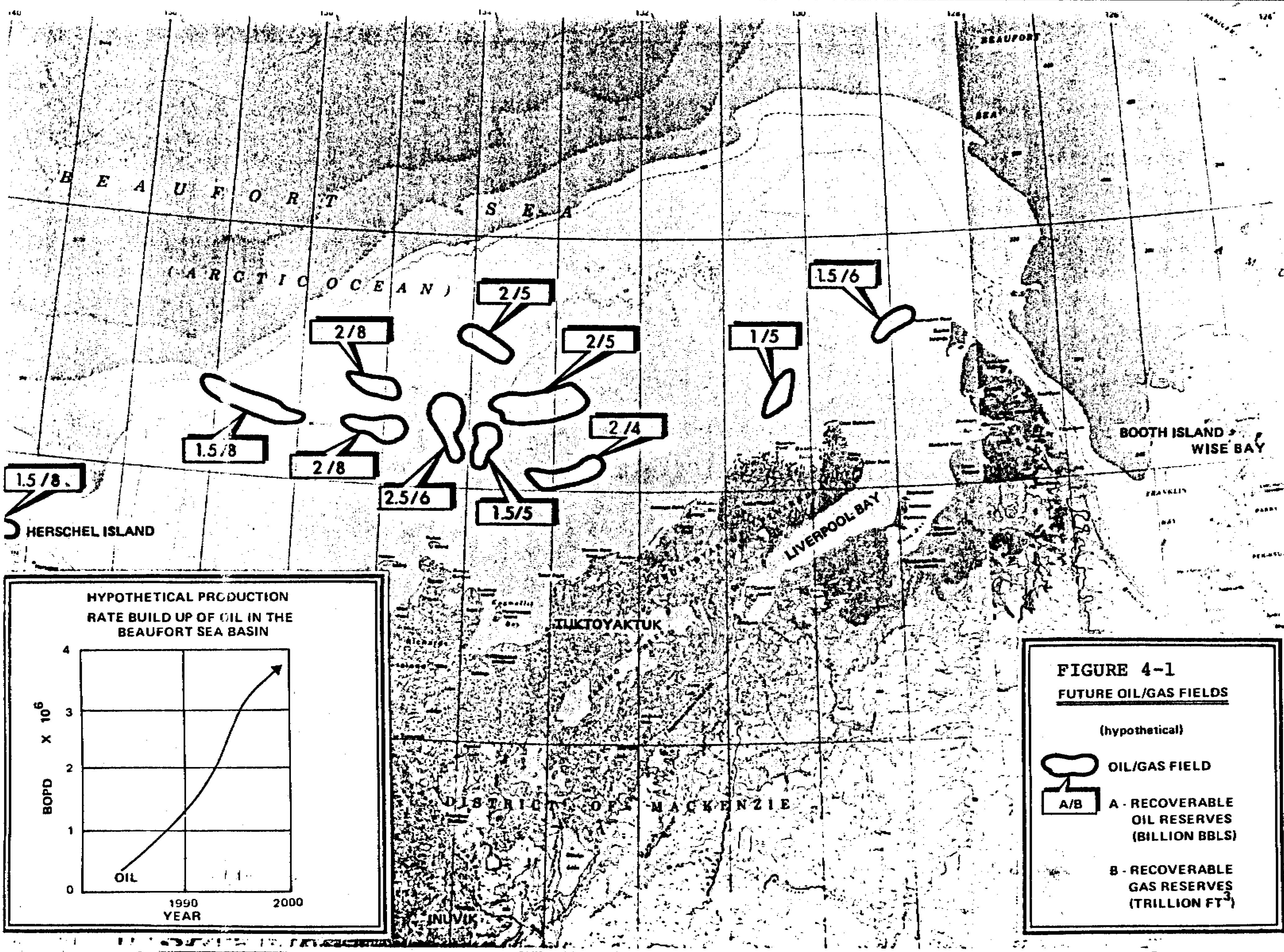


FIGURE 4-1
FUTURE OIL/GAS FIELDS

Figure 4-3 summarizes in pictorial format, the array of marine systems presently used or planned for the Beaufort in the future.

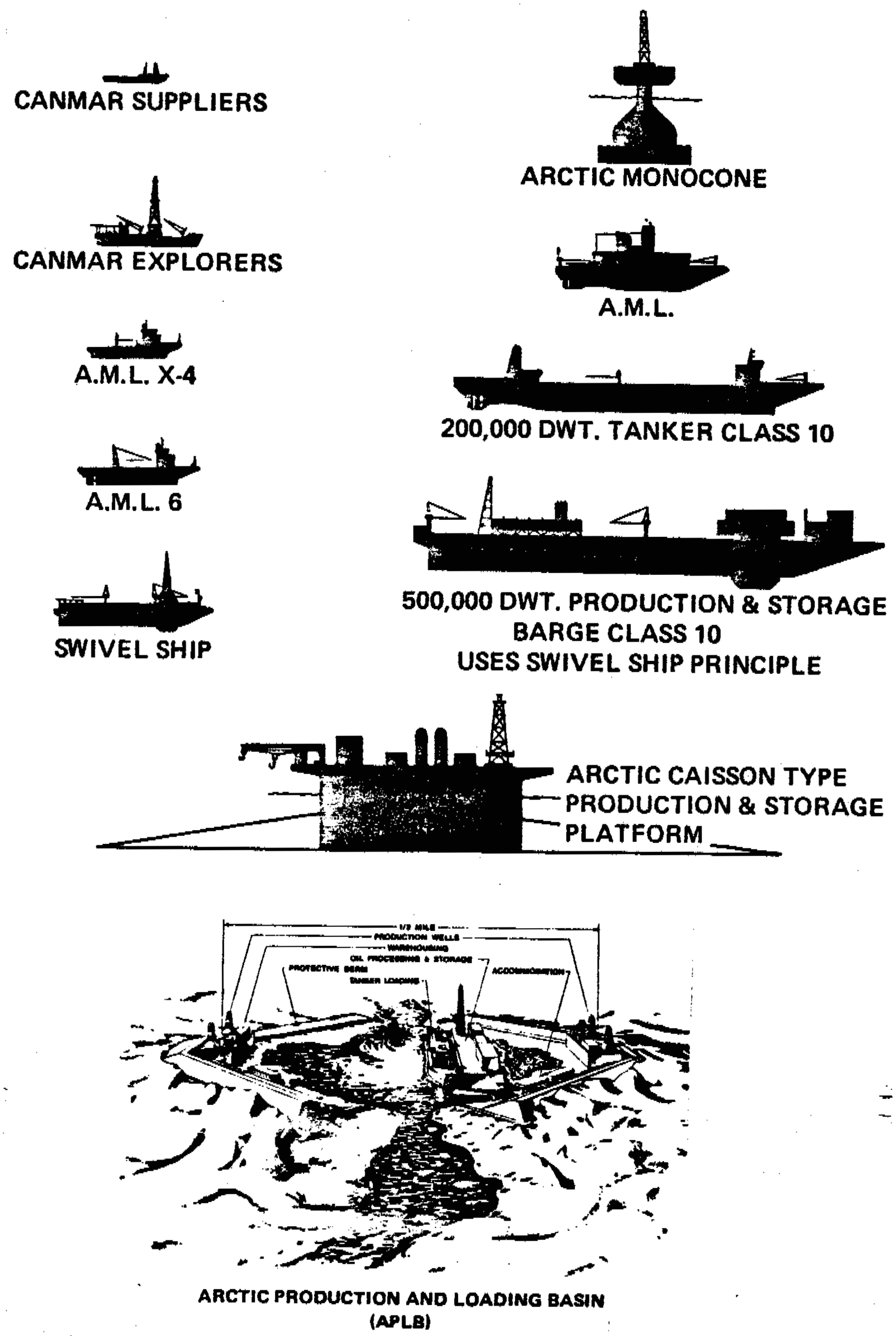


FIGURE 4-3

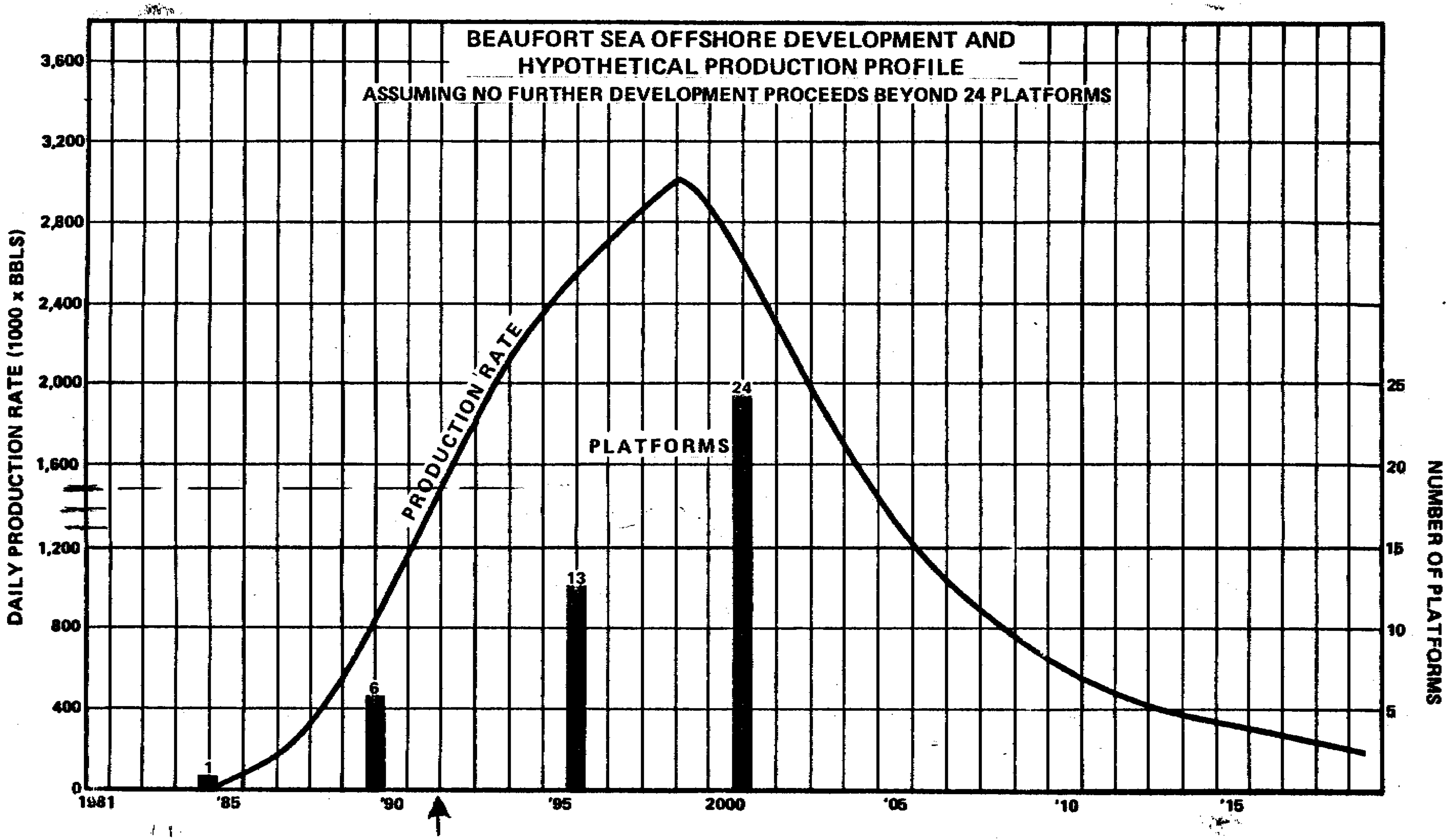
The development and production phases will for the most part, employ conventional technology, modified where appropriate, to accommodate the arctic environment. Bottom founded caissons, platforms, variations of man-made islands, and some subsea completions will be the basis for development. At least two platforms will be required for the average oilfield, with each development facility accommodating 40-60 wells.

A minimum of two drilling rigs at each development location except monocone structures, will provide drilling and completion operations. Average per well production is expected to be in the order of 5-10 thousand barrels per day, along with associated gas estimated at approximately 800 cubic feet per barrel. Some of the wells would be utilized for water injection and/or for injection of solution gas. Approximately of 24 production platforms are projected, reaching peak production of three million barrels of oil and 1.8 billion cubic feet of solution gas per day by 2000 (Figure 4-4).

The drilling/production platforms are envisaged to be totally self-contained, with living accommodation; processing facilities for separating oil, water and gas; power generation facilities; gas compression facilities; oil pumping facilities; and all the support facilities required for the drilling and production operation.

In addition, the platforms may be equipped for crude oil storage up to a capacity of three million barrels. Alternatively, and in particular for discoveries close to shore, underwater pipelines for both oil and gas could carry the production to a shore based facility for separation of oil, water and gas.

FIGURE 4 - 4



BEAUFORT SEA OFFSHORE DEVELOPMENT AND
HYPOTHETICAL PRODUCTION PROFILE
ASSUMING NO FURTHER DEVELOPMENT PROCEEDS BEYOND 24 PLATFORMS
DAILY PRODUCTION RATE (1000 x BBLS)
3,600
3,200
2,800
2,400
2,000
1,600
1,200
800
400
0
PRODUCTION RATE
PLATFORMS
1
6
13
24
NUMBER OF PLATFORMS
25
20
15
10
5
1981
'85
'90
'95
2000
'05
'10
'15

During at least the early development/production years, solution gas would be re-injected and all oil would be transported via arctic class icebreaker tankers through the eastern and/or western Northwest Passage to southern markets. Tankers could be loaded directly at the offshore production platforms, or in the case of shorebased storage facilities, the processed product could be subsequently re-delivered by pipeline to an offshore terminal for loading.

The icebreaker tankers would be supported by one or more large icebreakers. These icebreakers would serve to ensure that breakout routes would be open through particularly difficult sections of the Northwest Passage. If necessary, the icebreakers could be used to push the icebreaker tankers through these areas. The capacity of each tanker will be in the order of 1.4 million barrels, and two tankers would be required per 80,000 barrels per day of field production. Production from the initial field would be serviced by two tankers, cumulating to between 10 and 20 tankers at the peak of tanker utilization.

Once economic threshold limits are achieved, pipeline transportation of the oil and gas to southern markets becomes desirable. It is anticipated, however, that the pipeline(s) would continue to be supplemented by tankers as may be required.

Substantial shorebased facilities will be required to support the development components anticipated for Dome's offshore Beaufort interest lands. The ultimate determination of harbour and shorebase needs, functions, sites and facilities will be dependent on the nature, location, magnitude and timing of offshore discoveries, as well as the types of development technology employed.

Over the short term (1980-81), the administrative, support, and supply services provided by Inuvik and Tuktoyaktuk, combined with the winter moorage capabilities of McKinley Bay and Wise Bay/Summers Harbour, should be sufficient for the Company's needs.

For the medium term (1982-86), shorebased needs are projected to include all of those provided at the aforementioned sites, but at increased levels of activity. In addition, there will be the need to establish at least one 10 metre draft harbour capable of supporting year round drilling activities, and an area of 17 metre draft (could be the same area) to permit refueling, mooring, and dry-docking of vessels such as class 6 icebreakers and Arctic Drilling Barges (ADB's).

Over the long term (1985-2000+), in addition to those requirements previously described, the area of 17 metre draft harbour available would have to be incrementally increased to accommodate a larger fleet of deep draft vessels requiring refueling, mooring and possibly dry-docking for maintenance purposes. The vessels that may have to be serviced at this time could include class 10 icebreakers, icebreaker tankers, and arctic drilling or production barges. The deep draft site could also be utilized for the modularized assembly of production, processing, storage and other facilities transported in from the south.

The bulk of construction for the drilling, production, storage, transportation and other facilities to be used in the Beaufort Sea would be undertaken in southern Canada. The various modules would be transported to the north, where they would be assembled and installed. For the present scenario, at the peak of construction activity in the north, up to six construction barges may be operating. In addition, by 1995 approximately 33 supply or tug boats will be required to support the various construction and operational activities ongoing at this time. Finally, several types of dredges will be required in order to dredge and maintain harbours, construct artificial islands, fill caissons, excavate for pipelines, submarine facilities, etc.

All of the various components outlined in this section require manpower. Making certain assumptions, one can estimate that by the year 2000 (when 24 production platforms may be operating) approximately 4,200 offshore and 1,000 onshore permanent jobs may be provided in direct support of the production drilling operations. Assuming 24 hour per day operations, and applying actual experience on the number of people required per job, the total number of offshore personnel employed could reach 13,500, while in the order of 3,000 personnel would be required for onshore support activities.

Having described a scenario of staged development which could assume very significant proportions if and when it comes about, the next 2 sections will examine in more detail the technical concepts associated with the major development components.

BEAUFORT REGION DEVELOPMENT CONCEPTS
OFFSHORE FACILITIES

At this time, the extension of seasonal operations to achieve year round exploration, production and transportation capabilities remains an important goal. The major obstacle is the presence of sea ice for approximately three quarters of the year. It should be noted, however, that the magnitude of this challenge is not unlike that faced in the early days of North Sea development.

The first significant oil discovery in the North Sea was made eleven years ago in 1969 and first production began in 1971, only two years later. Today twelve fields are producing with nine in various stages of development and it is expected oil production will exceed 2.4 million BOPD.

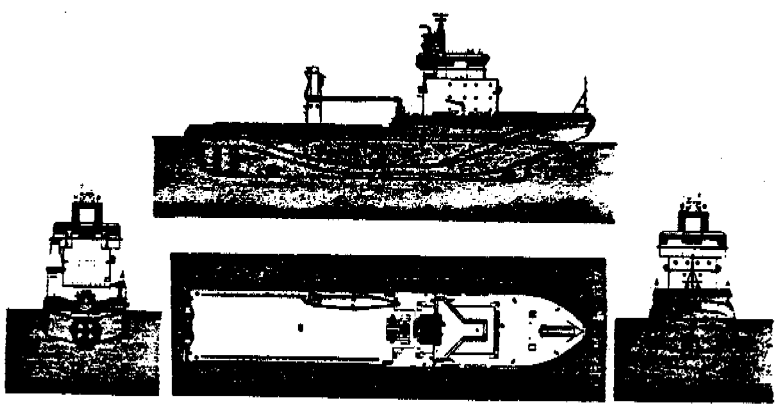
The technological achievements in the North Sea have been impressive. In the northern areas during early drilling, severe sea states caused excessive down-time. Today, down-time for drilling operations with the latest design of semi-submersible drilling rigs is generally less than 10 percent and often less than 5 percent. Production platform designs are based on sea states in excess of 100-foot waves. Yet at the time of the first oil discoveries, all the necessary technology for development was not available. Application of existing technology, development of, and application of new technology helped make development in the North Sea successful.

In many respects the Beaufort Sea provides a less difficult operating environment than that of the North Sea. Moderate sea states require structures to be designed for only 25-foot waves. However, forces imposed by ice and particularly ice islands are expected to be greater in magnitude than a 100 foot North Sea design wave. The open water period in the Beaufort Sea does correspond closely to the weather window of the North Sea, suggesting similar logistics and planning strategy can be applied to the Beaufort Sea as is used for the North Sea.

Using the North Sea analogy, if a discovery was confirmed in 1980 in the Beaufort Sea, oil production could commence in 1985 and production rates between five hundred thousand and one million barrels a day could be reached by 1990.

The Beaufort Sea technology continues to evolve and expand based on operational experiences gained, and the results of ongoing multi-million dollar research programs associated with the current exploration phase. A definitive example of this is the Company's new Class 4 experimental icebreaker, which recently performed impressively in travelling through multi-year ice of the Northwest Passage (Figure 4-5). The extensive ice research programs have likewise contributed significantly to Dome's ability to undertake preliminary design and planning work leading to the development of viable Beaufort Sea Production systems.

FIGURE 4-5



PRINCIPAL PARTICULARS:–

Length Overall	90.65	Metres
Length Between Perpendiculars	79.56	Metres
Breadth	17.25	Metres
Depth	10.00	Metres
Draft	8.50	Metres
Displacement	7,000	M.T.
Shaft Horsepower	16,400	
Complement	22	Crew
	12	Passengers

DOME PETROLEUM LIMITED

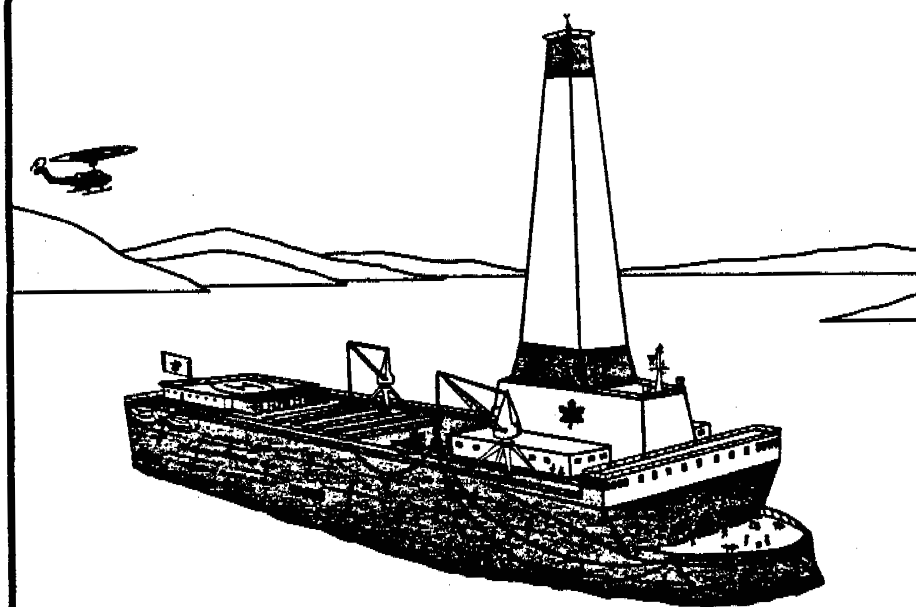
AML X4 ICEBREAKER (KIGORIAK)

Exploration Systems

All of Dome's current exploratory drilling programs are being carried out with four conventional, ice reinforced drillships. Four years of experience with these first generation arctic offshore drilling systems, and generally favorable climatic conditions, have permitted the extension of the drilling season to almost five months in 1979. Nevertheless, because of the under-utilization of equipment, the Company's drilling efforts in the Beaufort Sea continue to rank as the most expensive operations in the world.

Looking into the future, Dome is projecting that towards the end of 1982 the Company's first Arctic Drilling Barge (ADB) could be ready for drilling during the winter of 1982-83 (Figure 4-6). A subsequent ADB could come on line in 1984.

FIGURE 4-6



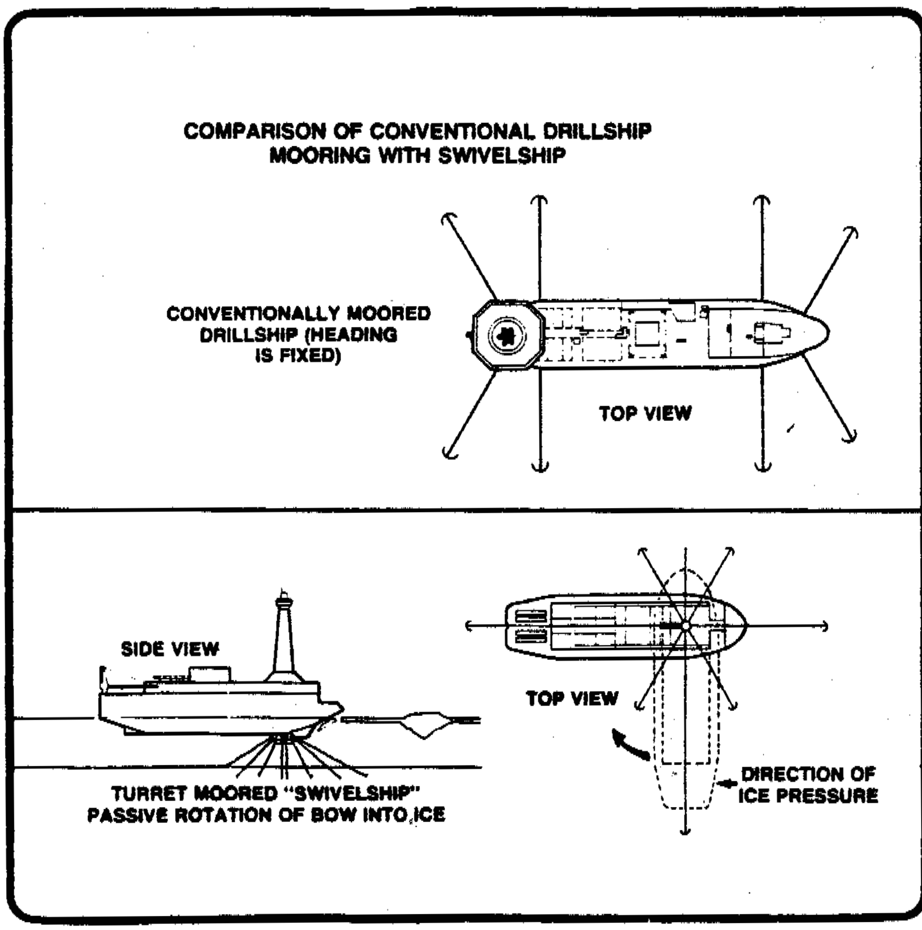
DRILLING BARGE

By 1984-85, exploratory drilling could be conducted by two ADB's in combination with some of the conventional drillships, up to a projected total of six being used during peak exploratory/delineation drilling periods.

It is anticipated that the ADB's will extend the Beaufort Sea drilling season to at least 8 months, and possibly the entire year. Some of the ADB's unique features include an offset turret mooring system utilizing 16 anchors mounted on a swivel directly under the drilling derrick, and a class 10 hull.

Figure 4-7 shows a comparison of the conventional drillship mooring with the Arctic Drilling barge offset turret mooring system.

FIGURE 4-7



A conventionally-moored drillship remains on a fixed heading even though wind and ice directions change. As a result, when the ice direction is broadside, tension on the anchor chains may be extreme, resulting in the suspension of drilling either temporarily in the summer, or for the winter period relatively early in the season (November).

The offset turret mooring system will permit the ADB to "ice-vane", and always turn the Class 10 bow into the direction of advancing ice. This action is predicted to reduce tensions on anchor chains to at least one twentieth of that experienced with the conventional system.

The drilling equipment of the future will be very similar to that used on existing drillships with the BOP stack positioned on the sea floor and controlled hydraulically from the surface. A complement of approximately 100 personnel will be required per drillship. Floating rigs may be used for exploratory, delineation or development purposes. When used for exploratory or delineation purposes, a single exploration or delineation well will be drilled at a given location and upon completion may be abandoned or retained for later completion as a satellite production well. For development drilling, the floating vessel could be moored for a period of up to four years over a multi-well drilling template containing up to 16 wells.

Production Systems

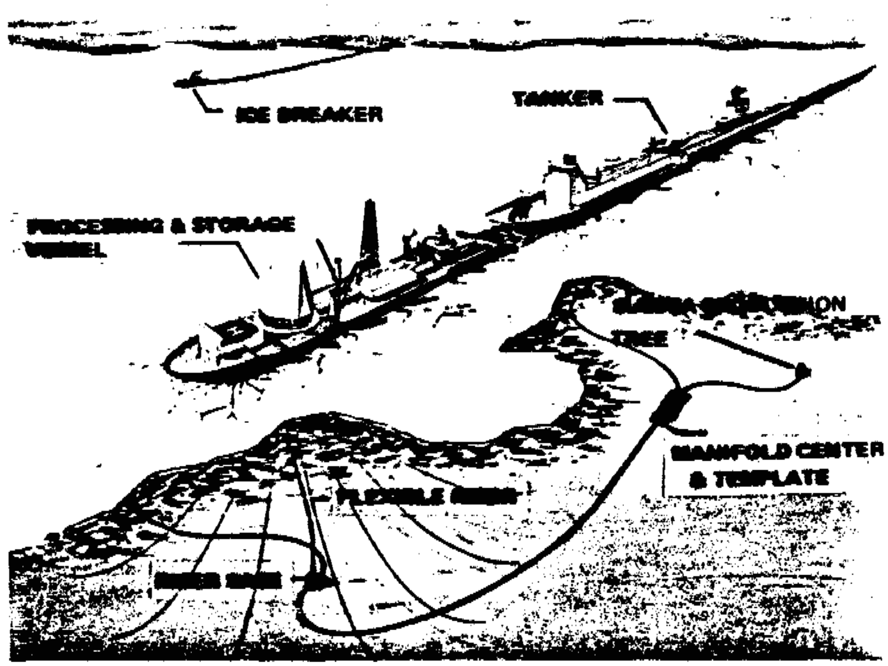
The final design of specific Beaufort Sea production facilities cannot commence until sufficient delineation drilling has been completed to establish the exact location of such facilities and the requirements of the production system. In addition, site specific geotechnical and other physical environmental data must be obtained before the installation of any production facilities.

However, production concepts have been developed that could be applied to the range of ice conditions, water depths and seafloor conditions encountered in the Beaufort Sea. These concepts will now be described.

Floating Production Platforms

As indicated at the end of the previous section (exploratory drilling), some development drilling could take place from floating platforms. Particularly to achieve early production, a floating production facility, such as illustrated in Figure 4-8, could be used.

FIGURE 4-8



BEAUFORT SEA EARLY OIL PRODUCTION SYSTEM

This type of vessel (or floating platform), essentially an enlarged version of the ADB, could approach a dead weight tonnage of 500,000 tonnes, and a length of 1,500 feet. It would have better station-keeping capabilities than those of the smaller ADB, and should permit the vessel to operate in a producing mode for at least 9 or 10 months/year.

It would be capable of receiving, processing and storing production from wells drilled by floating vessels and completed subsea. Stored production would be transferred directly to Arctic Class icebreaker tankers.

Bottom Founded Production Platforms

Several different types of bottom founded production platforms are currently under active evaluation for year round operation in the ice-covered waters of the Beaufort Sea Basin. The major categories include the conventional artificial island, the caisson, the monocone, and most recently the Arctic Production and Loading Basin.

To a large extent, the question of which type may be used hinges on the water depth associated with the particular field under consideration. Water depths at present promising sites range from 75 feet and 98 feet at Tarsiut and Ukalerk respectively, to 171 feet at Nerlerk, 187 feet at Kopanoar and 211 feet at Nektoralik.

Artificial islands have been successfully used for exploration drilling in water depths to sixty feet. For production purposes suitable artificial islands could readily be constructed in water depths of 75 feet. Caissons are considered feasible for water depths ranging from 75 feet to 150 feet, while for water depths of 150 feet to 250 feet, the monocone would be most suitable. The Arctic Production and Loading Basin concept is currently receiving active consideration for the Kopanoar drillsite.

Artificial Islands

Conventional artificial islands could provide the production platforms for fields in relatively shallow water. To date 17 artificial islands (Figure 4-9) have been built by other operators in the Beaufort, in waters up to 62 feet deep. The primary construction material for these islands would be dredged sand and other indigenous materials. The total fill requirement could range from 6 to 15 million cubic metres. Onsite work leading to the construction of one variant or another of an artificial island could commence as early as 1983.

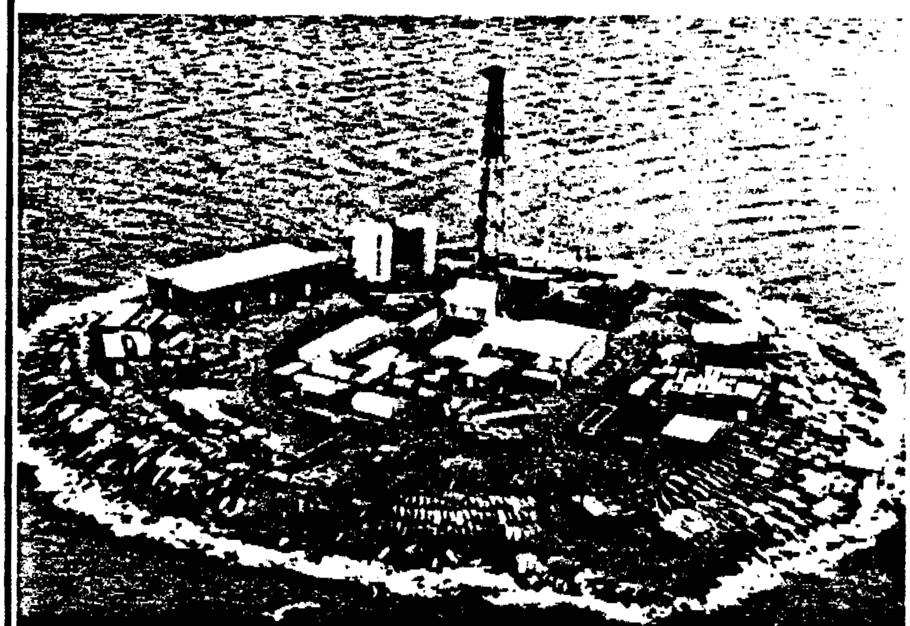


FIGURE 4-9 ARTIFICIAL ISLAND

Arctic Production and Loading Basin

The Arctic Production and Loading Basin is a recently developed platform concept which is being given serious consideration for the Kopanoar site. If feasible, such a facility would provide a protected environment for drilling and production operations, crude oil storage, and a safe location for loading of arctic class icebreaking tankers for operation on a year round basis. The structure would be created by using a combination of sand and ice to construct two semi-circular sections with tanker entry and exit points at each end. The interior dimensions of the harbour would provide a turning radius for icebreaking tankers. See Figure 4-10.

Drilling barges, production/processing barges and storage units would be positioned around the interior perimeter of the harbour. Sufficient space would be available for four (4) drilling rigs; production or processing capacities of up to 350,000 BPD; and crude oil storage up to five (5) million barrels.

Flexibility would exist for bringing in, via subsea pipelines, crude oil production from other prospective fields or satellite locations.

As a result of the encouraging oil discovery at Kopanoar M-13, design engineering and economic feasibility studies are being carried out for the possible construction of an APLB at the Kopanoar site.

The APLB would be constructed mainly from dredged local fine sand, coarse sand, gravel and/or rock which would be transported to the construction site from remote areas. Approximately 60 million cubic meters of sand would have to be dredged, over a 3 to 4 year construction period.

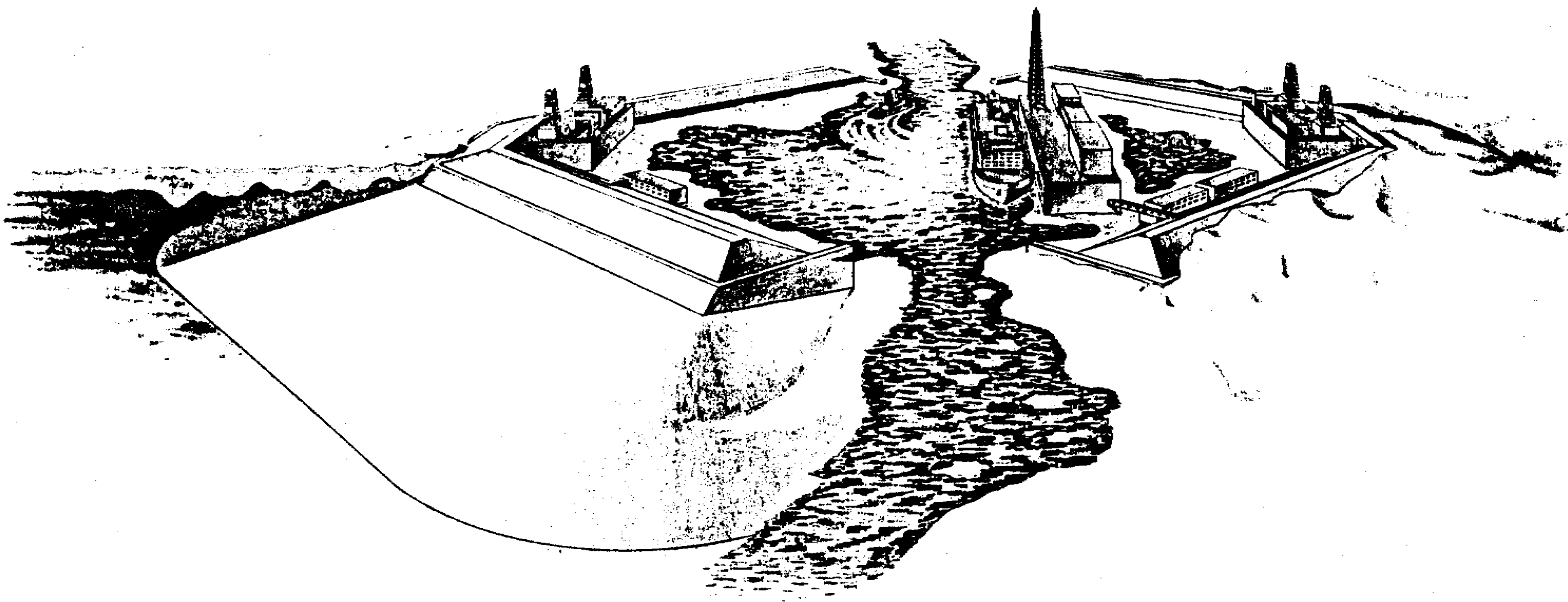


FIG. 4 - 10

ARCTIC PRODUCTION AND LOADING BASIN (APLB)

Caisson Retained Platforms

Caisson retained platforms, like artificial islands, resist ice forces by their large mass and become incrementally more costly with increasing water depth. The caisson platform (Figure 4-11) could be constructed of steel and/or concrete, and would be placed on the sea bottom, probably on a pad of suitable material placed there by dredging. Additional dredged material would be used to fill the caisson. Estimates of the material required to complete a caisson retained platform would range from 0.75 to 4 million cubic metres for the pad, and a further 0.75 million cubic metres for the caisson. Out of the 24 platforms projected in the scenario, approximately 10 may be of the artificial island or caisson platform type.

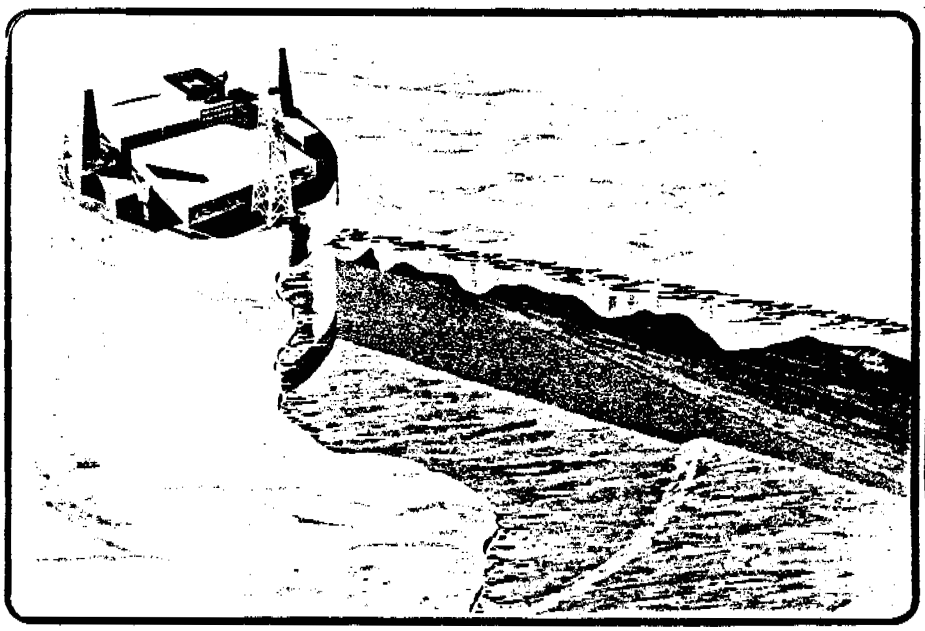
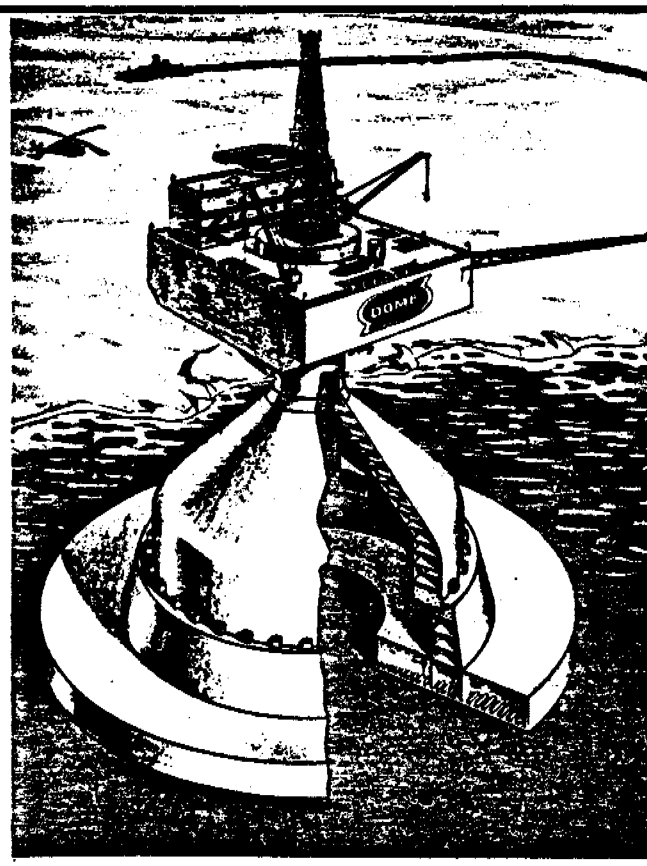


FIGURE 4-11 CAISSON OIL PRODUCTION PLATFORM

Monocone Platforms

For the deeper waters of the Beaufort Sea (generally in excess of 150 feet) a gravity-type monocone platform would probably be used (Figure 4-12). The sloped subsea column combined with a relatively small diameter "neck" at the ice-air interface would permit the structure to take advantage of the relatively poor flexural strength characteristics of sea ice. In this manner approaching ice would ride up and break around the structure.

FIGURE 4-12



ARCTIC PRODUCTION MONOCONE

For the possibility of encounter with ice islands, however, other measures may have to be considered. These could include: moving the island off its collision course; breaking up of the island; designing the monocone structure such that the working deck and neck portion of the platform could be moved off the site; or constructing a subsea berm of dredged material around the monocone, thereby causing ice islands to ground and not reach the structure.

As with all other large structural components, the monocones would be prefabricated in southern shipyards, towed to the Beaufort, and installed over the prospective field. The basic superstructure would be built of steel and/or concrete.

Platforms - General

Regardless of the type of platform selected, all will be fully integrated units capable of carrying out delineation and production drilling, as well as activities associated with the recovery, processing, storage and offloading of hydrocarbons. It is anticipated that each production platform, except the monocone, will be serviced by a minimum of two drilling rigs, and between 40 and 60 wells would be drilled per platform.

The drilling rigs will be conventional, consisting of a substructure, derrick, mud processing and mud pumping components. Provision would be made for the storage of mud chemicals, cement, tubular goods, etc. Living quarters and service functions would be provided for approximately 150 production operations personnel.

According to the scenario, one to three platforms would be required for production purposes per field, with up to 24 platforms on line by the year 2000, when peak production would be attained. On this basis a total of approximately 1200 development production/injection wells would be drilled.

A simplified development schedule for a single production platform capable of producing an estimated 200,000 barrels of oil per day, along with attendant facilities is shown in Figure 4-13).

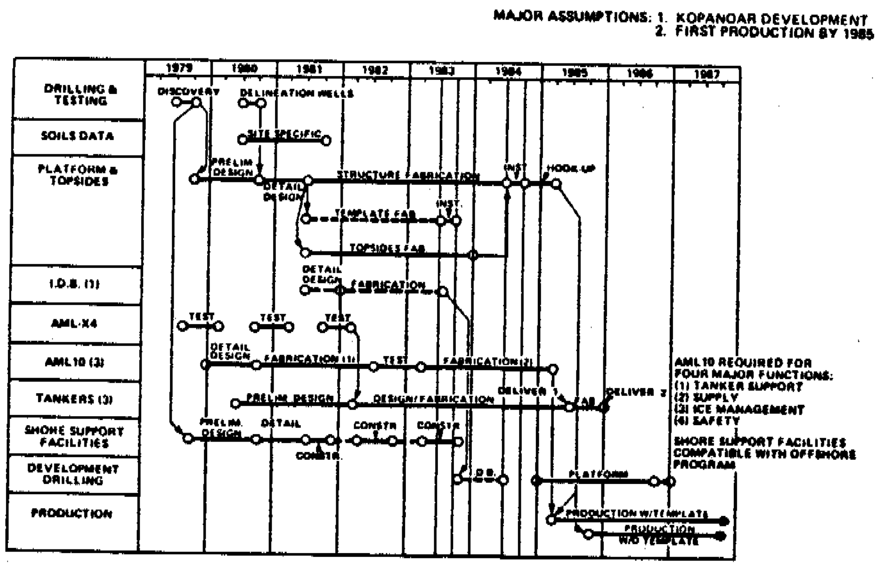
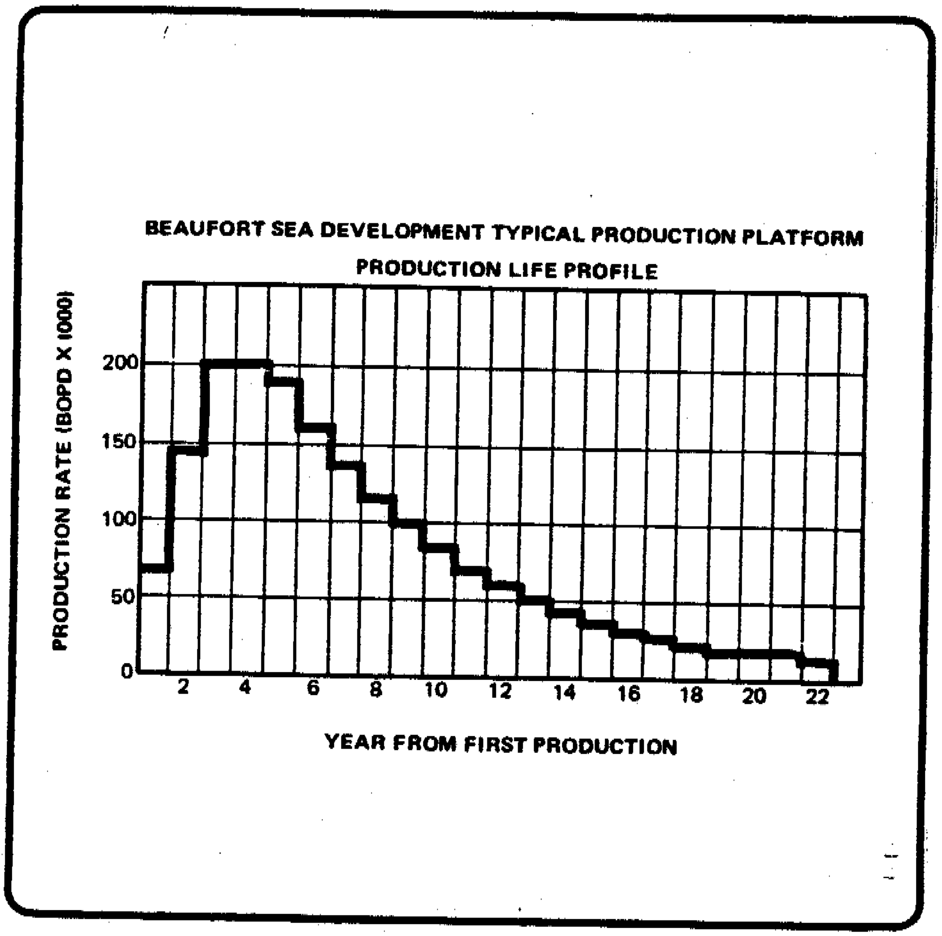


FIGURE 4-13 DEVELOPMENT SCHEDULE FOR A SINGLE PRODUCTION PLATFORM

It should be noted that the installation "window", estimated at one summer season, is preceded by approximately 4.5 years, to permit the design, construction and installation of the appropriate facilities. Finally, Figure 4-14 depicts the hypothetical production life profile which may be expected for a Beaufort Sea platform. The projection anticipates a rapid build-up to the 200,000 barrels of oil per day level, followed by a gradual decline in production from the wells over a 22 year period.

FIGURE 4-14



Subsea Production Facilities

The development scenario presented in this document presumes that the majority of the production will be produced from wells drilled from fixed (bottom founded) platforms. In addition, a minor portion of the development is expected to include wells drilled from floating vessels and completed subsea.

Subsea systems envisaged for the Beaufort Sea would be similar to subsea production technologies already in service throughout the world. Subsea well completions fall into two basic configurations: single or satellite wells, and clustered or template wells.

Satellite wells would be drilled for exploratory or delineation purposes but, after evaluation of their hydrocarbon potential, could be retained for completion as a production well. Satellite wells could be either wet (open to the seawater) or dry (enclosed by a one atmosphere steel chamber). A flowline bundle would carry production either to a platform or to a subsea manifold centre and would provide for control of the production tree from a remote location. Where required, the production tree and flowline would be located below the original sea bottom for ice scour protection.

Clustered wells could be drilled where it proves to be more advantageous to drill wells from a floating rig and complete them subsea rather than install a platform.

Oil Storage and Transfer Systems

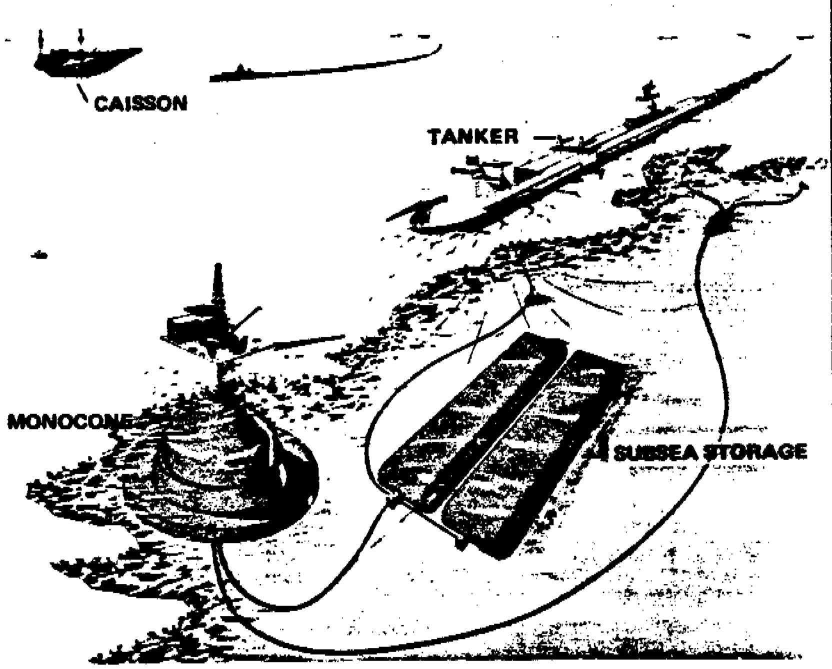
Offshore pipelines and production flowlines in the Beaufort Sea are expected to be conventional. Construction and installation will generally have to accommodate the short open water seasons available, although it is conceivable that underwater pipelining could be done in the shorefast ice zones during the winter months. Additionally, in shallow waters, there will be the need to protect pipelines from ice scour. This will most likely be accomplished through trenching/burial below the depth of ice scour, utilizing cutter suction dredges, backhoes, plows, or other technologies as may be required.

The storage of produced crude oil may be achieved in a variety of ways depending on the type of production platform involved. However, before proceeding, it must be stressed that all oil will be "dead" crude having a Reid Vapour Pressure (RVP) of 10-12 or less, prior to being placed into storage.

Where crude oil storage is to be accommodated at offshore platforms, a storage capacity of 2 to 3 million barrels will generally be required. For floating production platforms, the crude may be stored in tanks within the 500,000 DWT vessel itself, or it could be transferred into a second floating tanker vessel, such as a Class 10 barge. Oil storage could readily be incorporated within one or more vessels located within the offshore harbour concept.

Alternatively, the crude may be transferred into subsea storage tanks (Figure 4-15). These storage tanks would utilize conventional technology, would be constructed of steel or pre-stressed concrete, and would have a compartmentalized total capacity of up to 3 million barrels. The tanks would be positioned on or below the seafloor, as may be appropriate, adjacent to the production platform.

FIGURE 4-15



BEAUFORT SEA PERMANENT OIL PRODUCTION SYSTEM

In the case of the some bottom founded platforms, particularly caissons or artificial islands, oil storage capacity may be provided as an integral part of the facility. It is anticipated that caissons may be able to store up to 3 million barrels within the structure. For the artificial island concept, similar storage capacities can be accommodated.

A further alternative to all of the preceding options is that production of both oil and gas may be transported to a shorebased facility via pipeline for subsequent processing and storage.

Offloading of the crude from storage tanks to Arctic Class tankers would be carried out through the application of conventional technology modified to suit the specific conditions. One system for loading the subsea storage tanks is to use steel pipelines which would transfer the crude to subsea manifolds which in turn would be connected to marine risers feeding into the moored tankers. Oil from onshore storage tanks would most likely be returned offshore via pipeline to an offshore terminal for loading.

BEAUFORT REGION DEVELOPMENT CONCEPTS - ONSHORE FACILITIES

In order to support the development components envisaged for Dome's Offshore Beaufort interest lands it is clear that onshore facilities will play an increasingly important and more diversified role. Land is required for harbour sites, marine terminals, pipelines, engineering, and research centres, administrative offices, housing, construction or fabrication sites, and storage/stockpile areas.

General

This section describes the land requirements that can be currently forseen by Dome Petroleum in the Beaufort Sea development over the short, medium, and long term. Seven major onshore sites or site classes are discussed including:

- Tuktoyaktuk
- Inuvik
- McKinley Bay
- Wise Bay
- Deep Draft Harbour site
- Marine Terminal site
- Auxilliary requirements, such as borrow pits, access roads, pipelines.

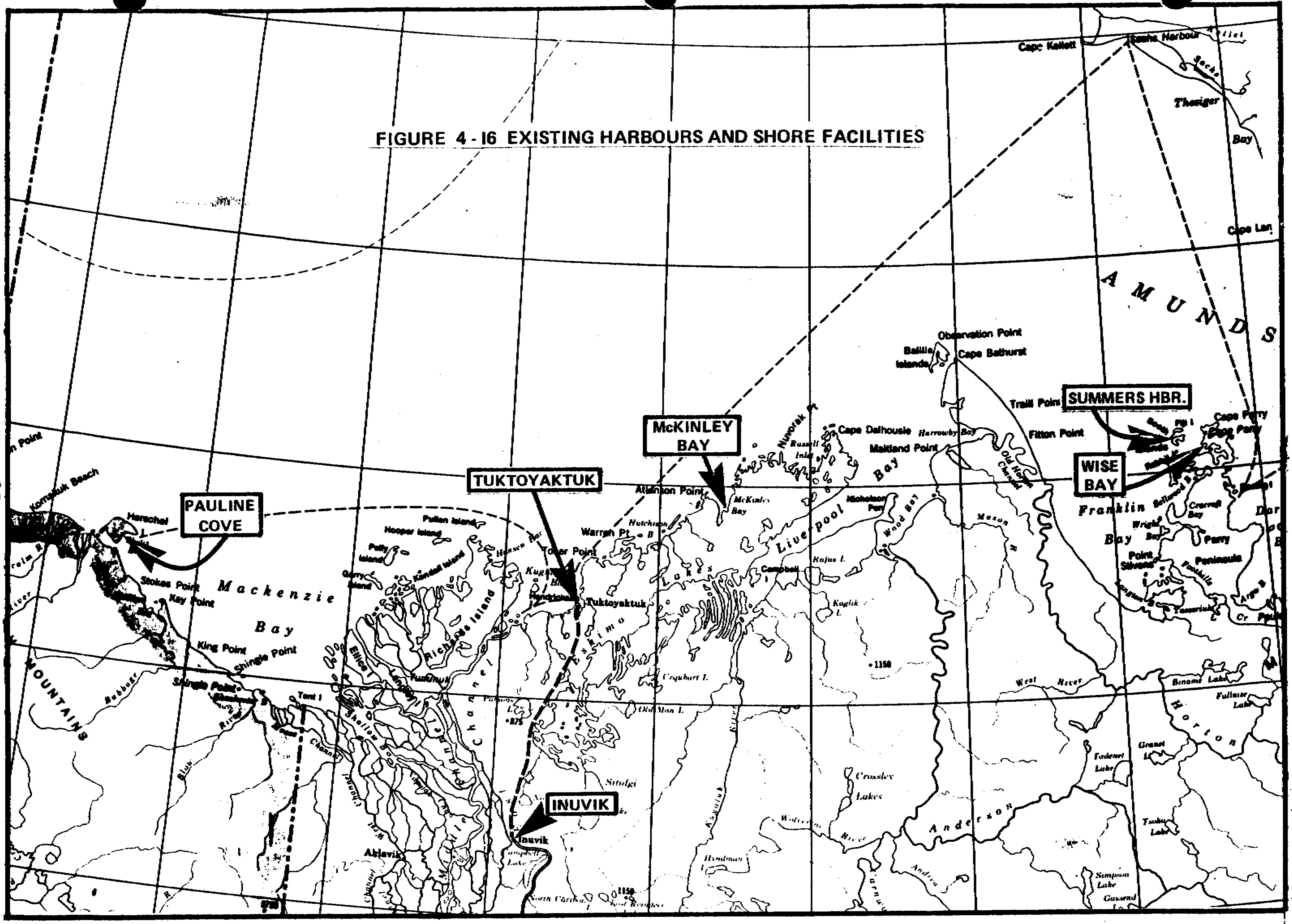
The ultimate determination of all onshore requirements and locations will depend on the location, nature, magnitude and timing of actual offshore hydrocarbon discoveries, as well as the specific technology of development to be employed in the Beaufort.

In general, criteria for siting onshore facilities depends on environmental and social considerations but is initially restricted by physical and operational requirements. For example, a site with safe navigation channels and adequate shore acreage reduces the probability of damage to vessels and structures. A site with naturally adequate water depth, maneuvering room, suitable level land, and close to offshore activities costs less to develop and operate. Permanent marine service bases and harbours should be close to the offshore rigs and production platforms they support to attain operational efficiency and reliability. Onshore oil terminals and LNG plants must be located at sites where there is sufficient offshore water depths, while being close to production platforms to minimize the cost of pipeline construction. These same physical and operational requirements will also largely control the siting of borrow pits, pipelines, roads, communication sites and other auxiliary requirements.

From an evaluation of these requirements there are only a limited number of useable coastal areas along the Beaufort coastline where potential industrial facilities can be located.

Some good natural harbours and shore facilities exist in the Beaufort region, and are used by Dome/Canmar (Figure 4-16). These sites have included Tuktoyaktuk, Inuvik, Pauline Cove, Summers Harbour and communication facilities at Hooper Island, Atertak, and Atkinson Point. Additional mooring facilities have been dredged at McKinley Bay in response to the Company's needs for a 10 metre deep overwintering anchorage. Also, Wise Bay is being established as a supplementary marine fueling site due to its excellent 20+ metre deep natural harbour.

FIGURE 4-16 EXISTING HARBOURS AND SHORE FACILITIES



- 23 -

Over the short term (1980-81) the administrative, support, and supply services provided by Inuvik and Tuktoyaktuk, combined with the winter moorage capabilites of McKinley Bay and Wise Bay/Summers Harbour, should be sufficient for the Company's needs.

Medium term (1982-86) requirements are projected to include all of those provided at these sites, but at increased levels of activity. In addition, there will be the need for a harbour capable of supporting year round activities. This harbour should be at least 17 m deep to permit refueling, mooring, and dry-docking of vessels such as Class 6 icebreakers and Arctic Drilling Barges (ADB's).

Over the long term (1985-2000+), in addition to those requirements previously described, the area of deep (17 m) draft harbour available would have to be incrementally increased to accommodate a larger fleet of deep draft vessels requiring refueling, mooring and possibly dry-docking for maintenance purposes. The vessels that may have to be serviced at this time could include Class 10 icebreakers, ice breaking tankers, and Arctic drilling or production barges. The deep draft harbour could also be utilized for the modularized assembly of production components, and as a marine terminal for processing and storing oil and LNG. Due to the large offshore area to be serviced it may be necessary to have one such harbour in the western Beaufort (Yukon Coast) and a further harbour at Wise Bay or on the Bathurst Peninsula. The location for a deep draft port remains to be determined.

Tuktoyaktuk

The operations and supply base for Dome's current exploration drilling program is located at Tuktoyaktuk (Figure 4-17). This site offers several advantages for continuing to serve as a supply base including: its central location to the Dome interest offshore operations, the existing harbour, shore facilities, airstrip, and other support services.

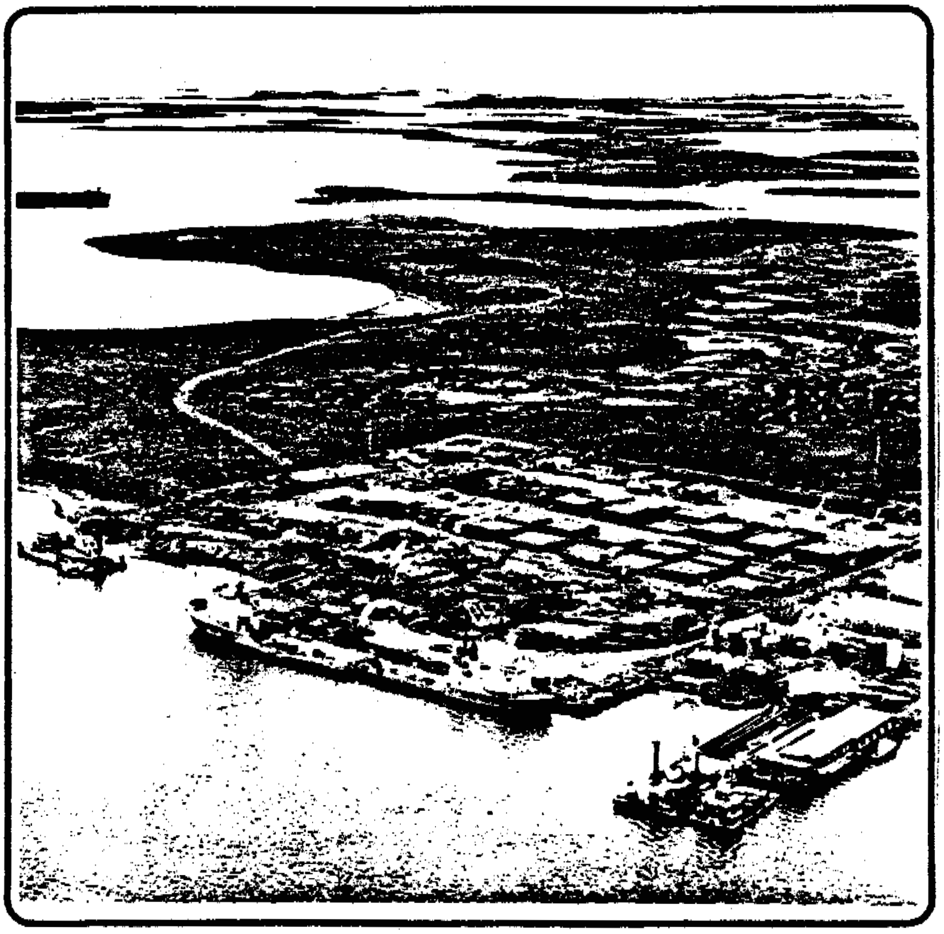


FIGURE 4-17 TUKTOYAKTUK SUPPLY BASE

The support functions envisaged for Tuktoyaktuk in the future will include:

1) harbour and docking facilities for shallow draft vessels
2) shallow draft ship repair and maintenance
3) light steel fabrication/machine shops, etc.
4) warehousing and storage for equipment and materials
5) camp facility for supply personnel
6) accommodation for personnel in transit to and from Company field operations
7) major airport facility to support offshore activities
8) aircraft repair and maintenance

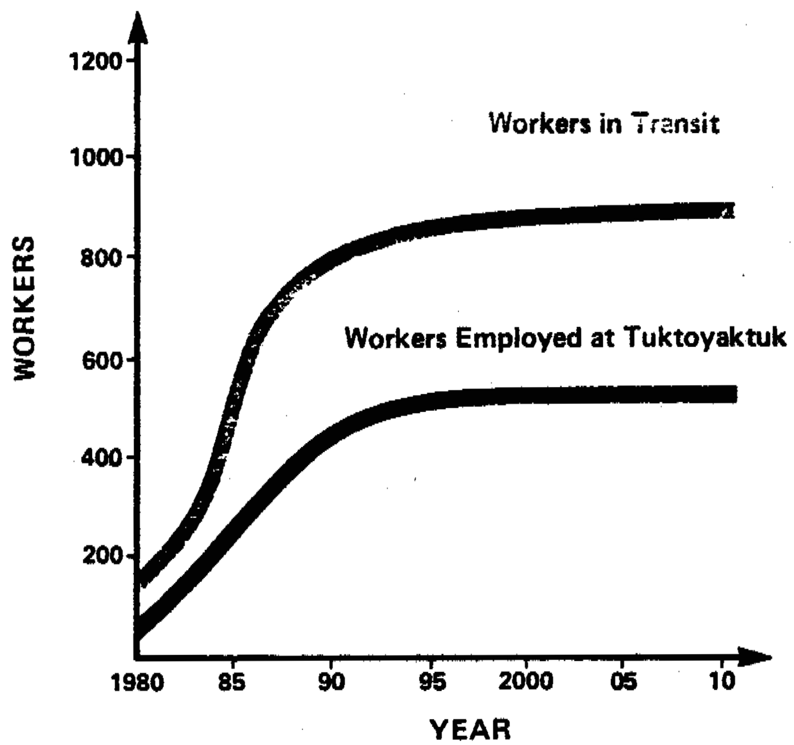
With increasing levels of offshore activity, base supply and support functions have been and will be expanded and upgraded.

Tuktoyaktuk Harbour has acceptable depths and is spacious. Average depths are well over 10 metres, covering an area in excess of four km^2. However, access into the harbour is limited to vessels drawing 5 metres or less due to shallow water depth in the entrance channel. Current plans to dredge the entrance channel 6 metres will enhance the shallow draft capability and long term future of this harbour. Experience in the construction and operation of the new channel will help determine the feasibility and economics of possible further deepening.

The present dock at Tuk Base is 120 metres long with a draft of 4.3 metres and can accommodate two supply boats at once. In 1980, proposals include adding 160 metres of dock in a stair-step configuration out into the harbour. The additional dock area will allow a total of four supply boats plus two barges to load or unload simultaneously. The total area of reclaimed land is about 4340 square metres.

The present Canmar base at Tuktoyaktuk includes a 6 hectare storage yard, dock/staging area and camp facility accommodating nearly 200 people. With anticipated needs, this facility could be expanded as necessary and could employ up to 500 seasonal workers. An additional 300+ employees could be temporarily accommodated there in transit to and from construction and operation sites. (Figure 4-18)

FIGURE 4-18



ESTIMATED EMPLOYEES AT TUKTOYAKTUK

New facilities are in the planning stage for Tuk and construction could commence in 1981 if field development proceeds. The facilities may be on land or barge-mounted, but in either case will have accommodation for 350 people, be capable of feeding 600 people a day and have 50 offices. The barge/floating hotel concept has the advantages of low cost construction in the south and low installation cost as no land fill would be required.

The airstrip at Tuktoyaktuk is currently being upgraded and lengthened to 1,600 metres to permit the landing of large commercial aircraft. Additional land is being acquired near the airstrip to accommodate a large hangar, terminal, offices and maintenance shops.

Tuktoyaktuk will continue to be a focal point for the Company's marine and drilling operations. Dome has a history of successfully working in the community, and a related infrastructure has already developed there. The nature of future operations will be similar to those now carried out in the shallow draft harbour, but would increase in intensity and size.

Inuvik

A wide range of services and supplies are already being provided in Inuvik to support the exploration drilling operation. For offshore development, activities would be expanded. Administration offices, field engineering and research offices, the regional operations office, and the communications headquarters could be located at Inuvik. It could also serve as a major supply and service centre for related activities such as commercial airlines services, supply company field headquarters, and service-related industries.

Expansion of activities at Inuvik would be consistent and compatible with the established infrastructure, social setting, and environment.

McKinley Bay

A 10 metre channel and mooring basin are being dredged in McKinley Bay during 1979-80 to permit overwintering of the present drilling fleet for the short and medium terms.

Over the long term, the basin could be converted to a deeper draft harbour. In this event, the access channel and basin would require deepening to 17 metres, involving the dredging of an additional 25 million m^3 of material. Further investigation and operational experience is required to evaluate this possibility.

Terrain conditions adjacent to McKinley Bay are generally unfavorable to the development of essential onshore facilities. Therefore if McKinley Bay was pursued further for this purpose, consideration would have to be given to the construction of an "artificial island" shore base, perhaps utilizing some or all of the dredged material excavated during the process of deepening the harbour area.

Wise Bay

Wise Bay located on the Parry Peninsula continues to represent the best deep draft natural harbour for vessels drawing up to 25 metres of water in the Beaufort Sea area. The Company has applied for a leasehold interest on approximately 7 hectares of land for the development of a tank farm and small support camp to serve short term uses.

In the medium term, Wise Bay appears to be a suitable site for fueling and servicing of deeper draft vessels such as Class 6 to 10 icebreakers, and Arctic Drilling Barges. In the long term prefabricated offshore production systems could be assembled at Wise Bay.

The expansion of Wise Bay as a major deep draft harbour is possible but would depend on the development of eastern Beaufort oil and gas. It is too far removed from current areas of interest (e.g. 410 km from the Kopanoar discovery) to warrant the development of a deep draft harbour and marine terminal.

Deep Draft Harbour

Deep draft vessels, year round operations, and the development of the oil and gas reserves will necessitate the development of a deep draft harbour in close proximity to the offshore discoveries. As has been discussed, there are some limitations to sites such as Wise Bay, Tuktoyaktuk, and McKinley Bay. If Wise Bay's deep offshore waters and excellent terrain conditions were as close to the drilling operations as McKinley Bay or Tuktoyaktuk, locating a deep draft harbour would be an easy decision. This however is not the case.

A recent in-house review (Dome 1979) identified over 20 harbour sites of which the 10 most promising were evaluated in detail. As a result of this analysis, King Point on the Yukon coast, Baillie Islands at Cape Bathurst and Wise Bay on the Cape Parry Penisula came out most favorably.

In addition, two government reports identified and evaluated potential deep draft harbours and marine terminals along the Alaska, Yukon and N.W.T. coasts.

A U.S. Dept. of Commerce, Marine Administration report entitled <u>Arctic Marine Commerce</u> evaluated 28 sites and concluded:

> "The best candidate site for a very deep water terminal (86 ft 3 miles offshore) to export oil and gas supertankers from the Arctic Slope is Babbage Bight (King Point), about 40 miles ~~east~~ west? of the U.S.-Canadian border."

The Canadian Department of Public Works report entitled <u>Herschel Island: Feasibility of a Marine Terminal</u> indicated that for year round operation of a deep draft icebreaking tanker (326,000 DWT Class, 76 ft draft) the most favourable marine terminal location would be Babbage Bight-King Point.

Results of all this work clearly show the potential of King Point as a deep draft harbour and a location for a land based marine oil terminal.

Even though the location of a deep draft harbour and a marine oil terminal remains to be determined, this section discusses the potential of using an area such as King Point.

Figure 4-19 shows an example of how King Point could look as a deep draft harbour. This example shows a 2 km long breakwater extending into water 20 m deep to provide anchorage and drydocking facilities for shallow, medium and deep draft vessels. On shore a 3600 metre airstrip, camp, tankfarm, storage, and staging area cover 16 hectares of land.

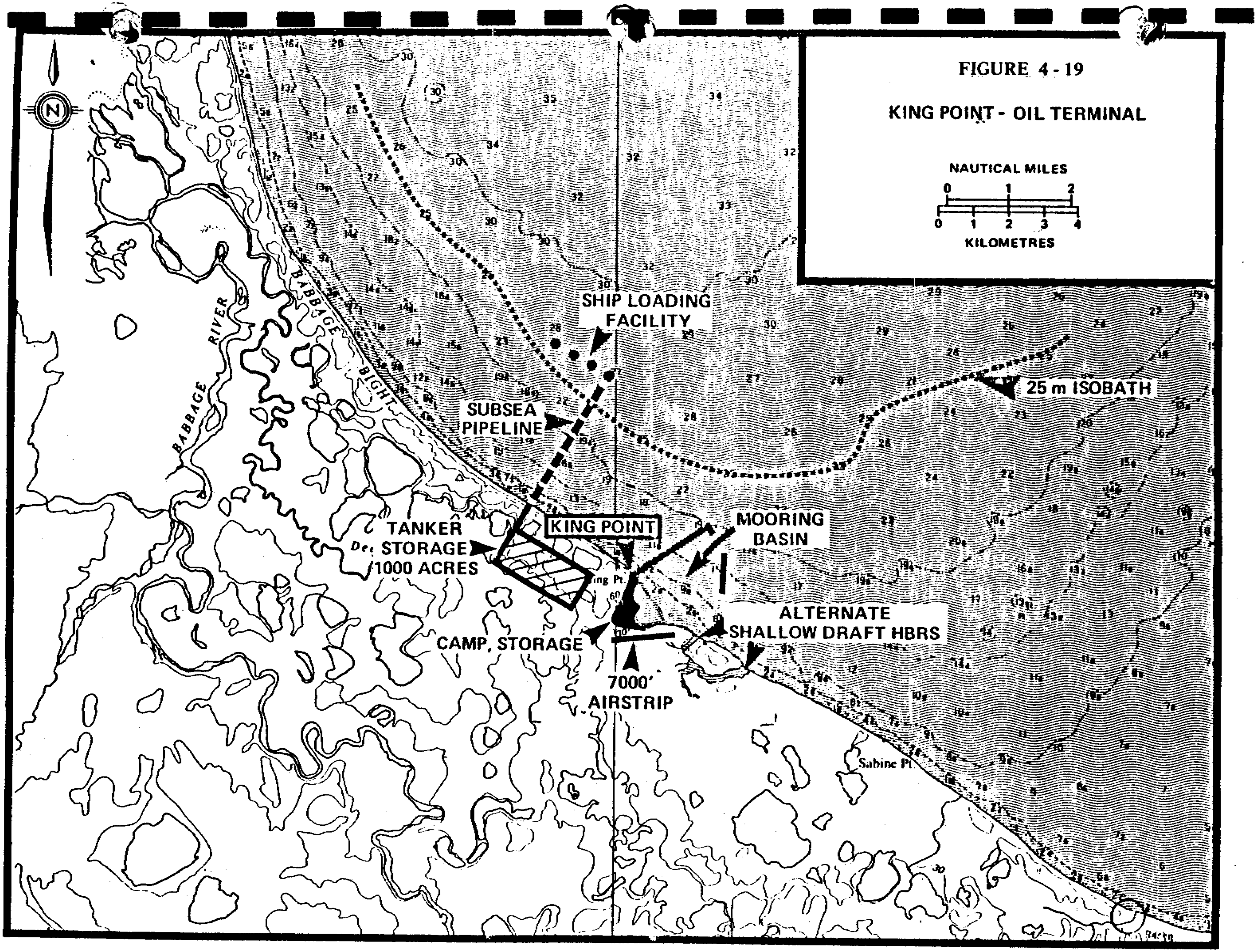


FIGURE 4 - 19
KING POINT - OIL TERMINAL
NAUTICAL MILES
0
1
2
0
1
2
3
4
KILOMETRES
N
BABBAGE RIVER
BABBAGE BIGHT
SHIP LOADING FACILITY
25 m ISOBATH
SUBSEA PIPELINE
TANKER STORAGE /1000 ACRES
KING POINT
MOORING BASIN
ALTERNATE SHALLOW DRAFT HBRS
CAMP, STORAGE
7000' AIRSTRIP
Sabine Pt.

MARINE TERMINAL

In the long term the King Point region could be developed into an oil marine terminal. Oil would be brought ashore in much the same manner as in the North Sea. Oil from the Ninian and Brent fields is brought by subsea pipeline, some 200 km to the terminal at Sullom Voe.

In this case Kopanoar is 180 km from King Point. As in Valdez or Sullom Voe, the terminal and harbour site at King point could cover between 499 hectares (Valdez) and 1200 hectares (Sullom Voe). This would include the harbour, docks, camp storage tanks, power plant, office building, fire station and oil spill contingency equipment. Figure 4-20 shows a comparison of the amount of land for the Valdez and Sullom Voe terminals.

From the figure it is clear that King Point region has the potential to accommodate such a facility.

Some of the possible advantages of locating a deep draft harbour and marine terminal at King Point include:

- centralization of major land use activities in one region
- its proximity to offshore and onshore hydrocarbon reserves
- the 25 metre deep offshore waters within 4 km of shore
- the deep offshore waters providing maximum flexibility for vessel navigation during winter months

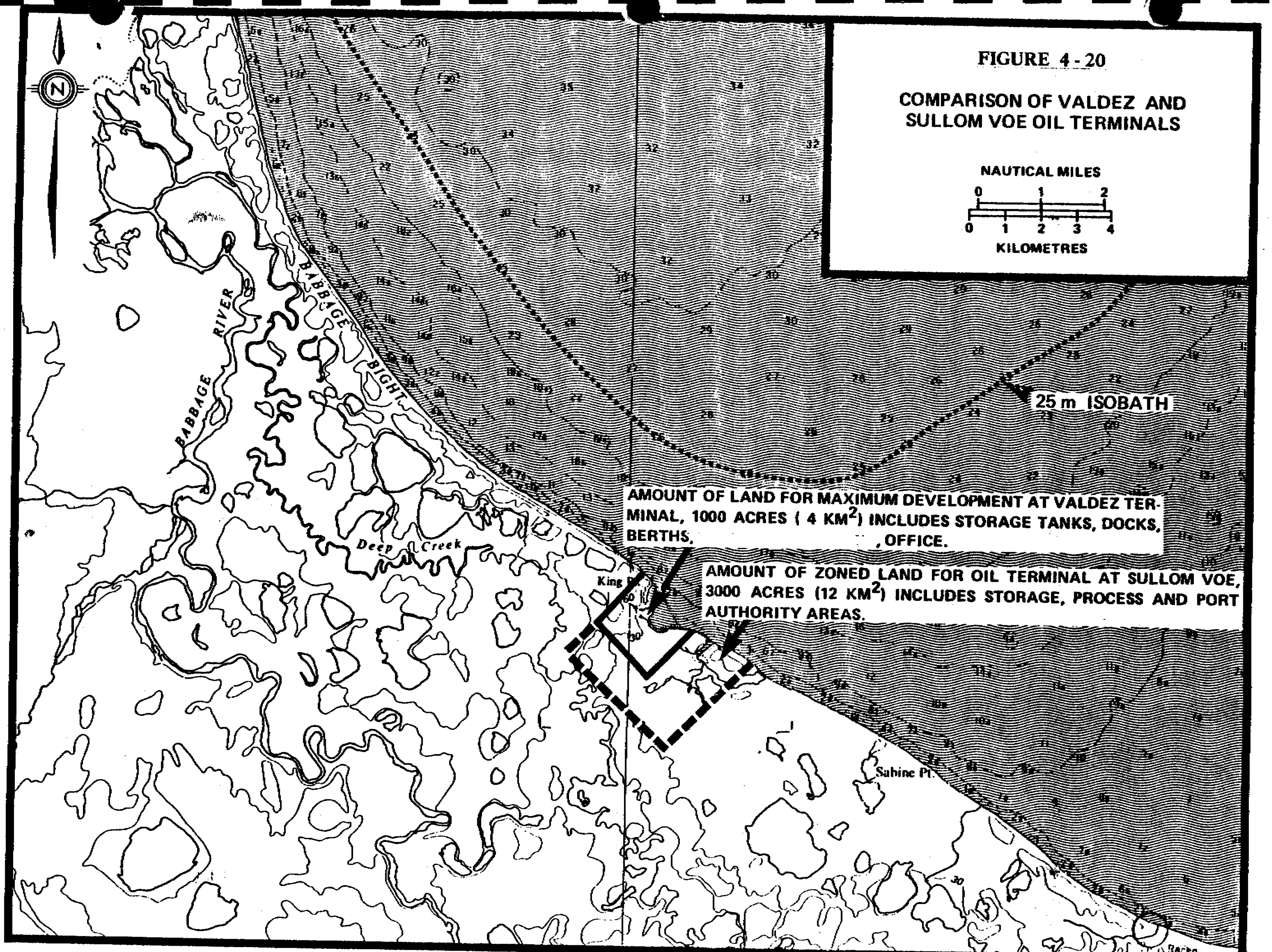


FIGURE 4-20

COMPARISON OF VALDEZ AND SULLOM VOE OIL TERMINALS

- the capability of modifying and expanding the harbour with minimum dredging and as the need requires
- the quantity of suitable level land adjacent to King Point
- the quantity of gravel at the site, (i.e. over 53 million m^3 of gravel within a 10 km radius).
- the presence of a large granite deposit (40 km SW) which would be potentially important in the construction of offshore structures

Auxilliary Requirements

In addition to the major land use requirements that have previously been discussed, there will be a need for associated onshore facilities as hydrocarbon development proceeds.

Appropriate sources of fresh water would be needed to supply operational requirements. Solid wastes, both combustible and non-combustible, would require disposal by techniques such as incineration or landfill.

Land based communication facilities and navigation stations for vessels, will have to be provided as the need arises.

Borrow pits will have to be developed to provide gravel and rock for the construction of roads, airstrips, foundations, and armouring of offshore structures. Land would be required for, and disturbed by the pits, stockpile sites, overburden dumps, and drainage water treatment ponds. Extraction, crushing, and transportation equipment would be utilized to perform these functions.

Roads would be required to haul material from borrow pits, transport personnel between accommodation and transportation or working facilities; service onshore pipelines for hydrocarbons, water and sewage; and possibly to link King Point to the Dempster Highway.

Figure 4-21 shows an example of how offshore and onshore oil and gas finds could be linked to a marine terminal at King Point. This gathering system would use the King Point terminal as a centralized storage and transfer point for tanker shipment south. The major land pipelines could be restricted to corridors within the MacKenzie Delta region although some corridor may eventually be required along the Yukon coast. At a later date, if required, this same gathering system could be adapted to a direct overland pipeline route to southern markets.

At such time as overland pipelines are used to transport hydrocarbons to southern markets there will be a need for a gas processing plant and oil pipeline terminal. A central development zone in the delta region may resolve many of the local concerns and still be compatible with all oil and gas operations in the region. Figure 4-22 shows the potential locations of Campbell Lake, North Inuvik site, Devils Lake and Parsons Lake for the development of a gas processing plant and oil pipeline terminal.

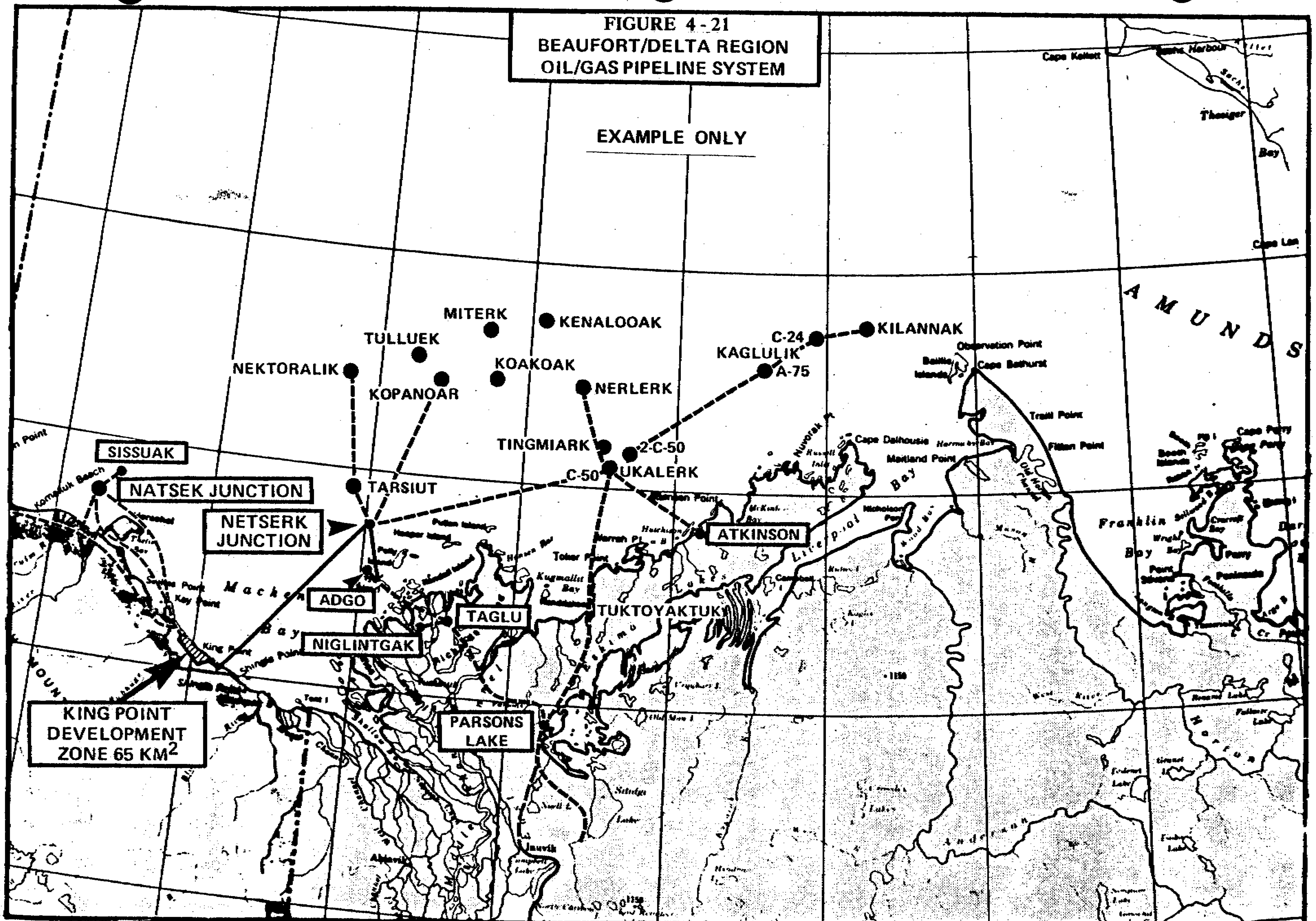
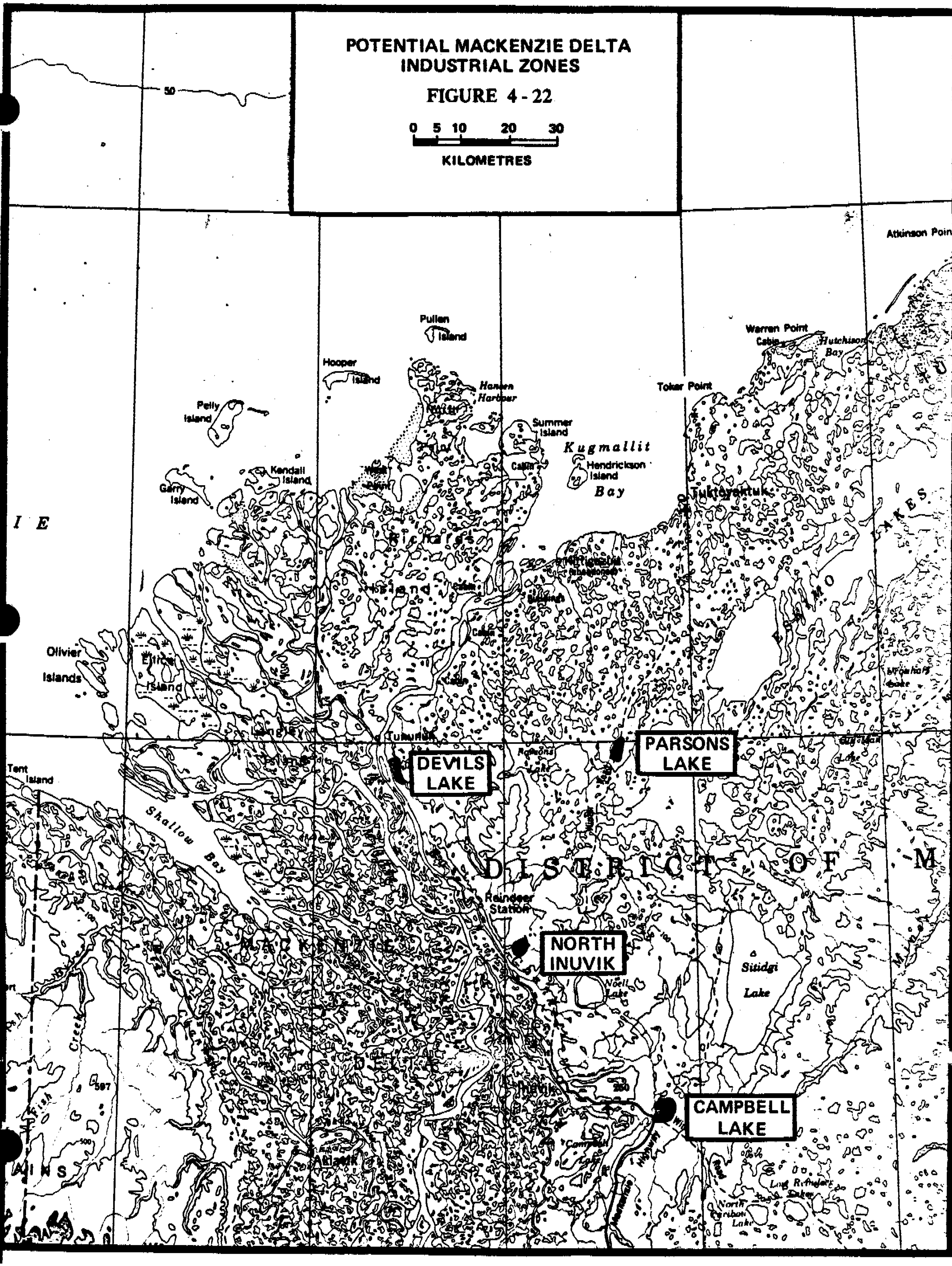


FIGURE 4-21
BEAUFORT/DELTA REGION
OIL/GAS PIPELINE SYSTEM

POTENTIAL MACKENZIE DELTA INDUSTRIAL ZONES

FIGURE 4 - 22



MARINE TRANSPORTATION

The scenario has assumed that Arctic Class icebreaker tankers will be used, at least initially, to move oil out of the Beaufort Sea. A staged, field by field development is envisaged, that will lead to the incremental build-up of produced oil flow peaking at approximately three million barrels per day by the year 2000.

The threshold of reserves required to initiate oil movement by tankers is approximately 1/10th of that required to finance a pipeline. This results in earlier cash flow, and the ability to increase the facilities incrementally as reserves and markets grow. In addition, the ships will be constructed in southern Canada, thereby permitting better cost control, minimal environmental and social impacts, and the distribution of the workload throughout Canada over an extended period of time.

On this basis, the Company proposes to initiate transport of oil with Arctic Class tankers. Once the Beaufort Sea Basin oil production rate approaches or exceeds 1.5 million barrels per day, it would become economically attractive to move oil by pipeline to southern markets. However, tankers would probably continue to supplement pipeline transport as appropriate.

Proposed Routes

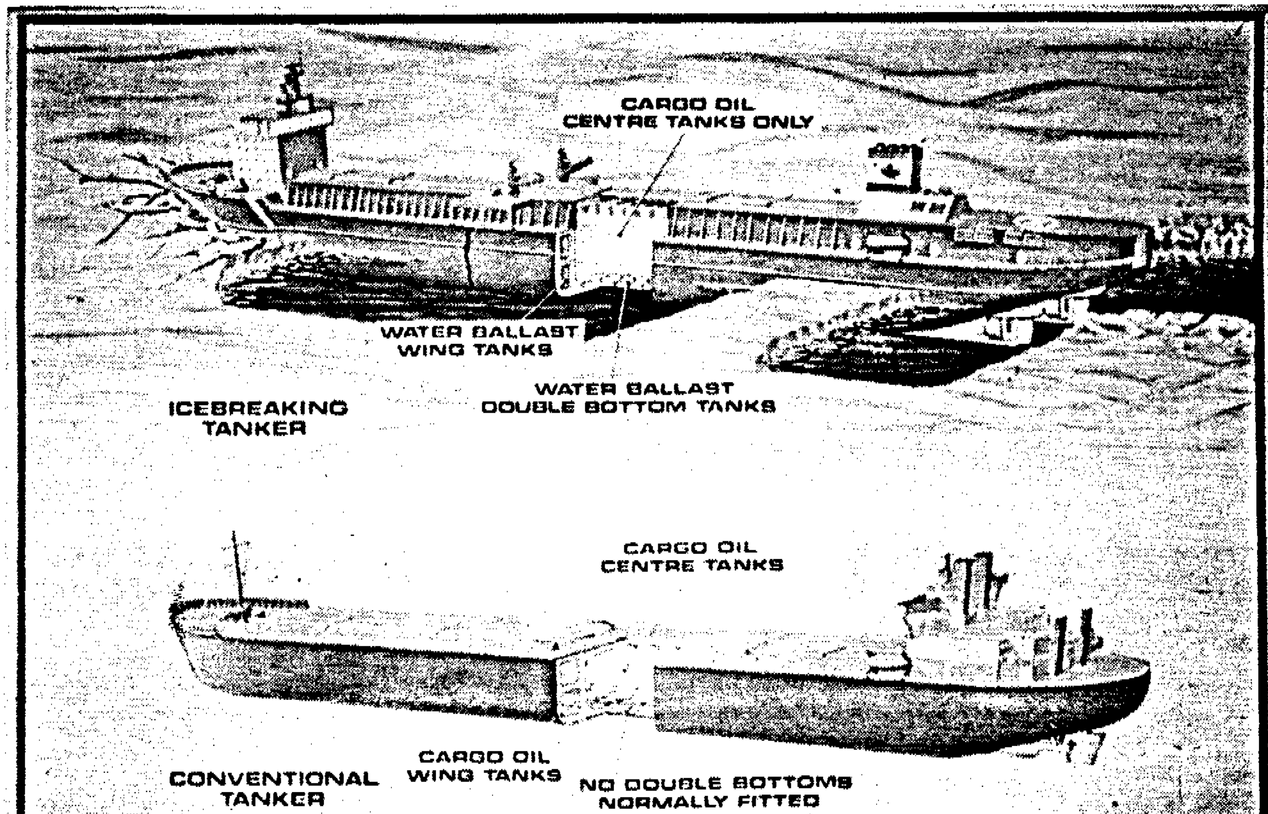
It is anticipated that Arctic Class icebreaker tankers would initially transport oil through the eastern Northwest Passage to eastern North American ports. The specific route would vary with the seasons, prevailing ice conditions, and other factors, but would generally proceed through Prince of Wales Strait, across Viscount Melville Sound, along the north side of Parry Channel into Baffin Bay, and then near the Greenland coast to the south (Figure 4-23). The route to western markets would generally follow the 30 metre isobath around Alaska's North Slope through the Bering Strait.

FIGURE 4-23 PROPOSED TANKER ROUTES

The Ships

The physical difficulties inherent in moving ships through arctic ice on a year round basis are formidable, as are the technological achievements in icebreaker design, construction, and subsequent performance which will be required. Recent successful experiences with the Company's new experimental AML-X4 icebreaker, and the results of ongoing multi-million dollar research efforts are very encouraging. The results of this research should auger well for the development of safe Arctic Class tankers.

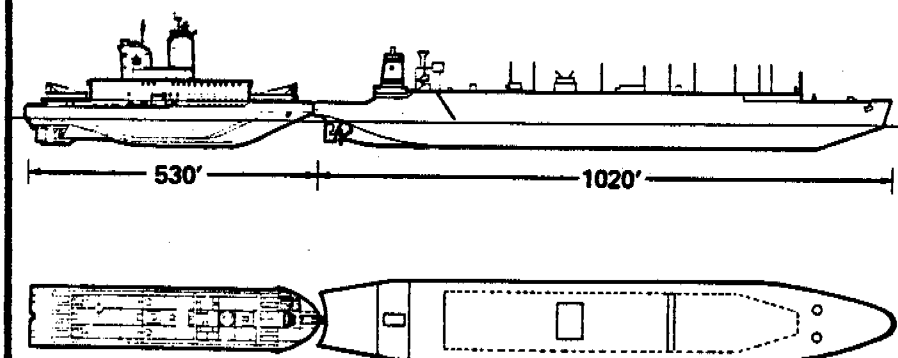
The tankers used to transport oil through the Arctic Seas will be Class 10 double-hulled vessels of approximately 200,000 DWT, and with an oil storage capacity of 1,400,000 barrels, (Figure 4-24). This figure also illustrates the future tanker in comparison with its more conventional sister ships currently used in ice-free waters.



COMPARISON OF IBT VS CONVENTIONAL TANKER

FIGURE 4-24

Of particular note is the fact that in the arctic vessels, oil will be carried only in the center tanks, separated from the outer hull by ballast water wing tanks, thereby greatly reducing the chances of oil losses through puncturing of the hull. In addition, the bridge and superstructure will be located near the bow of the vessel to improve navigation, visibility and directional control. The large variable pitch propellors, protected by nozzles, will be placed as deep as possible to minimize ice encounters; and the stern of the vessel will be notched to receive additional power to be provided by class 10 icebreaker "locomotives" (Figure 4-25) as may be required.



ARCTIC MARINE LOCOMOTIVE PUSHING AN LNG CARRIER OR ICE REINFORCED OIL TANKER

FIGURE 4-25

The so-called Arctic Marine Locomotives (AML-10) will serve to assist icebreaker tankers by "close coupling" to these tankers and pushing them through the more difficult regions of the Northwest Passage, as may be required. The relevant dimensions and power related statistics for both the icebreaker tanker and the AML-10 are provided in Table 4.1.

TABLE 4.1 DIMENSIONS AND POWER STATISTICS OF THE FUTURE ARCTIC TANKER AND AML-10

	Arctic Tanker	AML-10
Length (m)	372	162
Breadth (m)	50	34
Depth (main deck) (m)	28	30
Displacement (DWT)	200,000	45,000
Horsepower	50-100,000	100,000

The transport of oil to market would be initiated by two tankers to service early flows from the first field. Thereafter, further tankers would become operational on the basis of two per 80,000 barrels of production. The current scenario projects use of between 10 and 20 tankers at the peak of tanker utilization.

The average round trip travel time to the east coast of Canada or the U.S. would range from 28-35 days, depending on conditions encountered. Projected cruising speeds are for 20 knots in open waters, reducing to approximately three knots in 10-foot thick ice and perhaps some ramming in heavier ice. All vessels will be equipped with the most advanced ship-borne navigational systems available, in order to permit the safest possible passage through all areas, particularly the higher traffic regions in the approaches to southern ports.

Vessels requiring maintenance (particularly dry-docking) will most probably be serviced in southern ports. However, accommodations may have to be made at a suitable deep water location, e.g. Wise Bay, to handle such a vessel in the event of an emergency.

Ancilliary Activities

The efficient and safe operation of icebreaker tankers will require significant updating of the bathymetric data along portions of the marine route, and the placement of shorebased navigational aids in key locations. Continuing cooperation between Dome Petroleum and the federal government will ensure the timely and satisfactory completion of these important undertakings.

Similar to the operational control and safety system philosophy built into all other phases of the Beaufort Sea development, the tanker crude transfer and storage systems would be designed to very stringent industry and government design codes and regulations.

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5. ENVIRONMENTAL SETTING

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5 ENVIRONMENTAL SETTING

The environmental setting which follows represents a highly condensed summary of important environmental considerations for the entire area which may be influenced by Dome's development plans. Since the scenario centres on the marine environment and its contiguous coastal zone, the setting likewise concentrates on this region. In the interests of readability, few references to the literature are cited in this summary.

CLIMATE

Regional Climate

In the Arctic, the angle of incidence of the sun's rays through the atmosphere is low. As a result, the atmosphere there receives less solar heat than in lower latitudes where the angle is higher. Some of the heat which does reach the atmosphere is reflected back into space by the cloud cover usually present over the Arctic. Of the heat which reaches the earth, only a small percentage is actually absorbed by it because of the high reflectivity of ice and snow which covers the Arctic most of the time.

The net result is a generally cold climate, with approximately 160 days per year having minimum temperatures of 0° F (-18° C) or lower in the southern Beaufort Sea, ranging to 200 or more days per year with 0° F or lower in the Viscount Melville Sound Area (Figure 5-1). In addition, much of the ground is permanently or discontinuously frozen (Figure 5.2) and large expanses of sea and glacial ice remain throughout the brief arctic summer, thereby further contributing to cooling of the atmosphere.

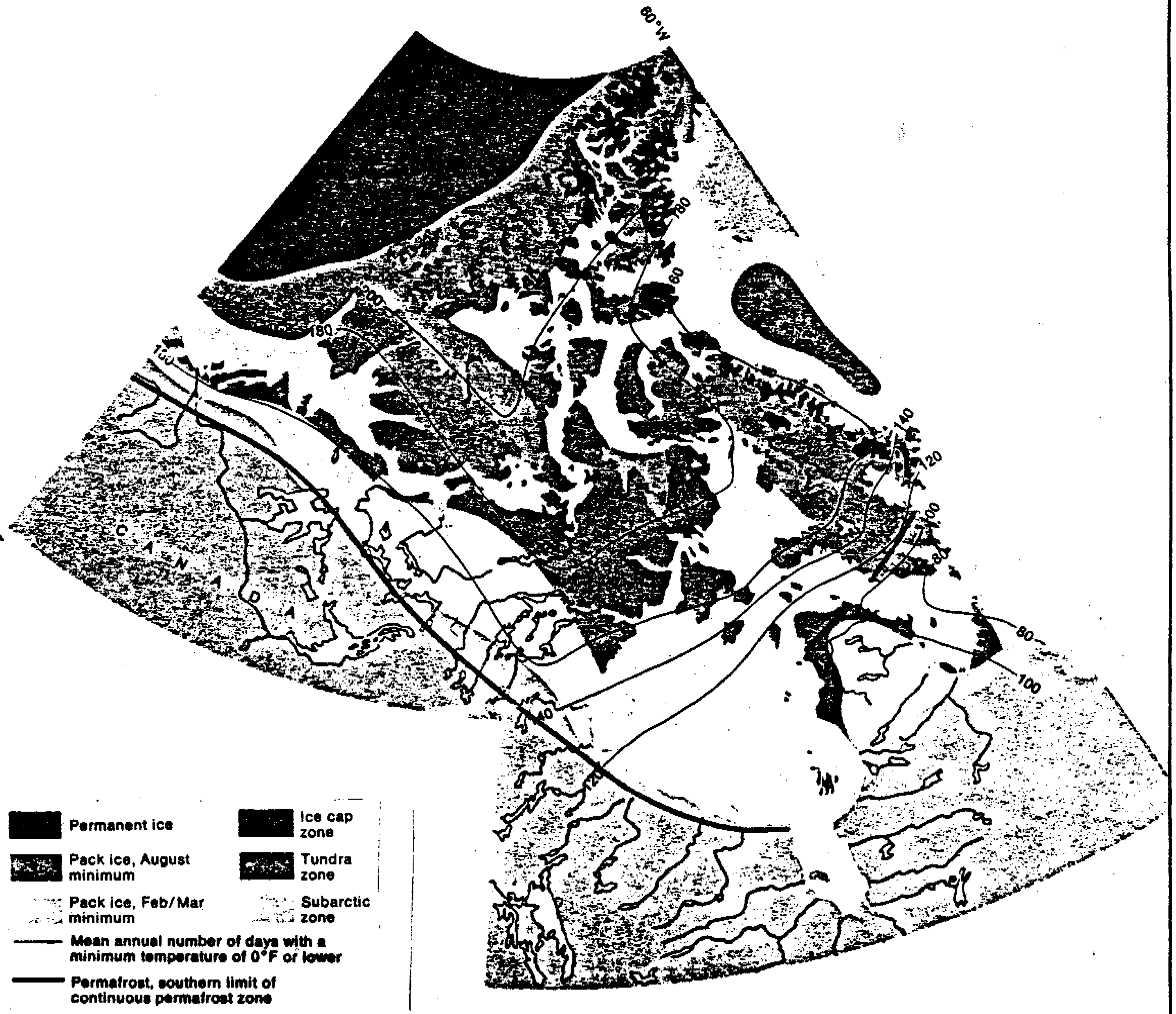
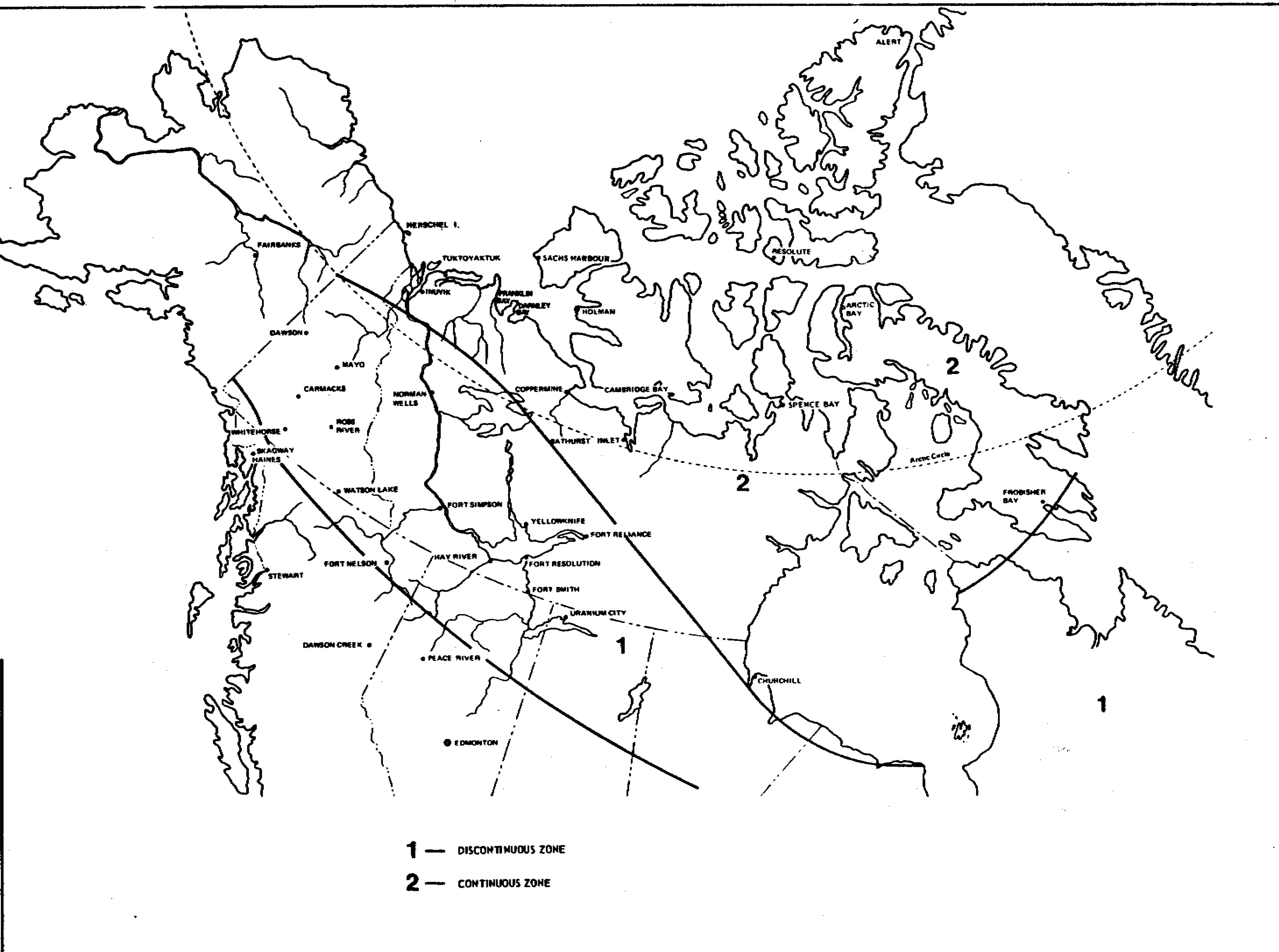


FIGURE 5 - 1

SEA ICE AND CLIMATIC ZONES OF THE ARCTIC



(from DPW, 1972)

FIGURE 5 - 2
PERMAFROST REGIONS

SCALE IN MILES 200 0 200

Differences in seasonal conditions may give rise to wide variations in climate within relatively short distances. This is especially true in certain coastal regions where there may be some open water and frozen water surfaces and both snow-covered and bare ground, each having distinctly different effects on the temperature of the air above. Topographical differences also give rise to variations in climate. For example, in the Canadian Arctic Archipelago, the dissected surface of the topography hampers the clearing of sea ice from between the islands resulting in a lower mean annual air temperature than a point of equal latitude on the west coast of Greenland where the ice is cleared by the circulation of ocean currents.

The extreme arctic climate is often described as that in which the mean monthly temperature never rises above freezing. The less extreme but still severe arctic climate includes areas in which the mean temperature is above freezing but below 10° C for the warmest month and the average for the coldest month is below -10° C. The former is thought of as the ice cap climate and the latter as the tundra climate, which approximates the northern limit of trees.

Air Temperatures

Along the mainland Beaufort coastline between Herschel Island and Cape Lyon in Darnley Bay, air temperatures may be expected to fall to at least -30° C on about 90 per cent of the days between January and April, and to -40° C or lower between one-third and two-thirds of these days. Summer temperatures in July and August may reach 25° C.

[illegible]

-26° C at Herschel Island and Babbage Bight and about -28° C at Horton River in Franklin Bay, and Clapperton Island in Darnley Bay. The mean monthly air temperature in July is about 8° C on Herschel Island and Babbage Bight and abo [illegible]

River and Clapperton Island.

Wind Chill

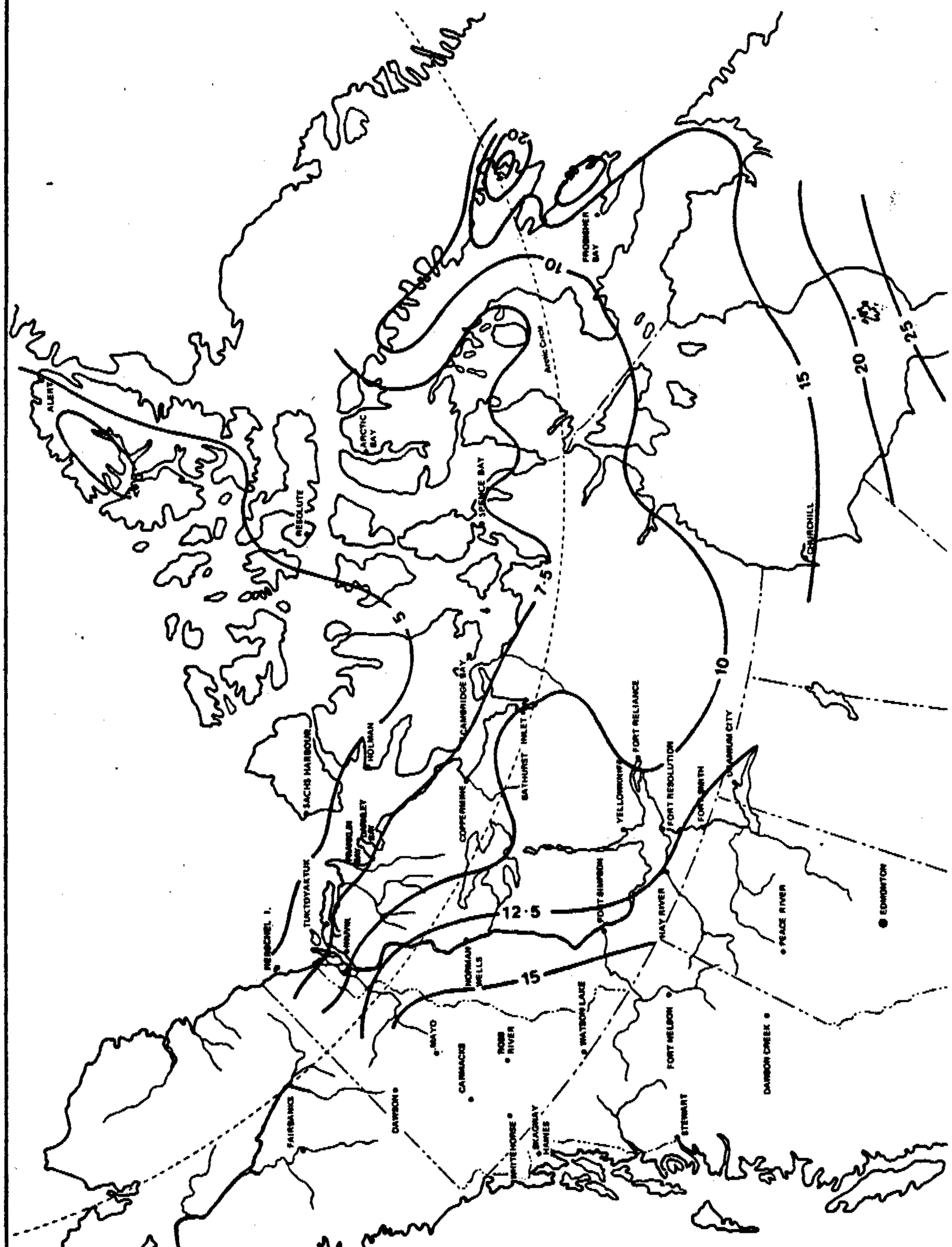
The temperature of the air alone is not the only factor involved in the concept of cold. A relatively high air temperature combined with a moderate wind speed can cause a greater rate of heat loss and more personal discomfort than a much lower air temperature combined with a low wind speed. For example, a temperature of -14° C and a wind speed of about 32 km is just as effective in chilling as a temperature of -40° C and a wind speed of only 3 km per hour. The combination of temperature and wind speed in the evaluation of heat loss underlies the basic philosophy of the concept of wind-chill.

The method of evaluating wind-chill currently in use is considered imperfect by many. Consequently, the concept is the object of continuing research to define it in terms of the many factors involved, both physical and physiological. Under the current method, exposed flesh freezes at a wind chill value of 1400 kg calories per hour per square metre.

Precipitation

Because the water-vapour capacity of cold air is relatively low, water-vapour added to arctic air quickly saturates it, thereby lowering the amount of moisture available for precipitation. Consequently, precipitation in the Arctic is generally low.

Along the mainland coastline of the Beaufort Sea, accumulated snow in one year seldom exceeds 76 cm at all sites except Clapperton Island where it may reach 127 cm. In the High Arctic, at Resolute, the mean total annual snowfall is in the order of 63 cm. Snowfalls can occur at any time of the year, but most frequently occur between September and May. Annual precipitation rates for northern Canada are shown in Figure 5-3. Precipitation in most areas ranges between 12.5 and 19.0 cm per year.



(from DPW, 1972)

FIGURE 5 - 3
MEAN TOTAL ANNUAL PRECIPITATION IN NORTHERN CANADA (INCHES)

SCALE IN MILES 200 0 200

Night-Day Regime

One of the most important characteristics of operations in the Arctic is the uncommon daylight cycle. Apart from the psychological impact of long periods in the winter when the sun does not rise above the horizon, and equally long periods in the summer when the sun does not set, the influence of these characteristics on the volume of work which can be accomplished is deserving of special consideration. Fortunately, the long period of continuous daylight and twilight coincides with the best climatic conditions for work in the open.

During the winter period from January to April, work in the open will be drastically reduced and probably precluded for long periods due to the severe climatic conditions. However, certain kinds of work would be better performed during this period, e.g. the local transportation of construction materials on the ice surface, using the ice as a platform for submarine work, etc.

Wind

Data sources for surface winds in the Beaufort Sea include synoptic charts, occasional ship reports, on-shore weather station records, and short-term private industrial wind recordings.

Normal winds over the Beaufort Sea area are from the southeast to northeast for about 30 percent of the year. Winds from the west and northwest blow a further 16 percent of the time during the summer. Winds from other points are relatively uncommon except near the coast where terrain may have a direct influence on direction.

Wind speeds are generally below 20 mph (32 kmh) for about 88 percent of the year. Strongest winds, and the greatest frequency of strong winds, occur in September and October.

Visibility

The air masses in the north are generally free of pollutants and, in the absence of precipitation or any of the obstructions to vision discussed below, visibility is clear. Over the year, visibility in the Dome lease area is restricted to less than 0.8 km for 12% of the time, 0.8 to 1.6 km for 2%, 1.6 to 4.0 km for 3% and 4.0 to 10 km for 12% of the time. The limited data indicates that these averages do not vary much throughout the year.

Over flat open spaces a wind speed of 24 kmh is often sufficient to lift powdery arctic snow from the ground. This blowing snow gives the appearance of more frequent snowfall than is actually the case. With winds greater than 48 kmh visibility is reduced by the blowing snow to less than 0.8 km and the snow may be lifted to several thousand feet. Most visibility restrictions in winter are due to this cause. From October to May, drifting snow may restrict visibility to near zero for 3 to 4 percent of the days. On approximately a further 5 percent of the days, visibility will be limited to within 3 km.

In summer, fog ranks high as a factor reducing visibility in areas near open water. The most common fog forms when warm moist air moves over a colder surface such as occurs with warm sea air moving over the ice pack or with warm land air moving out over the sea. During summer, fogs limit visibility to less than 10 km for 25 percent of the time and to less than 0.8 km for approximately 10 percent of the time over the Dome lease area.

Winter fogs form most readily with temperature in the -24° C to -35° C range and calm winds. Because an area of open water is most necessary to fog formations, the infrequent winter fogs may indicate open leads or polynias.

Ice fog, the smog problem of the north, is relatively infrequent at present because the low moisture content of the cold air prevents the formation of ice crystals. Ice fog usually results from the direct sublimation of moisture on hydrocarbon particles. However, as human activity increases, nuclei produced by combustion will cause a local increase in ice fog formation.

The extent of the ice fog is thus closely tied to human activity. Airplanes have fogged in airfields in the Arctic while taxiing out to the runway, the ice fog forming about nucleii of exhaust articles. Another type of mechanically produced fog is an "animal" or "human" fog. On calm days with a temperature of 50° below zero or lower, the moisture given off by an animal is sufficient to cause a light fog in its immediate vicinity. These fogs can be dense enough to obscure an entire herd of reindeer or caribou. At temperatures below -40° C an ice fog is likely to persist due to the natural winter inversion. However, it dissipates rapidly with increasing wind speeds or temperatures.

Ice crystals, formed by the sublimation of water vapour at very low temperatures, produce an obstruction to vision that may lower visibilities. The ice crystal "haze" may cover an extensive area, both horizontally and vertically, but visibilities are usually not lowered below 3 kilometres as the phenomenon normally occurs with relatively clear skies.

Steam fog (arctic sea smoke) forms during the winter in the vicinity of open leads or tidal cracks in the ice; the result of upward moisture flux. The excess moisture in the cold air quickly condenses. Steam fog is usually observed during the period October through April, is relatively localized, and only persists for a few kilometres downwind from the open water.

Whiteout is an optical phenomenon which may occur when a uniform low overcast sky covers an unbroken snow surface. With the sun low in the sky, a diffuse reflection of light from both snow and cloud acts to completely eliminate shadows from all objects. Perspective and orientation are lost to the observer. The horizon becomes difficult or even impossible to define. White objects plus surface irregularities such as snow ridges or crevasses become undiscernable, while the judgement of distance to darker objects, although perhaps clearly visible, becomes difficult. Under these conditions travel becomes difficult.

Other phenomena producing similar effects to whiteout are fog, ice fog, ice crystals and falling snow. Each of these features can diffuse light from an overcast sky and confuse visibility.

Icing

There are three main mechanisms of icing that result in the accumulation of ice on the hulls and superstructures of ships or oil rigs. The first is that of freezing rain or drizzle which freezes on contact and coats objects with a sheet of ice. The frequency of occurrence in the north is low, usually confined to the period September-October, and averaging less than 25 hours over these months. The second is that of steam fog, which is limited in area and usually occurs later during the winter. At sea, moored vessels would experience more icing problems from steam fog than moving ships. Finally, spray, lifted from the wave crests by strong or gale-force winds, will create icing problems on superstructures, if their temperature is lower than the freezing point of salt water. However, small concentrations of ice will serve to dampen out waves, and concentrations of greater than seven-tenths will eliminate them. This type of icing is generally limited to the stormy period of September through November.

Temperature Inversion

Temperature inversion, increase in temperature with increasing height above ground, is caused by the negative radiation balance over snow and ice surfaces which are present during the greater part of the year. The resulting decrease in air density with height, plus frequent multiple discontinuity levels in temperature and humidity, leads to distortion or limitation of visibility, abnormal acoustic effects and strong erratic winds. Inversions often result in bending of radar beams around the earth's surface, mirages, looming of objects which are over the horizon, and other optical and/or acoustical phenomena.

Inversions play a major role in atmospheric pollution by acting as a barrier to the dispersion of pollutants, thus trapping them near the ground. Smoke plumes from chimney stacks will frequently remain at a fairly constant height under inversion conditions and drift away from the source.

Dangerous pollution conditions have been known to develop in parts of the world during calm or light winds under pronounced inversions. Inversion conditions in the Arctic tend to occur far more frequently than in southern regions.

SEA ICE

General

Sea ice represents the single most important feature of the offshore arctic environment. It follows then, that ice represents the greatest challenge to the successful development of the Arctic's offshore resources.

The state, characteristics, and motion of ice are of vital concern to certain transportation, construction and operational interests. Such ice features as lifting force (the vertical pressure exerted by the ice by virtue of changing water level), strength, pressure, bearing capacity, extent, growth, break-up, freeze-up and jamming must be considered. These are intimately related to the design and maintenance of icebreakers, caissons, piles, dams, and oil rigs; the use of ice as a bridge; the jamming of ice which may cause flooding; shore-front structure damage; and transportation blockages.

In addressing the subject of ice, for what amounts to almost the entire Arctic, it must be appreciated that the scope is not only large, but the science of studying ice is complex and evolving. The following quotes from Wilkinson, (1970) serve to elucidate just some of the basic vocabulary currently in use.

> "Men who have fought to get their ships through, or around or over sea ice have invariably come to regard it as something very special in their lives. Like the Eskimo hunters before them they soon came to realize that the simple

> term "sea ice" was wholly inadequate to describe a phenomenon of such complexity and power. Gradually they evolved a special vocabulary to describe the sea ice in all its many shapes, action and moods. Ice makes on the surface of the sea; in the early stages of its formation it is slush ice and rind ice, pancake ice and young ice. It becomes one year old ice, two year old ice, three year old ice; winter ice, cake ice, brash ice. On the surface of the sheltered inlets the smooth sheets of land-fast ice are bay ice. On the land-fast floe there is a floe-edge, an ice-foot, and ice tongues. On the free-floating ice is pack ice. Fields of pack ice are often hundreds of square miles in extent, made up of thousands of ice chunks that are hummocked and rafted into haphazard shapes and formations.
>
> Sea ice can be broken, weathered, cracked, submerged, rounded, honeycombed, rotten. Floating with the sea ice are the massive icebergs and ice islands from which are calved smaller growlers and bergy-bits. Among the ice are leads of open water; on the ice surface in summer are streams of fresh water; amongst the Arctic Ocean ice fields are polynias of open water. Into the air above the sea ice rises steam-fog, sea-smoke, frost-smoke; reflected in the sky is the ice-blink or water-sky."

The Arctic Ocean's mobile crust is by far the largest expanse of dynamic, solid material on earth. Figure 5-4 illustrates the general pattern of sea ice migration in the polar reaches north of the Western Hemisphere.

Of most direct consequence to Dome's Beaufort interest lands, is the large clockwise circulation of ice off our western Arctic shores, referred to as the Beaufort Gyre. This "backeddy of" ice, with a diameter of approximately 1200 km, is largely driven by winds generated by high pressure air masses common in northern latitudes. Although the speed of ice movement in the gyre varies with season and years, it has been estimated that 7 to 10 years are required for ice to complete a circuit.

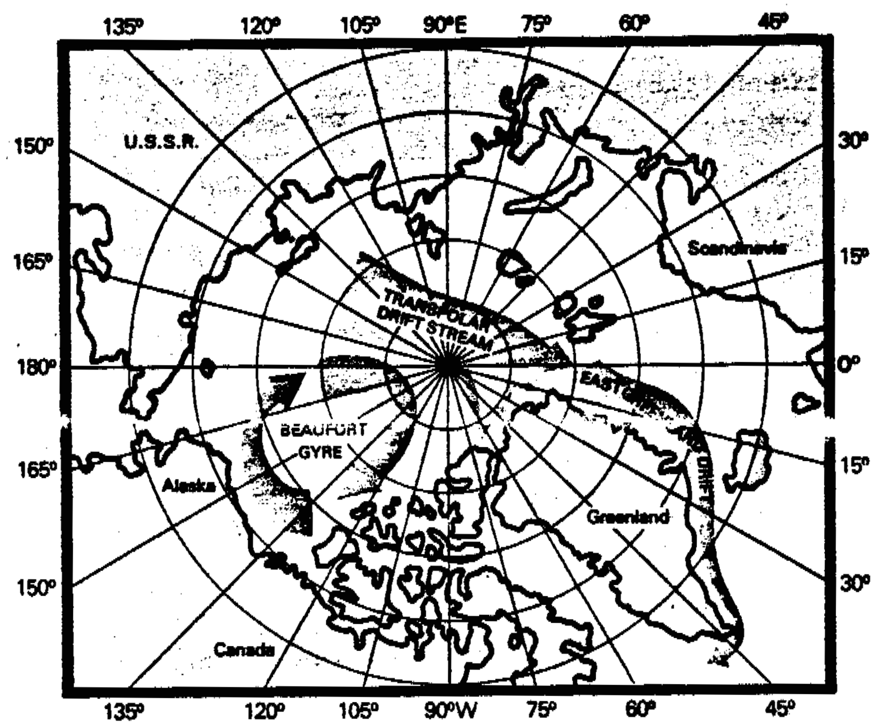


FIGURE 5 - 4 MAJOR ARCTIC OCEAN SURFACE CURRENTS (FROM MILNE, 1978)

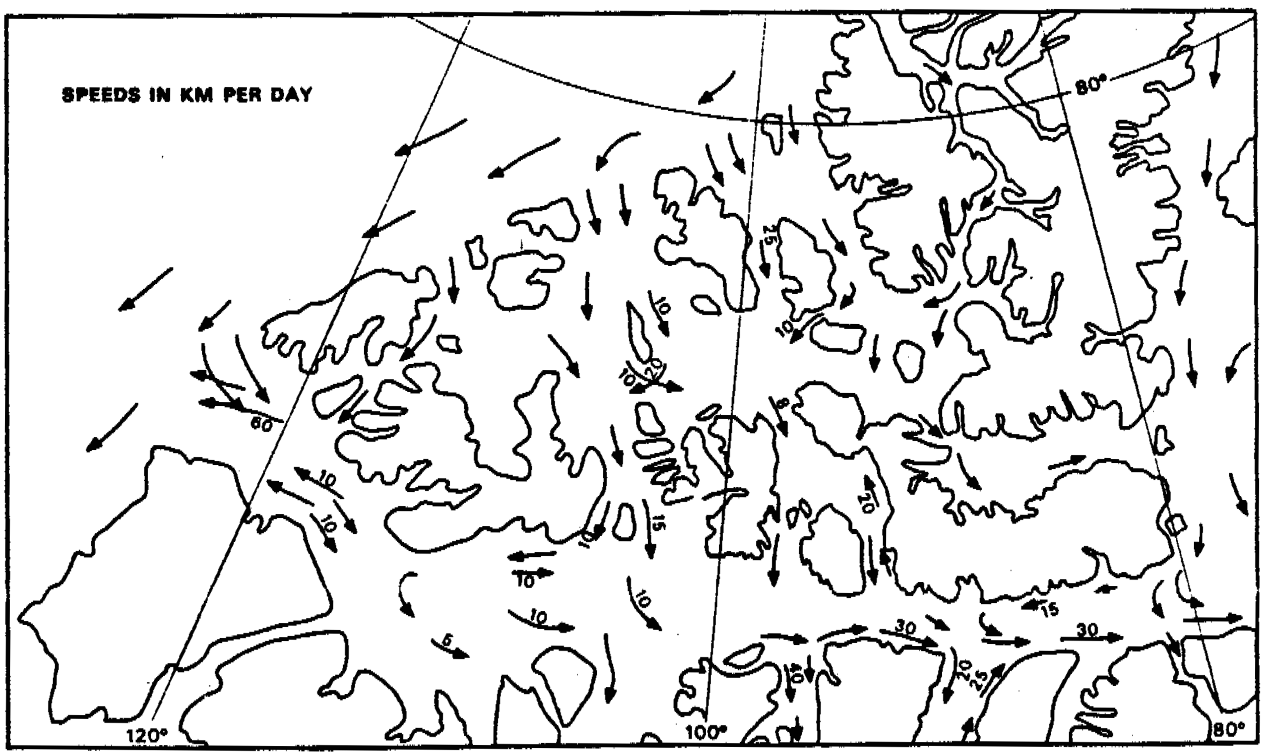


FIGURE 5 - 5 GENERALIZED SURFACE WATER MOVEMENTS (FROM SMILEY AND MILNE, 1979)

Drifting ice in the Arctic Islands generally moves south and east, particularly in winter (Figure 5-5). The migrating ice follows the prevailing water movements such that the islands themselves acts as a "drain" to the cold surface waters of the Arctic Ocean.

This water moves eastward over the Barrow Sill, north of Somerset Island, and southward into Wellington Channel. Parry Channel surface water exits into Baffin Bay. Lancaster Sound deepens toward Baffin Bay; this allows Baffin Bay water from the west Greenland current to underflow and then mix with the arctic surface water. The heat input from the water originating from Baffin Bay's more moderate climate, causes thinner ice and more persistent open water in summer throughout eastern Parry Channel.

Generalized surface water circulation patterns in this area differ from summer to winter, and from one summer to the next. For example, multi year pack ice can drift into M'Clure Strait from the Arctic Ocean, or be cleared out in summer. In Lancaster Sound, the westward surface water flow along South Devon Island is evident in summer but not in winter.

Towards the eastern end of the Arctic, including Lancaster Sound and Baffin Bay, icebergs take on a prominent role. The icebergs originate mainly from the glaciers of west Greenland, with lesser numbers being generated from the glaciers and iceshelves of Ellesmere, Devon and Bylot Islands. Those entering northwest Baffin Bay may assume enormous proportions of perhaps 100 million metric tons, and with drafts of 300 metres.

Most of the bergs encountered in Lancaster Sound are believed to come from Melville Bay. Additional icebergs are transported into the area from west Greenland via the northerly component of the west Greenland current. Bergs moving southward but approximately 35 km or more east of Devon Island, tend to continue southward with the basic flow of Baffin Bay.

Beaufort Sea

The greater part of the Beaufort Sea is filled with heavy floes or pack ice throughout the year. Typical of the Arctic Ocean, it is ice of which the quantities and kinds are controlled by factors such as origin, formation, growth, deformation, drift, disintegration and decay. In addition to ice formed directly by the freezing of sea water, large iceberg-like ice islands up to 60 metres thick calved from the northern ice shelf of Ellesmere Island, will occasionally be encountered. The broad expanses of flat pack-ice surface are broken by ridges and hummocks which occasionally rise to 10 metres or more above the general level. Even in winter, thermal and wind stresses may cause fracturing and the formation of open leads. These soon freeze over but often melt open again in summer. First year ice attains its maximum level thickness of approximately 2 metres just before the summer melt period in June. There is a brief period, when the snow and surface ice are melting, in which the bottom ice is still growing. Level multi—year ice attains an equilibrium thickness of approximately 4 metres.

The mainland coast and west coast of Banks Island lie exposed to the moving pack. The fast ice (primarily first-year ice 1.75 to 2.1 metres thick) is only a few kilometres wide along the east Alaskan Coast but extends from 16 to 48 km offshore in the vicinity of the delta. The break-up of this ice generally begins in Mackenzie Bay and then progresses along the coast on either side. It may be expected to loosen and break up early in July and, except in bad ice years, a 150 - 200 km band of open water exists along the coast throughout August and September. In severe ice years, however, the ice may not open until well into August and ice may form again in September. On the other hand, the open-water, ice free season has occurred in some years as early as June and ended late in October. In fact, the distribution of open water in summer is largely a function of the prevailing winds, which experience large temporal fluctuations.

Westerly winds guide the Beaufort Sea ice landward and if they prevail throughout much of the summer, may result in a bad ice year, such as occurred in 1974. On the other hand, easterly winds carry the main pack away from the land and, with melting, open a passage from Point Barrow to Cape Bathurst and off Banks Island.

Where shallow water extends long distances seaward, one is likely to encounter grounded floes early in the season or during the entire season if the Beaufort Sea pack is near the coast. Medium and large floes, particularly those that are heavily hummocked, often ground in 18 metres or less.

In the southern Beaufort Sea, landfast ice prevails from eight to nine months each year. During the brief summer period, this ice disperses and an open water area may extend to beyond 200 km from the coast. Yearly variations can be extreme, however, as exemplified by the poor year experience in 1974 when prevailing northerly winds kept multi-year ice floes within 50 km of the Tuktoyaktuk shoreline for most of the open water period.

In spring, southeast winds are generally prevalent in the southeast Beaufort Sea and a polynia begins to form in the Cape Bathurst area, usually in March or April. The Cape Bathurst polynia usually expands slowly in all directions after formation, with the Beaufort Sea gyre west of Cape Parry causing a net drift of ice away from the Cape Bathurst area.

In saltwater areas in the vicinity of Mackenzie Bay, clearing occurs near the end of June. By mid July coastal areas contiguous to Amundsen Gulf are cleared, although in some years (such as 1978) areas east of Cape Bathurst have remained ice enclosed until late in the summer. Clearing elsewhere along the Arctic Coast is usually delayed until late July. The average number of elapsed days from the mean date of water clear of ice ranges from 30 to 110 days along the coast.

Freeze-up in the southeast Beaufort Sea occurs on average in the second week of October, but varies from late September in a congested season to early November if the pack has moved well offshore. The Beaufort Sea anticyclone, which usually dominates the weather picture in late September, helps to move the polar pack shorewards, thereby aiding the rapid formation of ice.

The mean number of elapsed days from the mean date of the first year ice to mean date of complete freeze over ranges from 20 to 25 days along the Arctic Coast. Mean dates of complete freeze over for the southeast Beaufort Sea range from October 21 at Shingle Point; October 15 at Tuktoyaktuk; October 13 at McKinley Bay; November 5 at Cape Bathurst; and November 15 at Cape Parry. The Amundsen Gulf area is the last to completely freeze over because of the variable currents and polynia there.

During the winter, a belt of landfast ice extends seaward to about the 20 m depth contour in the south Beaufort Sea as far east as Cape Bathurst. Its width varies from a few kilometres to as much as 50 km. Amundsen Gulf and areas immediately outside the landfast ice are usually covered with first year seasonal pack ice which moves with the permanent pack ice. Maximum thickness of first year ice along the Tuktoyaktuk Peninsula (approximately 2 m) is usually reached sometime in May. The permanent pack ice is generally found 100 to 200 km seaward of the landfast ice. The moving pack ice shears against the stationary landfast ice producing extensive pressure ridges reaching several meters in height,creating the ice zone termed the shear zone.

Northwest Passage

To assist the reader all place names used in this section are shown in Figure 5.6. As indicated earlier, surface water flows through the Arctic Archipelago generally dominate the drift of ice through Parry Channel. This flow is estimated at 0.15 m/s in Viscount Melville Sound and 0.25 m/s in Barrow Strait and Lancaster Sound. Tidal currents are relatively weak, being generally less than 1 m/s, but a combination of ebbing tide and net easterly set has produced observed currents as high as 1.5 m/s in the southern half of Barrow Strait.

Local winter freezing conditions in the Parry Channel can produce sea ice up to 2 m thick. This pattern is further complicated by ridging of first year ice, or the presence of thicker multi-year ice carried into western Parry Channel by the prevailing circulation. Two ice edges in Barrow Strait are stable and well established winter/spring features of the ice cover in Parry Channel. The East Barrow Strait ice edge forms between Maxwell Bay (South Devon Island) and Prince Leopold Island by mid January in most years, separating the

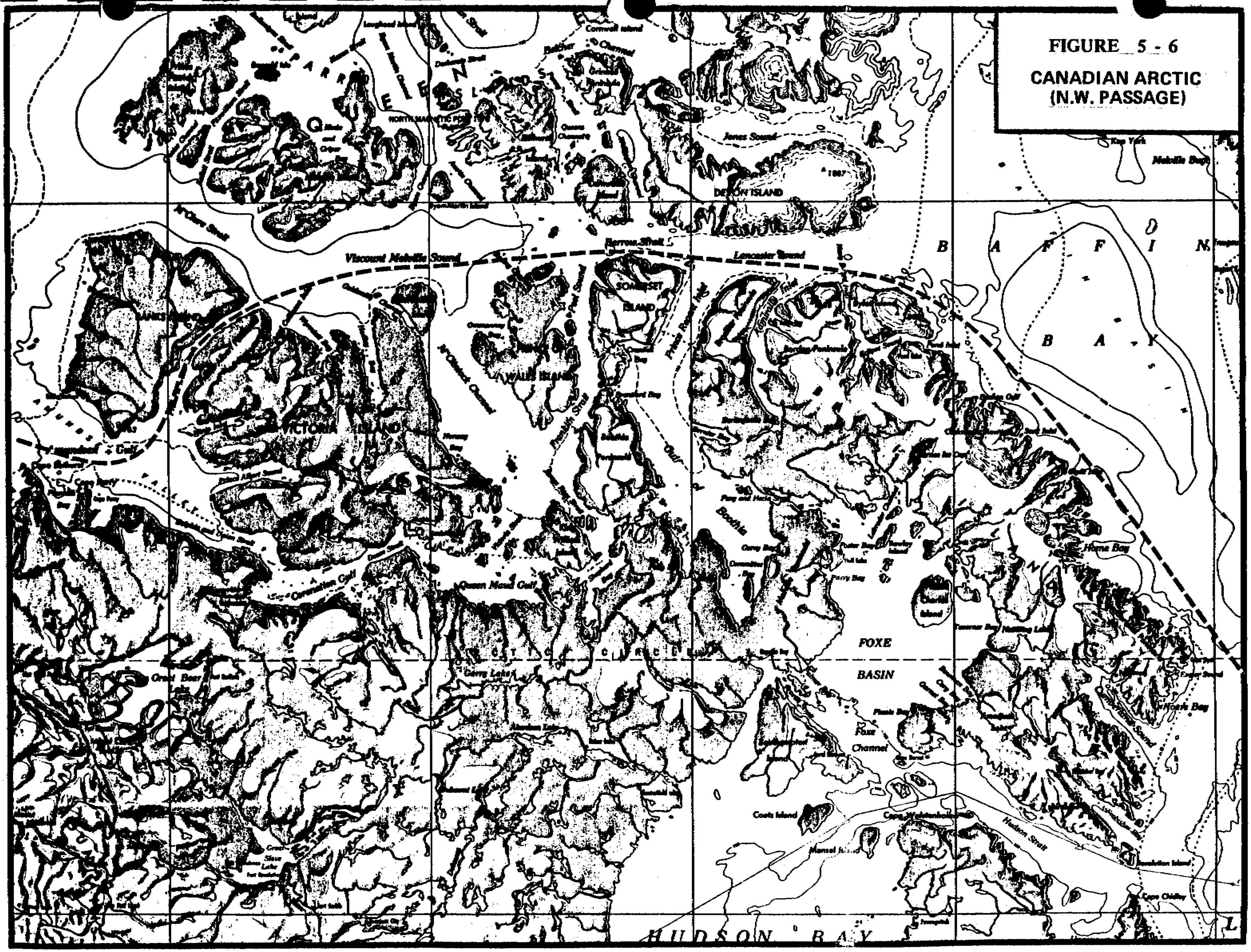


FIGURE 5 - 6

CANADIAN ARCTIC (N.W. PASSAGE)

stabilized ice cover to the west from the continually moving pack in Lancaster Sound. Break-up of this edge normally occurs in late June but can be as early as May in some years. This break-up allows ice to clear back to the West Barrow Strait ice edge, which runs in an arc between Cornwallis Island and northwest Somerset Island. The mechanisms causing the formation of the ice edge in East Barrow Strait are not understood. Development of the West Barrow Strait ice edge may be associated with the constriction in Parry Channel immediately to the east of the ice edge, which, combined with the presence of Lowther, Garrett, Griffith and Young islands, tends to stabilize it until late July.

The seasonal ice regime in the channel varies substantially. Because of the inherent difference in the characteristics of the sea ice regimes in the eastern and western sections of Parry Channel, these are discussed separately below.

Viscount Melville Sound

A solid ice cover, some of which is multi-year ice floes cemented together by local first year ice, blankets Viscount Melville Sound, from late October to mid August in most years. The most consistent, repetitive feature of summer clearing of ice is a polynia which forms along the southern and southeastern coast of Melville Island.

In August and September, ice movement southward in Byam and Austin Channels, combined with the geography of Byam Martin channel to the north which impedes the southward movement of sea ice, produces a large "open" area reaching from Byam Martin Channel to the edge of the ice pack in Viscount Melville Sound. The pack ice in Viscount Melville Sound tends to concentrate in the southern half, and during summer and fall, it usually tends to move eastward at 6 to 7 km/day. Maximum open water in Viscount Melville Sound usually occurs in early to mid September.

In unusual summers, almost all the sea ice may clear from M'Clure Strait and Viscount Melville Sound. However, during the following winter, newly forming ice may be unable to prevent penetration of multi-year ice from the Sverdrup Basin into Viscount Melville Sound, resulting in heavier ice in these areas the following year.

Refreezing leaves a characteristic long east-west lead at the approximate northern boundary of Viscount Melville

Sound. This lead separates the moving Parry Channel ice field from the immobilized new ice forming in Byam and Austin channels. South of this line, movement persists until November when refreezing is complete. Tides have some effect on the formation of shore leads and the delaying of ice formation in this area.

Throughout the winter season, movements in the order of a few kilometres can occur west of the ice edge in Barrow Strait, leading to active lead and open water formation well into eastern Viscount Melville Sound. Generally, however, movement is limited.

Barrow Strait-Lancaster Sound

By contrast, the sea ice cover in Lancaster Sound, and to a lesser extent in Barrow Strait, rarely becomes completely fast and the timing of the break-up is highly variable. The dominant feature of ice conditions in eastern Parry Channel is the well defined ice edge which forms each winter in Barrow Strait. In Lancaster Sound eastward movement continues throughout the year and a stable ice cover never completely forms. The position of this edge varies greatly not only from year to year, but also within a given season, as large fields of fast ice break loose and move eastward. Repeated and apparently stable positions of this boundary have been observed from year to year from east of Prince Leopold Island to as far west as Griffith Island. Break-up and clearing in Lancaster Sound and Barrow Strait can precede that in Viscount Melville Sound by as much as two or three months.

After break-up, ice floes tend to drift toward the south side of Barrow Strait, and are carried eastward at speeds of up to 12 km/day. Exceptions occur in August and September, when eddies may form near junctions with other major waterways, such as Prince Regent Inlet and Wellington Channel, where they enter Parry Channel, resulting in recirculation of ice floes.

Icebergs found in Lancaster Sound have either been carried into the area from Baffin Bay or have calved from the glaciers on the south side of Devon Island. They tend to drift westward along the north shore of the Sound for some distance before the prevailing circulation carries them across to the south side of the Sound and out into Baffin Bay.

OCEANOGRAPHY

The oceanographic characteristics of the Dome interest lands area in the Beaufort Sea, as well as the marine route, are influenced largely by the meteorological, ice, and water mass properties of the Arctic Ocean in general. Therefore, for the purposes of this overview, a discussion of the oceanography of the entire area is warranted. The information presented in this section draws primarily from Beaufort Sea Technical Report Number 18. (Herlinveaux and de Lange Boom, 1975).

The Arctic Ocean

The Arctic Ocean differs from most other seas in that most of its surface is covered with ice, which acts as a lid, tending to isolate the water from the atmosphere. This isolation is not complete, however, because even in winter, the ice never forms one solid and continuous cover. As indicated in Section 5.2, it is always moving, and leads open and close throughout the year. Thus there is a continuous exchange of momentum, heat and moisture with the atmosphere, although much reduced from what would take place if the ice cover were to be removed. The details of the heat budget of the Arctic Ocean are not well understood and there is some concern that if the ice cover was somehow reduced the process may be irreversible, resulting in a major impact on global weather.

Temperature and salinity depth distributions collected from the Arctic Ocean over more than 70 years show no significant variation with time. There are repeated variations with geographic position and expected regular seasonal variations in the surface waters which indicate that the physical processes within the Arctic Basin are in a state of equilibrium.

The Arctic Ocean can be subdivided vertically into three major water masses, according to their temperatures; Arctic surface water, Atlantic water and Arctic bottom water. The boundaries at depth between these water masses are somewhat arbitrary since the water masses gradually merge into each other.

Of all the Arctic water masses, the Arctic surface water shows the greatest variability in its properties. This water extends in depth from the surface to about 150 m in the Eurasia Basin and to about 250 m in the Canada Basin (Figure 5-7). Further, the Arctic surface water can be subdivided into three regions which may be called the surface layer, the subsurface layer and the lower layer. The surface layer, extending in depth from 0 to 25 - 50 m, is cold, relatively dilute and has the greatest variability. This layer is nearly isohaline with salinities in the range 28.5 to 33.5$^{o}/_{oo}$, temperatures less than 0°C, and is generally near the freezing point.

The subsurface layer extends in depth from 25 - 50 m to 100 - 150 m, and is usually nearly isothermal, with temperatures in the range -1.9 to -1.3^{o}C. Its salinity increases markedly with depth, since the main halocline occurs

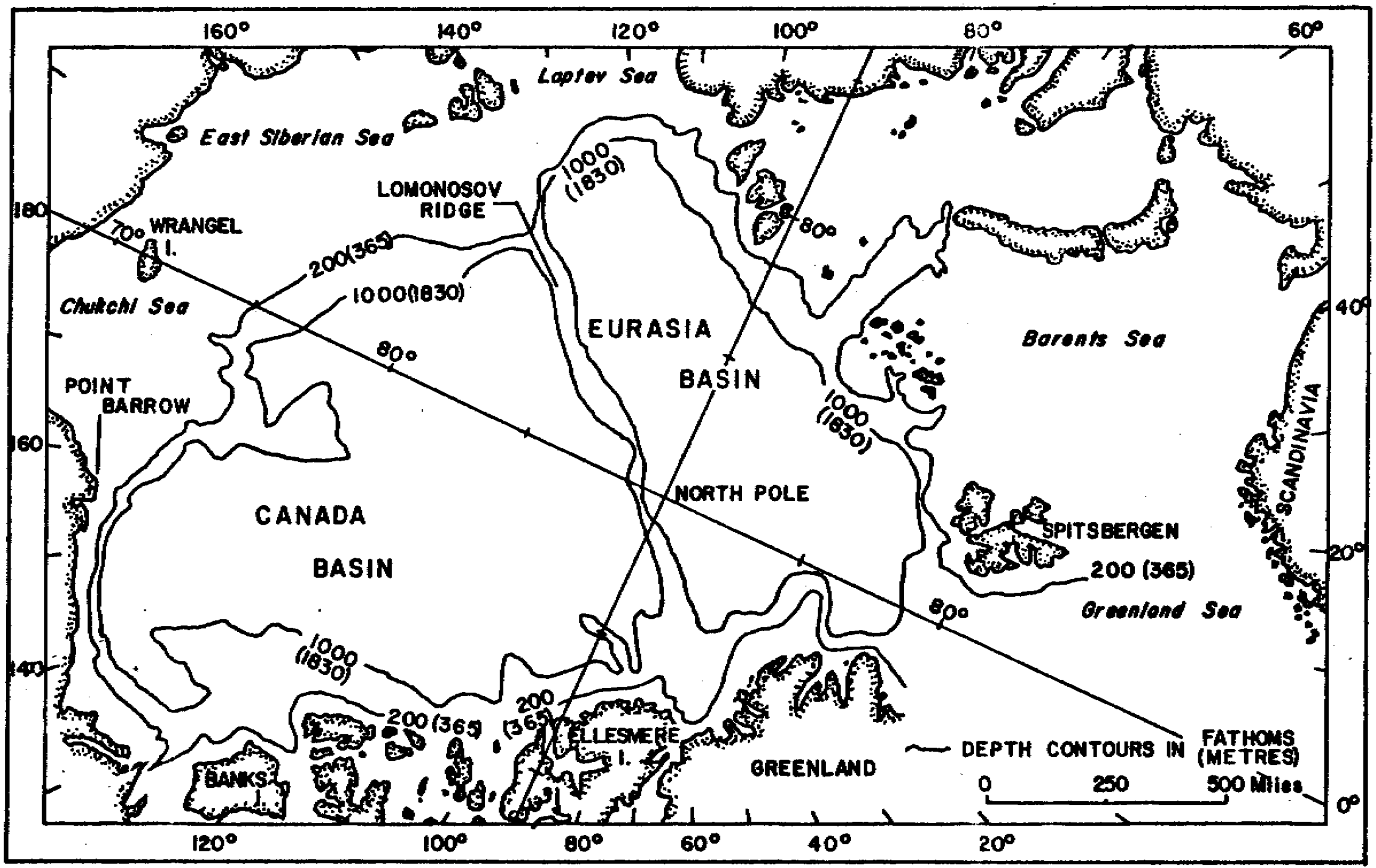


FIGURE 5-7 The Major Basins of the Arctic Ocean (FROM HERLINVEAUX AND DE LANGE BOOM, 1975)

in this layer. At a depth of 100 m, in the Eurasia Basin, all salinities are in excess of $33^{o}/_{oo}$, while some exceed $34^{o}/_{oo}$o. Its temperatures fall in the range of -1.8 to 0.1°C in summer and -1.9 to -1.3°C in winter. In the Canada Basin the subsurface layer extends somewhat deeper (150 m) compared to the Eurasia Basin and has generally lower salinities. The main halocline is correspondingly deeper so that salinities usually do not exceed $33^{o}/_{oo}$ until a depth of about 150 m is reached. The temperature structure is also different in the Canada Basin, frequently showing a slight maximum (0.5 to 1.0°C warmer than water above or below) at 75 to 100 m, with a minimum of -1.4 to -1.5°C at 150 m. This maximum is attributed to summer Bering Sea water that is advected around the Beaufort Sea Gyre, the temperature maximum being eroded by vertical diffusion as it progresses.

The mixing of winter Bering Sea water with bottom shelf water is suggested as the mechanism for maintaining the temperature minimum. The formation of the subsurface layer in the Eurasia Basin appears to take place in regions where submarine canyons indent the continental shelf. These canyons act like estuaries, allowing saline Atlantic water to move inshore where it mixes with surface water moving offshore, reducing its salinity and temperature.

The lower layer extending from a depth of 150 m in the Canada Basin (100 m in the Eurasia Basin) down to the Atlantic water has properties intermediate between those of the subsurface layer and the Atlantic water. These properties result from the mixing between these two layers so that the lower layer supports the main thermocline.

Variations observed in temperature and salinity throughout the Arctic surface water can be traced to two causes; seasonal weather changes and changes with geographic location of oceanic source waters and water-modifying processes. Seasonal weather changes result in changes in salinity and temperature as the sea ice melts and freezes, and as river discharge rates vary. The resulting changes in the stability of the water column determine the extent to which mixing takes place in the surface layer. In winter, freezing plus mechanical mixing due to wind-water to ice-water shears can produce a seasonal halocline and thermocline at depths usually between 5 m and 20 m.

The change from the continental slope to the continental shelf occurs at about 200 m; hence the nearshore waters are generally part of the Arctic surface water. The shallower depths and closer proximity to sources of fresh river water lead to greater variations in water properties than are found over the deeper basins. At the surface, salinities may at times drop as low as $0°/_{oo}$ or temperatures rise to more than 10°C, although these occurrences are quite localized.

Lying below the Arctic surface water is the Atlantic water, occupying depths from about 150 - 250 m down to 900 m. The most prominent characteristic of this water of Atlantic origin is the presence of temperatures above 0°C (exceeding 2.5°C near Spitsbergen) while salinities fall mainly in the range 34.8 to $35.0°/_{oo}$. Without going into detail about the circulation of this water mass, the Atlantic water enters the Arctic Ocean near Spitsbergen with a temperature maximum that can exceed 2.0°C at a depth of 150 to 200 m (with 1.0° to 2.0°C variations from season to season and year to year) and has characteristic salinities in the range 34.95 to $35.10°/_{oo}$ which change little with time. As this water follows the continental slope eastward, it rapidily loses heat so that on reaching the Laptev Sea the temperature maximum is only about 1.0°C and is found at depths between 200 and 250 m. By the time this water reaches the central Beaufort Sea and north of the Chukchi Sea the maximum temperature has decreased to about 0.5°C and is at depth ranging between 400 and 500 m.

At locations most remote from its source (northwest of Ellesmere Island or northwest of Point Barrow) the maximum is at a depth slightly below 500 m. This deepening of the temperature maximum can be attributed to the greater heat loss upward, since the temperature gradients are greater above the Atlantic water than below it. Measurements also indicate that larger current shears occur in the pycnocline (at 150 m) than below it, leading to greater mechanical mixing from above than from below the Atlantic water. Coincidental with the loss of heat, the salinities also decrease, falling in the range 34.90 to $34.93^\circ/_{oo}$.

Arctic bottom water fills the basins of the Arctic Ocean below about 900 m and represents roughly 60% of the total water volume. The characteristics of this water mass are temperatures below 0°C and salinities with a very narrow range (34.90 to $34.99^\circ/_{oo}$). In any particular location, the increase in salinity with depth is even less while its temperature decreases continuously with depth (to a minimum of -0.4°C at 2000 m in the Canada Basin). At any given depth, the measured range of temperature is about 0.2°C, with the Eurasia Basin showing a slightly greater range than the Canada Basin. The two basins are separated by the Lomonosov Ridge which has an estimated sill depth of 1200 to 1400 m. Temperatures in the Eurasia Basin are about 0.5°C colder below sill depth since this water cannot penetrate the Canada Basin over the Lomonosov Ridge. Below 2500 m, temperatures increase by about 0.2°C to the bottom, attributed to heating by adiabatic compression of the water as it sinks. The major source of the bottom water appears to be the Norwegian Sea where Atlantic water is cooled in winter to form the densest water of the Norwegian Current, and which flows into the basins of the Arctic. Small amounts of bottom water may be formed locally in conjunction with the submarine canyons of the Eurasia Basin.

The circulation of the Arctic Ocean is much less well known than the distribution of water masses, due in part to the great variability of currents. Present knowledge is based on the results of studies conducted from drifting ice islands, ice floes and ships. The mean circulation is slow (5 cm/sec or less) but much higher velocities can occur over short periods.

The mean circulation of the arctic surface water consists of two main features; the Beaufort Gyre and the Transpolar Drift Stream. The Beaufort Sea Gyre consists of a clockwise circulation centered at 80°N and 140°W over the Canada Basin and coincides with the mean atmospheric pressure anticyclone. Velocities are in the range of 1-5 cm/sec around most of the gyre with velocities of about 10 cm/sec north of Alaska. The Transpolar Drift Stream carries water and ice from the Asian shore past the North Pole to the east Greenland Current. The stream is continuous with the western part of the Beaufort Gyre and is responsible for the removal of ice and surface water from the Arctic Ocean.

The circulation of the Atlantic water has been deduced to be cyclonic (counter-clockwise), except for a small anti-cyclonic gyre north of Alaska. Velocities of the Atlantic water have been estimated to range from 1 to 10 cm/sec.

Bottom water is believed to originate from the Norwegian Sea, whereafter it moves into the Eurasia Basin, before crossing the Lomonosov Ridge to enter the Canada Basin. From the high oxygen values found throughout the water column in the Arctic Ocean (generally greater than 70% saturation), it is apparent that there must be renewal of the waters in the Arctic

Basin. The difficulty of determining residence times for the water masses is due to uncertainty about the rate of oxygen depletion.

In the Arctic Basin, runoff exceeds evaporation and precipitation. The excess fresh water is removed both as ice and as lower salinity surface water via the east Greenland Current. Present knowledge indicates saline water enters the Arctic Basin via the Bering Strait and the Norwegian and Greenland Seas, while there is an outflow through the Greenland Sea and the Canadian Archipelago. The circulation through the Archipelago is not well known, particularly its variation with time.

Beaufort Sea

The Beaufort Sea is a wedge-shaped integral part of the Arctic Ocean. The main water masses of the Beaufort Sea appear to be essentially those characterized for the Arctic Ocean in general.

The dominant marine feature of the nearshore south Beaufort Sea is the estuarine area resulting from fresh water and sediments discharged by the Mackenzie River. Over the centuries, sediment deposition from this turbid outflow has generated a wide shallow coastal shelf extending north and east of the Mackenzie Delta. Approximately 13.5×10^6 metric tons of suspended matter are contributed annually from this source.

The fresh water flows of the river, its associated sediment load, and the number of hours of daylight all vary with the season. This leads to yearly variations in the turbidity, temperature and salinity of the surface waters, as well as the extent of ice cover. Superimposed upon these variations are the influences of winds and the degree of summer ice cover.

Easterly winds are associated with divergent flow in the surface layer, leading to upwelling conditions with lower temperatures and higher salinities inshore. Under these conditions the ice tends to move offshore. Conversely, westerly winds lead to convergent flow and to a retention of the lowsalinity, warmer river water inshore, and tend to move the ice onshore. If the ice remains close inshore during the summer, the river water entering at the time is confined near the coast, resulting in a uniform, low-salinity (e.g., 5°/oo in 1974) surface layer. With the ice well offshore, the river water can spread over a larger area, and be more subject to the actions of wind, waves and currents. The presence of ice also lowers the temperature of the water as well as that of the air. As a result, fog is quite common in summer.

During winter the decreased river flow results in less fresh water input and less silt being transported to the Beaufort Sea. At the same time the decreased biological productivity leads to an increase in the water transparency. As winter progresses more ice forms, increasing the salinity and lowering the freezing point of the water. The freezing process also results in convective mixing within and thickening of the water surface layer. As the ice becomes thicker, its growth rate decreases due to decreased heat flow through it. The result is water layer immediately under the ice extending in depth to as much as 40 to 50 metres, which is isothermal and isohaline, and has a negative thermocline and a positive halocline at the lower boundary.

The water below this layer is generally only slightly influenced by seasonal changes; both its temperature an salinity increase with depth. In the entrance of Amundsen Gulf, a temperature of -1.7°C and a salinity of 31.12°/oo were recorded for the upper layer in winter. Expected temperatures for this layer in winter in the Beaufort Sea range between -1.65°C and -1.85°C and for salinity the expected values range between 30.0°/oo and 33.5°/oo. The rather small temperature and salinity vertical gradients during the winter result in a water column that has low stability, allowing wind in open water or current-generated under-ice mixing to take place easily and to a relatively great depth.

In contrast, the water column in summer is quite stable. The input of fresh water from melting ice and from increased river flow, as well as the increase in temperature due to insolation, all act to produce a low-salinity, relatively fresh surface layer, and strong stable stratification results. Mixing processes, whether wind or current-induced, are thus confined to this surface layer. At the same time, the increased silt load in the rivers and the increased biological productivity elsewhere lead to a decrease in water transparency within the upper layer.

The actual temperature and salinity ranges possible throughout the summer in the surface water are quite large and depend upon wind conditions, ice cover and location. The higher temperatures and lower salinities are generally found inshore, with low salinities also occurring near melting ice. Hence salinities can range from 0°/oo to 31°/oo and temperatures from 0°C to 13°C in the surface layer. While water transparencies in winter are generally greater than 70% of the value in air, minimum values of virtually 0% can be attained in summer at some locations. Near the bottom a turbid layer having transparency values less than 10% has been found in summer.

The largest persistent feature of circulation in the Beaufort Sea is the Beaufort Gyre, whose southern boundary lies at the northern edge of Dome interest lands during summer.

This eddy is huge, extending as far as the North Pole, and is associated with a clockwise circulation. Mean speeds in the southern Beaufort Sea are of the order of 4cm/sec, but a large variability exists.

The Gyre generally does not extend much further south than the edge of the continental shelf, to a depth of about 200 m. Closer inshore the surface water in summer moves to the east at about 50 cm/sec, fed largely by the Mackenzie River discharge. In Mackenzie Bay, most of the water from the river swings east along the northern side of Richards Island. However, near Kay Point there appears to be a current setting northwest, particularly during easterly winds. Inshore and close to the bottom, there appears to be a general current set to the northeast, following the bottom contours. This flow probably extends throughout the water column below the surface layer and has a speed of about 5 cm/sec.

The actual flow at any given time may be different from the general movements discussed above. Wind has a strong influence on the flow in the surface layer. Under west or northwesterly winds there is a marked flow to the east throughout the region, with the wind aiding the general easterly flow of the river water. Speeds of more than 60 m/sec have been recorded. These winds lead to an onshore convergence in the surface layer because of Coriolis effect.

Easterly winds lead to a westerly flow. Offshore velocities of over 50 cm/sec can occur under strong winds (10 m/sec). Closer inshore along the Mackenzie Delta and for a short distance along the Tuktoyaktuk Peninsula area there is still an easterly flow of the river water. The easterly flow soon reverses and leads to divergent flow (upwelling) along the coast. There is some evidence that the deeper water has a shoreward component.

When the wind is calm or changing, the flow becomes more complicated in some areas. Eddies (some larger than 15 km in diameter) can be found, complicating the current structure. They are revealed as anomalies in the surface salinity and temperature distribution.

Tides in the Beaufort Sea are semi-diurnal with a small range of 0.3 to 0.5 m. Except for an area north of Richards Island, near the entrance of Kugmallit Bay, there is very little obvious tidal motion. Generally, the tidal currents are masked by the mean flow. Only in the Richards Island area do the currents clearly show a tidal component superimposed on a small mean flow. The reason for this anomaly is not yet clear.

The action of waves provide the major erosional force in the nearshore Beaufort Sea. Acting together, short-period waves and long-period storm surges can and have seriously eroded coastlines and man-made islands and have inundated large areas of the relatively flat coastal land. The most likely conditions for such events occur in the presence of northwesterly gales during a good ice year. The long fetch allows large waves to be generated and provides conditions for positive storm surges. Most of the annual coastal erosion occurs during such conditions. Negative storm surges which are observed as a decrease in sea level at the shore are less of a problem, affecting mainly shipping in shallow areas. Not much is known about the currents associated with storm surges, although the shorter period waves generate littoral transport, moving finer sediments along the shore and thus contributing perhaps in some degree to the turbid layer near the bottom.

LOWER TROPHIC LEVELS

The following material presents a brief description of some of the most important components of the lower trophic levels. Primary production by phytoplankton and benthic algae are discussed first, followed by material on the epontic community, zooplankton and benthic animals.

Nutrients and Phytoplankton

As in other arctic regions, the primary productivity of the Beaufort Sea is limited by the development of a stratified and stable water column in the spring. A layer of low density water is formed at the surface by ice meltwater and runoff from adjacent land. This prevents or at least hinders vertical circulation of water. Due to such stability, plant nutrients are rapidly exhausted by growth of algae in the upper portion of the water column during spring or early summer, and these nutrients are generally not replenished until the following winter. In addition, the nearshore waters of the Beaufort Sea are often quite turbid due to the discharge of rivers. In such situations primary production can be further limited by insufficient light for photosynthesis.

Planktonic primary production in the Beaufort Sea may be low even by arctic standards. The Arctic Ocean is considered to be the least productive (1 to 10 g $C/m^2/yr$) ocean in the world. No productivity measurements have been performed in the northern Beaufort Sea, but environmental conditions there are similar to those in the Arctic Ocean. Higher production (up to 18 g $C/m^2/yr$) has been measured in nearshore regions of the western Beaufort Sea, but even there the productivity is lower than in Barrow Strait, Jones Sound and Frobisher Bay. It appears that production increases south of Point Barrow, Alaska; values up to 28 g $C/m^2/yr$) have been estimated for the northeastern Chukchi Sea.

Macrophytes

Besides phytoplankton, the other primary producers in the Beaufort Sea are epontic algae, benthic microalgae, and benthic macrophytes (kelp). Benthic macrophytes are normally absent or only very sparsely distributed along the margins of the Beaufort Sea due to ice scour and lack of suitably stable substrates for attachment. Macrophytes cannot grow in deep water because there is too little light for photosynthesis below a depth of about 100 m.

Small but dense patches of kelp have recently been found in Stefansson Sound near Prudhoe Bay. The substrate there is unusual in that boulders and cobble are common. In such a local area kelp is likely an important source of primary production. In addition, kelp beds provide shelter, attachment and food for a variety of microorganisms, invertebrates and fish, and serve as a basis for the development of complex communities not found elsewhere in arctic waters.

Benthic Microalgae

Benthic microalgae grow on any relatively stable substrate that is in water sufficiently shallow to permit adequate light penetration. Due to the turbidity of the water and the soft unstable substrates in most shallow areas of the Beaufort Sea, benthic microalgae may not generally be of great importance in this area. However, local areas can support large populations. Few studies of benthic microalgae have been performed in northern areas, and their importance in the ecology of northern seas is poorly understood. They have been reported to be important food sources for some amphipods, mysids, isopods and shrimp, but it is unclear whether these animals are deriving energy from plant tissue or from other microorganisms (e.g. protozoans, bacteria) associated with the bottom community.

Epontic Biota

At the present time, the significance of primary production by ice algae is uncertain. The best estimate to date is that epontic algae fix about 5 g C/m^2/yr, which would be a significant fraction of total annual primary productivity in the Beaufort Sea, where planktonic production is low. However, the importance of epontic algae may be even greater than its proportional contribution to total primary production would suggest. Epontic algae grow as a dense layer on the under-surface of ice during the spring, a time of year when phytoplankton are not yet abundant in the water column. The presence of a concentrated food source under the ice at this time could be quite important to herbivores.

Trophic relationships of organisms associated with the bottom of the ice are not understood in detail, but a variety of microorganisms, copepods and amphipods have been reported in association with ice. Some of these amphipods have been shown to feed on epontic algae, and other amphipods probably feed on the herbivorous forms. Newly released young amphipods sometimes occur in very large numbers on the under-surface of ice in spring.

Arctic cod are also sometimes found in close association with the under-surface of ice. The arctic cod appears to be an important link in food chains extending from lower trophic levels in the epontic community to seabirds and marine mammals. It is known that arctic cod do feed on animals that are sometimes associated with ice, but few data exist to confirm suspected relationships.

Zooplankton

The zooplankton communities of the Beaufort Sea consist of typical arctic species with the exception of a few north Pacific specimens that are carried into the area from the Bering and Chukchi Seas. Such specimens are more common in the Chukchi Sea than in the Beaufort Sea, but in general the zooplankton of the Chukchi Sea is poorly known in comparison to that of the Beaufort Sea.

In the Beaufort Sea, three zones contain characteristic and distinguishable assemblages of zooplankton. These zones are:

1. the shallow, brackish-water shoreline areas where a few species of euryhaline copepods can occur in large numbers (euryhaline species are those that can tolerate a wide range of salinities);
2. the surface waters in offshore areas, which contain the characteristic arctic zooplankton; and
3. deeper offshore waters (i.e. below 200 or 300 m) that contain a diverse but sparsely distributed community of zooplankton, primarily copepods. Many of the species in this last group are found in deep waters throughout the world's oceans.

Aside from these broad categories, some smaller areas are known to contain different assemblages of zooplankton. Waters within and in close proximity to the Mackenzie River estuary contain freshwater species. Some small sheltered bays in the Canadian Beaufort Sea have been reported to contain substantially larger numbers of zooplankton than normal. The significance and consistency of the latter finding are not known.

In general zooplankton abundance and biomass in the southern Beaufort Sea are higher than in the Arctic Ocean but lower than many other arctic areas of similar latitude. Primary production is also comparatively low in the Beaufort Sea and this may be directly associated with its apparent low secondary planktonic production. Similar information is not available for the Chukchi Sea.

Benthic and Epibenthic Invertebrates

This group of invertebrates includes three groups of animals: those that live in the substrate (infauna), in the water or detritus near the substrate (epibenthos), or attached to hard objects (epifauna).

The infaunal and epibenthic invertebrates of the Beaufort Sea consist of typical and widespread arctic species. Nearshore shallow water areas, especially the barrier lagoons, harbour large numbers of epibenthic amphipods, mysids and isopods. These animals are heavily utilized as food by marine and anadromous fish and by seabirds. Infaunal animals are scarce at shallow depths in the Beaufort Sea but are more abundant in shallow portions of the southern Chukchi Sea area.

At shallow and moderate depths in the Beaufort Sea, the biomass and abundance of infaunal organisms increase with depth. Their biomass reaches a maximum of 70 to 100 g/m^2) at depths of 30 to 200 m. Infaunal biomass in the Chukchi Sea is considerably higher (100 to 1000 g/m^2). Polychaetes are the numerically dominant animals at depths of 30 - 200 m, but bivalves probably account for most of the biomass. Beyond these depths infaunal biomass decreases with increasing depth and at depths of 1700 to 2600 m the biomass is about 10 g/m^2.

Echinoderms (mainly asteroids and ophiuroids) dominate the epibenthos at depths greater than 20 m in the Chukchi Sea. In the Beaufort Sea, a group of animals including a scallop, an urchin, a shrimp and ophiuroids account for most of the epibenthic animals taken in waters deeper than 20 m.

It appears that the shallow water epibenthic animals are omnivorous, opportunistic feeders that will feed on whatever organic matter is most available. A detritus-based food chain is probably of key importance to the deeper water benthos. Walrus and bearded seals prey on the deeper water infauna and epifauna.

Due to lack of hard substrates in the Beaufort Sea, epifaunal animals appear to be important only in a few isolated locations, where boulders or other appropriate surfaces are found.

Most benthic species inhabiting the Beaufort Sea do not appear to have pelagic larvae, but those few that do are often the most abundant species present. Conditions in the water column are important in the reproductive ecology of these species.

FISH

Although the present study area is extremely large, it harbours relatively few species of fishes. This becomes especially obvious when it is compared to regions of similar size in more southern latitudes. Over 300 species of marine fishes are known to occur along the southeastern and southwestern coasts of Canada. In contrast, only about 30 marine species are known to occur in Parry Channel. In arctic areas south of Parry Channel, numbers of species increase but do not approach those found in temperate seas. Approximately 38 marine species have been reported in the Beaufort Sea, 45 species from the northeastern Chukchi Sea, and about 90 species from Davis Strait (mostly from waters off southwest Greenland).

In the southern portions of the Beaufort Sea/NE Chukchi Sea study area, a number of typically Pacific species of marine fish are encountered. Few of these species have been able to survive in high arctic marine waters; thus most species found in the northern portion of the Beaufort Sea can be considered to be true arctic fishes.

Anadromous fish migrate to the sea for summer feeding and return to freshwater to spawn; most species also overwinter in freshwater. These types of fish (cisco, whitefish and arctic char) are common in coastal areas of the Beaufort and Chukchi Seas. The arctic char is distributed (sometimes sparsely) along coastlines throughout most of the study area. Due to the large size and palatability of anadromous char, accessible populations are fished domestically and commercially, as well as by sportsmen.

With the exception of anadromous species, the majority of marine fish in the study area are small benthic forms, such as sculpins, eelpouts and lumpsuckers. The role of these fishes in food chains is obscure. Large pelagic marine species, such as tunas and mackerels, are absent from arctic waters.

Considerable information is available on anadromous and marine fish in shallow waters along the Beaufort Sea coast and a reasonably complete species list exists for that area. In addition, the life histories of most anadromous fish are relatively well known and are being updated throught work such as that being undertaken by the Department of Fisheries and Oceans undertaken along the Tuktoyaktuk Pennisula. Information on fish in the northeastern Chukchi Sea is much more limited.

Anadromous Fish

From a human perspective, anadromous fish are by far the most important species in the Beaufort Sea. They include such species as arctic and least cisco, broad and humpback whitefish, and arctic char. These species are harvested domestically, commercially and by sports fishermen. Studies to date have shown that while anadromous fish are in the sea, they are most common in shallow water nearshore areas. Some species migrate long distances along the shoreline before changing directions and returning along the shore to the mouth of their natal river or stream. At the present time it is not known if anadromous fish require or merely prefer the nearshore waters, which are normally warmer and less saline than marine water farther offshore. During their summer stay in the sea, anadromous fish feed extensively on crustaceans, primarily mysids and amphipods. The energy obtained from this food is important to survival and spawning success. Due to the characteristics of northern and arctic anadromous fish (slow growth rates, late maturation, spawning only once every two or three years), they are especially prone to over exploitation. Once a population is reduced, many years may be required for it to recover.

Although over 30 species of fish have been recorded from nearshore waters of the Beaufort Sea, five species account for the majority of the fish present. These are the arctic and least cisco, arctic char, fourhorn sculpin and arctic cod. Only the last two are marine species. Other species of fish (e.g. Pacific herring, whitefish) may be abundant intermittently or in local areas. This is particularly true in the Mackenzie River estuary and adjacent areas, where arctic char are rare and broad and humpback whitefish become more common. In addition, some freshwater species such as northern pike can occasionally be found in estuarine conditions.

Marine Fish

Fish found in offshore waters are all marine species, of which the arctic cod is the most abundant (at least in the Beaufort Sea). Arctic cod are preyed upon by a variety of seabirds and marine mammals (e.g. belugas, ringed seals) and they are an extremely important food source for highly valued vertebrates.

The arctic cod is a relatively small (average 140 to 200 mm in length) and short-lived (5 or 6 years) fish. Many studies have reported arctic cod to be widely but sparsely distributed on the sea bottom or near ice. In addition, they occasionally occur in large schools that have been estimated to contain millions of fish. These schools are most commonly observed in nearshore waters in late summer and fall, but their precise locations and times of occurrence cannot be predicted with present information. Huge schools of arctic cod were reported along the northern coast of Alaska in Simpson Lagoon and Prudhoe Bay in the late summer of 1978, but few were found in these areas in 1977. Arctic cod spawn in winter, and apparently utilize some nearshore areas in the Alaskan Beaufort for spawning. Similar information about utilization of nearshore areas for spawning or by late summer concentrations is not available for the Canadian Beaufort Sea or for the Chukchi Sea.

Adequacy of Present Knowledge

The general patterns of fish utilization of the Beaufort Sea are relatively well known and species that are likely to occur in various moderately large areas are either known or can be predicted with a fair degree of certainty. Seasonal trends in the abundance of most anadromous species and some marine species can also be predicted, but insufficient knowledge exists to predict short-term, small-scale trends in abundance, or (for most species) absolute numbers.

A substantial body of data exists on the status of and habitat use by fish in nearshore shallow-water regions of the Beaufort Sea. Although much less is known about offshore areas, it appears that inshore waters are more important to the species of fish that we presently consider important. These are the common anadromous species that are harvested domestically, commercially and by sport fishermen. Ecologically important processes involving fish doubtless occur in offshore waters, but it is not possible to document them adequately at the present time due to lack of information.

Fish populations of the northeastern Chukchi Sea remain virtually unstudied in comparison to those of the Beaufort Sea. It is thought that habitat utilization and life histories of fish common to both areas may be quite similar, but the diversity of fish is greater in the Chukchi Sea. Some fish species that are important in the diets of birds and mammals in the Beaufort Sea are quite important in the Chukchi Sea.

Major gaps in knowledge of fish in the Beaufort Sea/NE Chukchi area include lack of data about (1) fish utilization of offshore waters, (2) habitat utilization and ecology of fish in winter, (3) nearly all aspects of fish utilization of the northeastern Chukchi Sea, (4) the distribution, movements and abundance of arctic cod, and
(5) critical areas (if any) for the maintenance of arctic cod stocks.

SEA ASSOCIATED BIRDS

Over a hundred species of birds have been recorded in the Beaufort Sea/NE Chukchi Sea portion of the study area. Of these, approximately 35 species are major users of the marine and coastal regions. The major groups of birds that extensively use the marine system include loons, brant, sea ducks, phalaropes, jaegers, gulls, terns, murres and guillemots. Others, such as swans, geese (other than brant), dabbling ducks and shorebirds (other than phalaropes), are abundant in coastal terrestrial areas.

In spite of the numerous studies of birds in the area in recent years, knowledge of the numbers of individuals, migration routes and concentration areas used by major species is at best spotty. The most extensive studies were conducted as part of the Beaufort Sea Project but extremely heavy ice conditions in the study years render some of the results atypical of more normal years.

In the eastern Arctic, over 80 species have been recorded in the Parry Channel/Baffin Bay/Davis Strait area, of which 35 species regularly use the marine system. The distribution of birds is uneven through this large area. Approximately 19 species commonly use the waters of Parry Channel with most individuals being found in Lancaster Sound and eastern Barrow Strait. The numbers of species increase to the south in Baffin Bay and Davis Strait; 31 species commonly use the waters of western Davis Strait. The number of individuals using Davis Strait is very large since virtually all of the sea-associated birds in the High Arctic migrate through or winter in Davis Strait.

The relatively warm, northward flowing current along the west coast of Greenland permits several temperate and sub-arctic sea-associated species to nest along this coast. These species include great cormorant, great black-backed gull, common murre, razorbill and Atlantic puffin.

In summary, the eastern Canadian Arctic has very substantial populations of several species of birds, including a number of species that are not normally found in the Beaufort/Chukchi area.

For the purposes of this overview, the following brief discussion on the birds will be separated into those of the Beaufort Sea/NE Chukchi Sea area, and the eastern Arctic area. Regretably, the information presented for the eastern Arctic will be particularily sketchy due to certain difficulties encountered in trying to obtain the desired information at this time. Nevertheless, the acute significance of the eastern Arctic bird populations is certainly recognized, and more appropriate information will be provided on the subject at a later date.

Beaufort Sea/NE Chukchi Sea

Marine Species

Three species of sea ducks (old-squaw, common eider and king eider) are abundant in the Beaufort Sea/NE Chukchi

Sea area, although there is conflicting evidence on the sizes of the populations using the region. The old-squaw nests on tundra throughout the area and the numbers involved are probably several hundreds of thousands. Available population estimates include 125,000 on the North Slope of Alaska, 208,000 in the Mackenzie Delta, Liverpool Bay, Old Crow Flats area, 6000 to 60,000 on Banks Island and 20,000 on Victoria Island.

The number of common eiders using the Beaufort Sea is a few hundred thousand birds at most. Estimates include 40,000 passing Point Barrow and unsubstantiated estimates of 285,000 and 550,000 moving through the Beaufort Sea. The nesting areas used by the common eiders that migrate through the Beaufort Sea are essentially unknown. Only a few small nesting areas have been found in the study area - the largest known colonies are about 100 pairs at Cross Island (barrier island in Alaska) and 50+ pairs at Cape Parry.

The king eider is more abundant than the common eider. Perhaps a million individuals summer in or migrate through the Beaufort/NE Chukchi area. A study at Point Barrow of part of the summer and fall migration suggested that about 750,000 king eiders passed the area. Another study estimated that over one million eiders (mostly king eiders) passed Point Barrow in summer and fall. The nesting population on the Alaskan North Slope is only about 10,000 birds and few nest between Alaska and the Bathurst Penninsula. Estimates of numbers nesting on Banks Island range from 100,000 to 150,000 and late summer populations of 800,000 birds have been estimated on Victoria Island.

The black brant is a marine goose that uses the Beaufort/NE Chukchi area. The North American winter population of this subspecies has been stable at about 140,000 birds in recent years. Estimates of the numbers in the study area are crude but perhaps a third (almost 50,000) of the North American population uses the area and more than half of these use the Alaskan Slope.

Four species of true seabirds nest in the area, mostly in the southern parts of the NE Chukchi Sea. Major murre colonies occur at Cape Lisburne and Cape Thompson; an estimated 365,000 common murres and thick-billed murres are present with the latter species being more numerous. The only other murre colony is a small concentration of about 800 thick-billed murres at Cape Parry. This colony is unique in that it is the only murre colony in the western Canadian Arctic. Three colonies of black-legged kittiwakes totalling 52,000 birds are present in the Cape Lisburne-Lewis-Thompson area. Small numbers (less than 1000) of black guillemots nest in scattered locations along the mainland coast of the Beaufort Sea/NE Chukchi Sea.

Three species of loons (yellow-billed, arctic and red-throated) are widely distributed breeding birds in coastal ponds and lakes throughout the Beaufort/NE Chukchi area. These species use marine areas during migration, and most individuals feed at sea during the nesting season. There are no reliable estimates of the numbers of loons in the study area, although a substantial proportion of the North American populations of yellow-billed loons and arctic loons may migrate into and through it. Three species of jaegers (pomarine, parasitic and longtailed jaeger) use marine areas during migration and during the summer in non-breeding years. No reliable estimates of numbers are available but these species usually do not occur in large concentrations. Rather, jaegers are likely to be widespread in small flocks of a few birds each.

Four species of gulls (glaucous, Sabine's, Ross's and ivory gulls) and the arctic tern commonly use the marine waters of the study area. The glaucous gull is the most widespread nesting gull species and small colonies and single nesting pairs are distributed on cliffs and islands throughout the study area. Little is known about overall numbers. Glaucous gulls feed in coastal marine areas. Arctic terns and Sabine's gulls nest on spits and islets in both marine and freshwater environments. Arctic terns are widespread and common while Sabine's gulls are relatively uncommon and nest primarily in the Canadian portion of the study area. Numbers of these species using the study area are not known. The ivory gull is a rare arctic gull that is often associated with pack-ice. It is found singly or in small groups in offshore waters, but does not nest in the Beaufort/Chukchi area. Ross's gull nests in Siberia but frequents the NE Chukchi Sea during September and October. Flocks of up to 4300 birds have been observed at Point Barrow.

Two species of phalarope (red and northern) are found in the study area. These are the only shorebird species that habitually swim and are pelagic during all but the nesting season. Numbers using the study area are not known but numbers of red phalaropes may be large.

Coastal Species

Several species of waterfowl and shorebirds inhabit coastal (terrestrial) areas during part or all of their stay in the Beaufort/NE Chukchi area. Although these species usually do not use marine habitats directly, they do use extensive low-lying areas such as the Mackenzie Delta which can be inundated by storm surges in the Beaufort Sea.

The main species groups that use coastal habitats extensively are the geese, ducks and shorebirds. In addition to the brant, three species of geese (Canada goose, white-fronted goose, snow goose) use coastal areas of the Beaufort Sea and NE Chukchi Sea. All three species nest in the area and migrate to and from their wintering grounds via overland routes. The snow goose nests at three major colonies in the area (Egg River, Banks Island--165,000 nesting birds; Anderson River Delta--3800; Kendall Island--800; these estimates are for 1976). These birds represent approximately 10% of the total species population. The two smaller colonies are located within the littoral zone. Prior to fall migration, up to 300,000 snow geese stage (feeding heavily to accumulate fat reserves) on the Mackenzie Delta and along the Yukon and eastern Alaskan North Slope. In years when early snowfall prevents use of the preferred uplands of the North Slope all staging activity can be confined to the littoral zone of the Mackenzie Delta.

The North American wintering population of whitefronted geese is about 200,000 birds and approximately 90,000 (adults and young) use the North Slope, Mackenzie Delta, and Anderson River areas during the summer. Nesting white-fronted geese are widely dispersed over tundra habitats. However, many subadults gather at traditional coastal areas where they moult. During moult, all flight feathers are shed and the birds are flightless for about three weeks. Traditional coastal moulting areas for subadult white-fronted geese are found in the Mackenzie Delta--Parry Peninsula area. The largest moulting concentration (20,000) was reported in Liverpool Bay. Fall staging whitefronts also use the littoral zone of the Mackenzie Delta and as many as 20,000 birds have been reported in this area at one time.

The Canada goose nests in low densities on mainland tundra and only moulting subadults congregate in coastal moulting areas in the Mackenzie Delta--Parry Penisula area. The largest reported concentration was 20,000 birds on the Anderson River delta.

Three main species of diving ducks (in addition to previously discussed marine species) use marine coastal waters during the moult. They are the surf scoter, white-winged scoter, and the greater scaup. Scaup are common nesters in the Mackenzie Delta-Liverpool Bay area whereas most scoters nest south of the study area.

At least 27 species of shorebirds regularly use the study area and 20 are known to nest there. Of these shorebird species, the phalaropes (already discussed), the ruddy turnstone and the sanderling are considered the most vulnerable to littoral zone disturbance.

The following sections review the major activities of sea-associated birds in the Beaufort/NE Chukchi area.

Wintering

Very few sea-associated birds winter in the area but a few glaucous gulls and common eiders winter in leads near Point Hope, Alaska. Although there have been no winter studies, it seems unlikely that birds regularly winter in the Beaufort Sea.

Spring Migration

Available information about spring migration routes over marine areas is summarized in Figure 5-8. Few quantitative data about offshore migration routes are available.

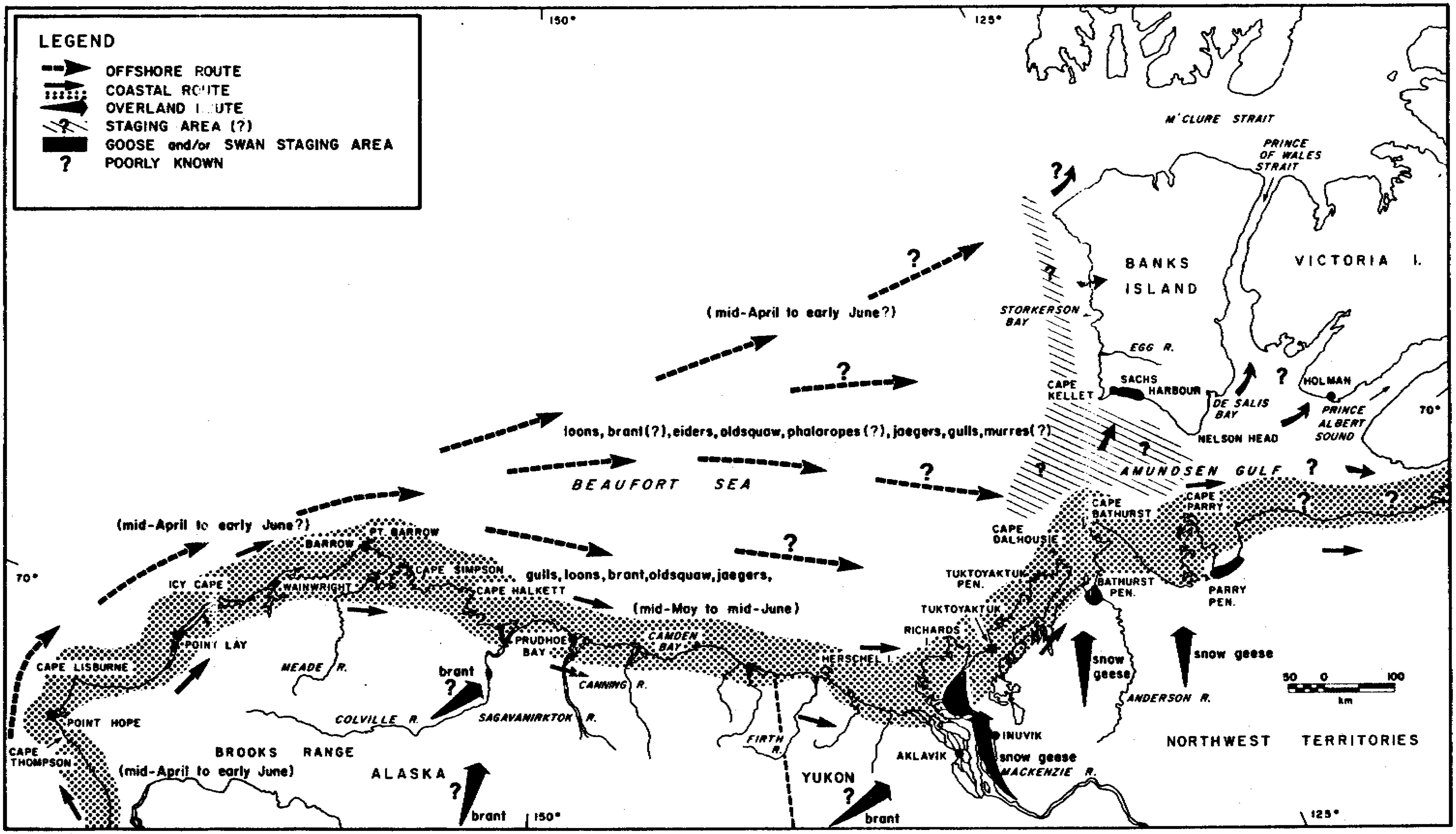


FIGURE 5-8 Summary of spring migration routes and staging areas of marine-associated birds in the Beaufort Sea/NE Chukchi Sea area.

Migration apparently follows the floe-edge along the northwest coast of Alaska. At Point Barrow, large numbers (several hundreds of thousands) of king eiders, common eiders and old-squaws leave the coast and migrate over the ice to the Banks Island and Amundsen Gulf areas. Loons, brant, phalaropes, jaegers, gulls and murres probably also use this route to some extent. The migration across the ice probably occurs over a broad front with specific routes perhaps related to the presence of leads.

Movements along the Beaufort Sea coast occur from about mid May to mid June whereas offshore movements begin in late April or early May.

Apart from the general lack of information about the numbers and routes of offshore migrants, a significant data gap is the lack of systematic information about the use of polynias and recurring leads by staging eiders and old-squaws. The areas of concern are the lead west of Banks Island, the Amundsen Gulf polynia and the lead off Cape Dalhousie. These open water areas are joined in some years. Non-systematic surveys have recorded large concentrations (e.g., 75,000 common eiders) in these areas.

Nesting

The Cape Lisburne-Cape Thompson area has the greatest concentration of nesting birds in the study area; 52,000 black-legged kittiwakes, 365,000 murres and approximately 4000 other seabirds nest in three colonies in this area.

After the seabird colonies, the snow goose colony on Banks Island is the largest concentration area for nesting birds (165,000 nesting geese and an unknown number of non-breeders and young). Although the colony is located 16 km inland, birds move toward the coast during the brood-rearing.

The small colony of murres (800) at Cape Parry is a unique feature of the western Canadian Arctic. Coastal lagoons are important sites for small colonies of common eiders, terns and gulls. In addition to the above areas, river deltas, particularly the Mackenzie and Anderson deltas, support high densities of several species that are widely distributed during the nesting season.

Moulting

Many waterfowl (ducks, geese, swans) and some seabirds (murres and guillemots) moult all of their flight feathers while in the study area. Flightless birds are vulnerable to disturbance, predation and contamination on their moulting areas since their mobility is impaired.

Waterfowl that moult in the marine environment include brant and several species of diving ducks (old-squaw, scoters, scaup). Moulting waterfowl concentrate in coastal waters. These concentrations can be large enough to include a significant proportion of the population. For example, the 25,000 black brant recorded moulting at Cape Halkett, Alaska, in 1966 represent approximately 20% of the North American population of that subspecies. Moulting areas tend to be traditional; however, there can be large annual variations in the numbers using a particular area.

The Cape Halkett area mentioned above apparently supports by far the largest numbers of moulting brant in the Beaufort/Chukchi area. Large numbers of diving ducks moult within the study area. Old-squaws are the most numerous and moult in coastal areas throughout the region. They tend to concentrate in certain areas such as barrier island lagoons and along the shoreward side of land spits. The Tuktoyaktuk Peninsula area maintains large numbers of moulting ducks; estimates include 160,000 old-squaws, 60,000 scoters and 32,000 scaup. Concentrations of these species (about 62,000) have also been found in adjacent Liverpool Bay. Between 50,000 and 100,000 old-squaws moult along the Alaskan coast from the Colville River to the Canadian border.

The moult of adult murres occurs after they leave the colony with their flightless young. The fall migration route of the murres from Cape Parry is not known but is most likely in a westward direction toward the presumed wintering areas in the Bering Sea. Murre migrations generally occur in offshore waters.

At Cape Lisburne and Cape Thompson, the murres probably disperse in offshore waters in a southerly direction toward their wintering grounds.

Fall Migration

Fall migration is very protracted and extends from the end of spring migration in late June until late October. As in spring, fall migration can follow overland, coastal or offshore routes. Figure 5-9 summarizes known fall migration routes from the Beaufort/Chukchi area.

Offshore migration routes are again thought to be the most used and are also the least known. In the eastern Beaufort Sea birds are believed to be widely distributed but as they approach Point Barrow there appears to be a constriction of the routes followed. As in spring migration, the offshore routes

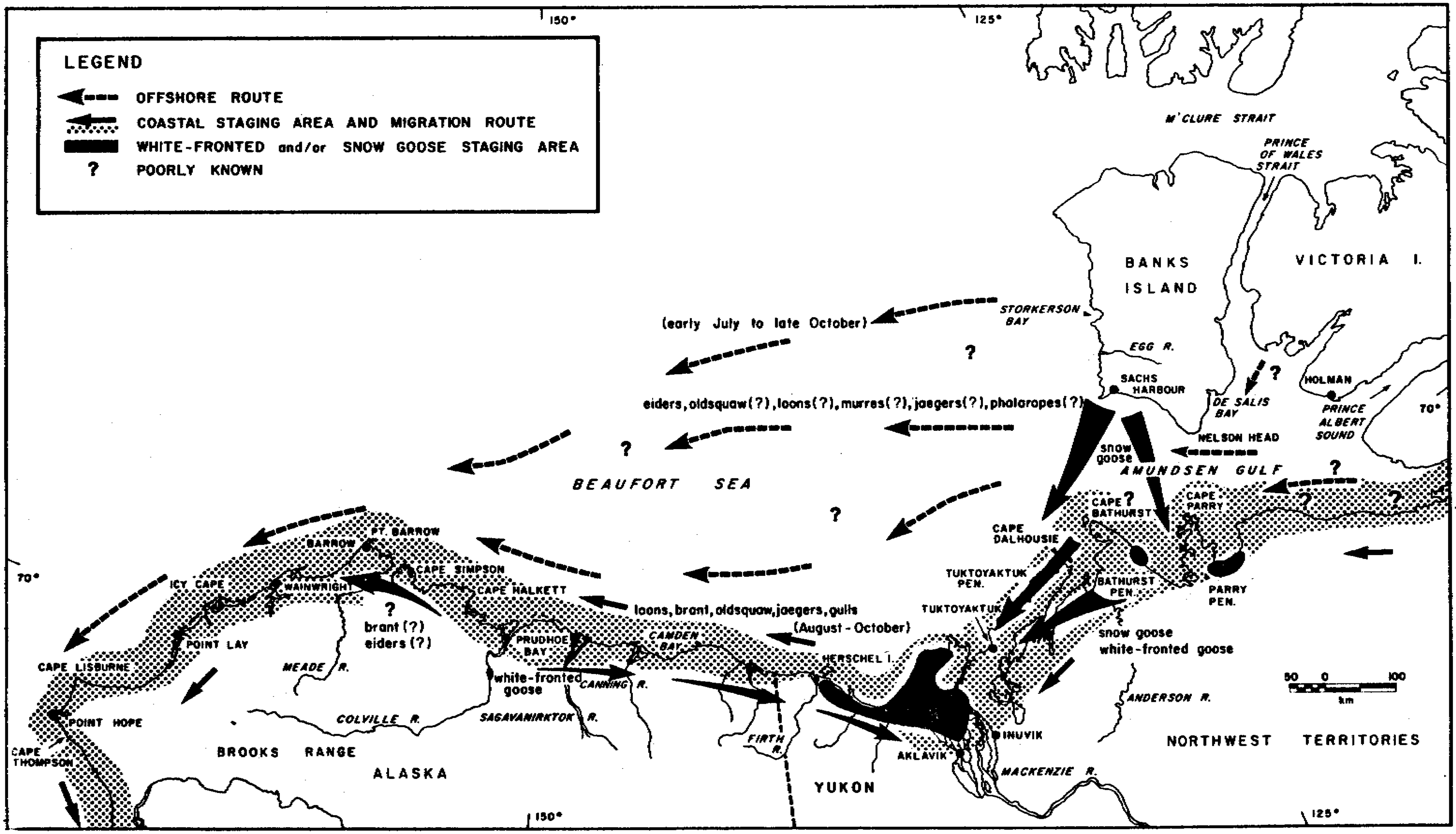


FIGURE 5-9 Summary of fall migration routes and staging areas of marine-associated birds in the Beaufort Sea/NE Chukchi Sea area.

in the Point Barrow--Cape Lisburne area are believed to follow a relatively narrow band.

Migration through offshore areas may begin in late June with a reverse migration of non-breeding jaegers and westward moult migration of male old-squaws. This is followed in early July by the beginning of migration of post-breeding male eiders to their moulting areas in the Bering Sea. Thereafter, there are migrations of female phalaropes in mid July, male and juvenile phalaropes in August, and female eiders and their young from late August through October. Loons also migrate through these areas in late August and September.

Although some westward coastal "fall" migration may occur in late June with the return of non-breeding jaeger and male old-squaws from their nesting areas, migration does not begin in earnest until mid August when staging and migrating brant begin their westward movements. Old-squaw and loons migrate through coastal waters during September and October.

Staging areas used by brant and old-squaw are located along the entire coastline of the Beaufort/Chukchi area. As during moulting, concentrations tend to occur in barrier-island lagoons, in bays and other sheltered areas. Build-ups of old-squaw in particular can be spectacular. Over 100,000 old-squaw have been recorded in Simpson Lagoon, Alaska, in late September.

Important coastal staging areas for overland migrant geese (snow geese and white-fronted geese) are primarily along the Yukon and Alaskan North Slope and in the Mackenzie Delta. Close to half a million staging geese can be found in this area during late August and early September.

Eastern Arctic
(Northwest Passage/Baffin Bay/Davis Strait)

Very large numbers of seabirds are found in Davis Strait, Baffin Bay and Lancaster Sound in summer. As many as two or three million seabirds migrate, nest or feed in Parry Channel during the open water season from April to October, representing over one-half of Canada's population of eastern Arctic seabirds. Northern fulmars, thick-billed murres, black-legged kittiwakes, black guillemots and eiders probably comprise the bulk of the migrants. If dovekies are included, the total numbers of seabirds may almost double. Although dovekies do not breed in Arctic Canada, they feed briefly at the entrance of Lancaster Sound en route to Greenland nesting-cliffs in spring.

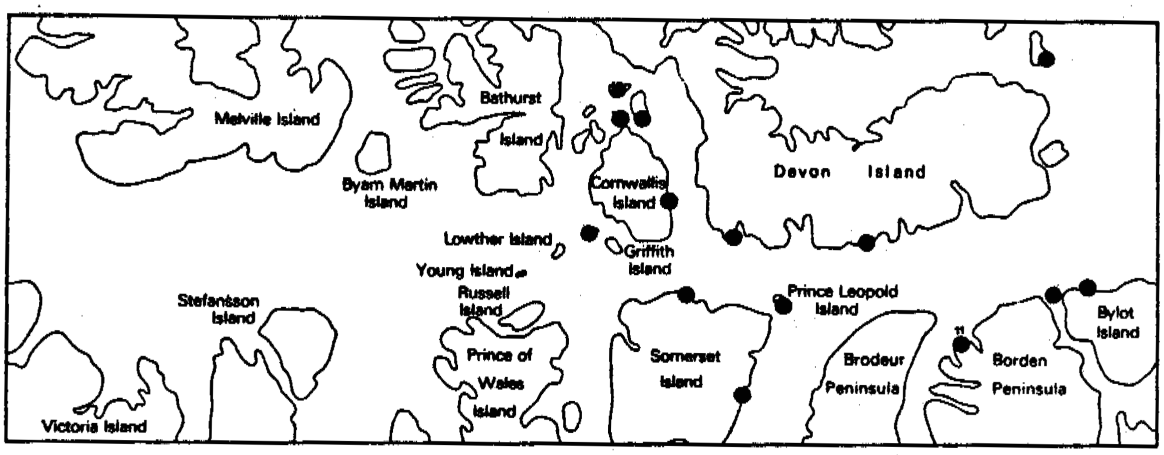


FIGURE 5-10 Locations of Major Seabird Colonies in or near Parry Channel
(From Smiley and Milne, 1979)

Major seabird nesting locales are known throughout Parry Channel, especially for colonial species, such as murres, kittiwakes and fulmars (Figure 5-10). Most colonies border the sea, with nesting ledges often situated on near-vertical, shoreline cliffs. The two largest colonies within Parry Channel are situated on North Bylot Island (Cape Hay), and Prince Leopold Island. Together with nearby colonies on South Devon Island [illegible] North Baffin Island [illegible]llarney Bay), distant Colburg Island and East Bylot Island (Cape Graham

Moore), these are the breeding sites of 50 to 60% of Canada's fulmars, and over 25% of Canada's thick-billed murres. Because of their proximity to the sea, these colonies are potentially highly vulnerable to disruption by marine traffic.

Virtually all of the eastern North American population of thick-billed murres either nests in or migrates through the Baffin Bay-Davis Strait area. The numbers at many murre colonies appear to be declining, and some colonies have been inadequately censused. However, the population still numbers a few million birds.

The eastern North American population of northern fulmars nests in Baffin Bay, Lancaster Sound and Jones Sound. The population numbers about 500,000 pairs of breeding birds and a large but unknown number of subadult non-breeders. The fulmar is a colonial species with a very long nesting cycle. Colonies are occupied from late April until late September.

The majority of the eastern Arctic population of black-legged kittiwakes nest in the Lancaster Sound-NW Baffin Bay area. About 200,000 birds may be involved.

Many other species of seabirds and sea-associated birds occur in the large area encompassed by Parry Channel, Baffin Bay and Davis Strait. Several of these species (e.g. king eider, common eider, old-squaw, black guillemot) are very abundant.

MARINE MAMMALS

Beaufort Sea/ NE Chukchi Sea

Fourteen species of marine mammals (including polar bear) have been recorded in the NE Chukchi Sea, Beaufort Sea area, although only nine species occur regularly.

Year-round Residents

Three species (ringed seal, bearded seal and polar bear) are permanent residents in the area. Ringed seals maintain breathing holes in the sea-ice throughout the winter. Bearded seals, although capable of maintaining breathing holes, tend to occupy the moving ice and thin ice areas in the transition zone between the landfast ice and the polar pack ice (Figure 5-11). Non-breeding subadult ringed seals are also most common in this transition zone. Breeding ringed seals occupy the landfast ice. Polar bears are common in the transition zone where they feed primarily on subadult ringed seals but also bearded seals. These bears are primarily adult males, subadults, and females with yearling cubs.

Pregnant female bears occupy maternity dens on land in coastal areas from about November to late March or April. Some maternity dens have also been found on the sea ice off Alaska. The females with their newly born cubs occupy the landfast ice after their emergence from dens. They feed primarily on breeding ringed seals on the landfast ice.

A fourth species, the arctic fox, is also present on the winter sea ice. Foxes roam the ice and feed on carrion left from seals killed by polar bears. In April and May, arctic foxes also prey on newborn ringed seal pups, which occupy birth lairs in snowdrifts on the ice. Most of the foxes return to land before break-up begins.

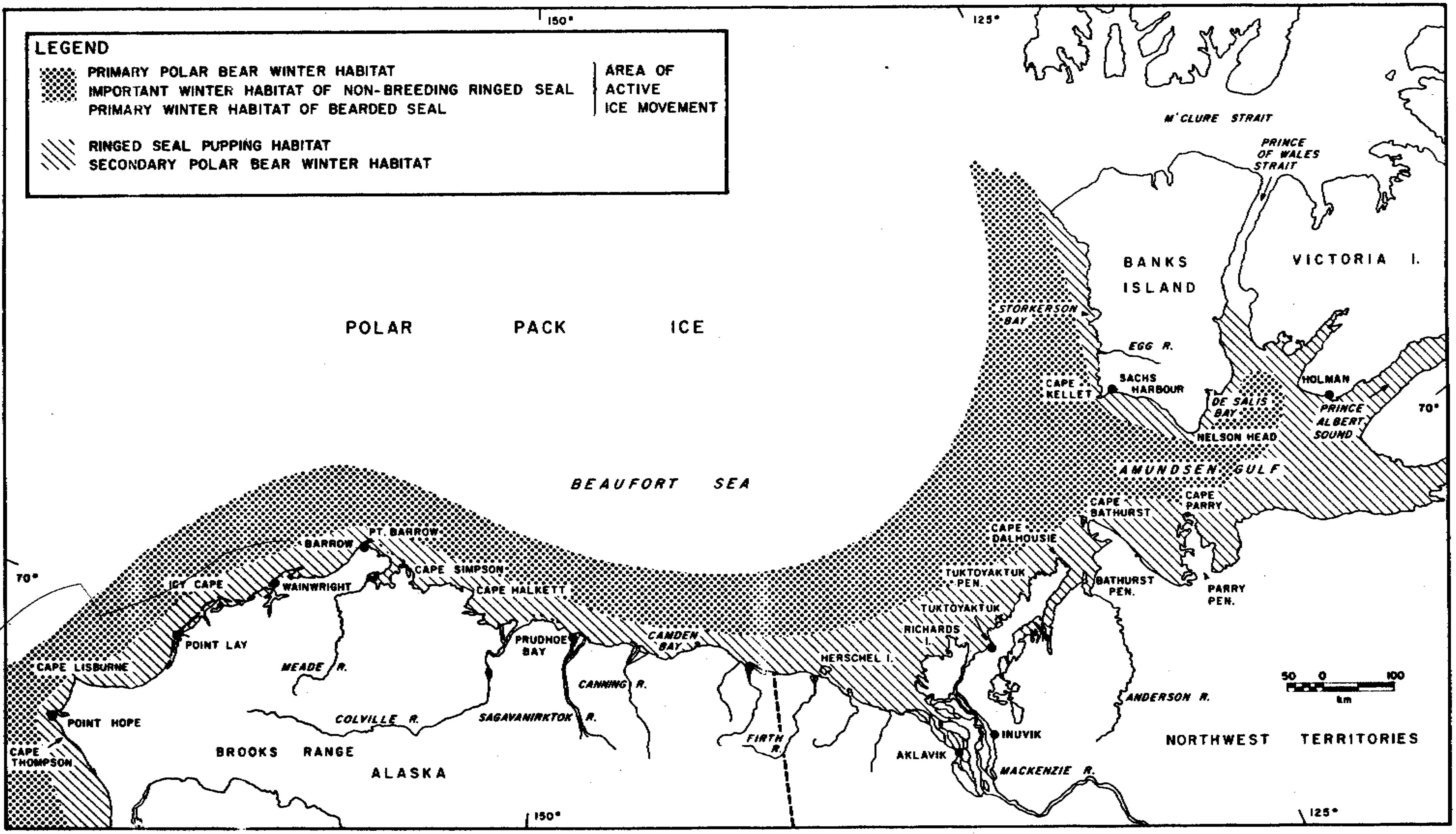


FIGURE 5-11 Summary of distribution of ringed seals, bearded seals and polar bears.

I. Stirling of the Canadian Wildlife Service has studied seals and bears in the Canadian Beaufort Sea for several years. These studies yield preliminary population estimates of about 80,000 ringed seals and 8,000 bearded seals for Amundsen Gulf and those parts of the Canadian Beaufort Sea that are within 160 km of the mainland coast and the west coast of Banks Island. Very few seals are found in the polar pack ice farther offshore. There are no estimates of the numbers of seals occupying the sea ice off the north coast of Alaska. An estimated 2500 polar bears occupy the sea ice off Alaska from Cape Lisburne to the Candian border and an additional 1700-1800 occupy the Canadian Beaufort Sea and Amundsen Gulf.

Populations of seals and bears in the Beaufort Sea undergo large, natural population fluctuations. Severe ice conditions in the winter of 1974-75 are thought to have been responsible for major declines in numbers (e.g. ringed seals declined from 78,000 to 35,000; bearded seals from 8000 to 2000; polar bears from 1800 to 1200). These declines were accompanied by drastic reductions in reproductive rate, emigration, changes in feeding habits, and stress. Under these circumstances it has been postulated that populations may be less capable of withstanding additional artificial or human-induced pressures on the environment.

During the summer open water period, polar bears retreat to the polar pack ice where some seals can be hunted. Very few bears are found on land during this period. The distribution of ringed and bearded seals in summer is poorly known. Some ringed seals are found along the south edge of the pack ice. Both species occupy open water areas and coastal ice remnants but quantitative assessments of their summer distribution are not available. However, during summer bearded seals are more common in the NE Chukchi Sea and western Beaufort Sea than in the eastern Beaufort Sea.

There is some evidence for a westward migration of young-of-the-year ringed seals out of Amundsen Gulf in late summer. Large numbers pass Cape Bathurst and Herschel Island.

Seasonal Residents

The most important seasonal migrants into the Beaufort Sea area are the bowhead whale and the beluga (white whale). The bowhead is an endangered species that is subject to a small but controversial subsistence hunt by Alaskan Inuit. This population of bowheads is estimated to number between 1783 and 2865 animals, representing most of the bowheads that remain in the world. The Mackenzie stock of belugas occupies the southeastern Beaufort Sea in summer; it numbers between 5500 and 6500 animals. A small group of a few hundred animals occupies the northwest coast of Alaska in summer.

Bowheads and belugas winter in the Bering Sea. They leave these areas in March and move north through the Chukchi Sea in April. The whales follow leads that parallel the NW coast of Alaska until they reach Point Barrow. East of Point Barrow, early migrating (May) individuals travel eastward far offshore through leads in the pack ice (Figure 5-12). These whales reach the lead along the west coast of Banks Island and follow it south to Amundsen Gulf. Later migrating whales migrate eastward farther south in the Beaufort Sea. Exact routes and timing of migration are variable depending on ice conditions.

The summer distribution of bowhead whales is not well known. In June and July, they are thought to occupy Amundsen Gulf and the extreme southeastern Beaufort Sea. By August some have moved west toward the Mackenzie estuary. There have been no quantitative studies of the numbers and distribution of bowheads during summer. Since it is possible that most of the

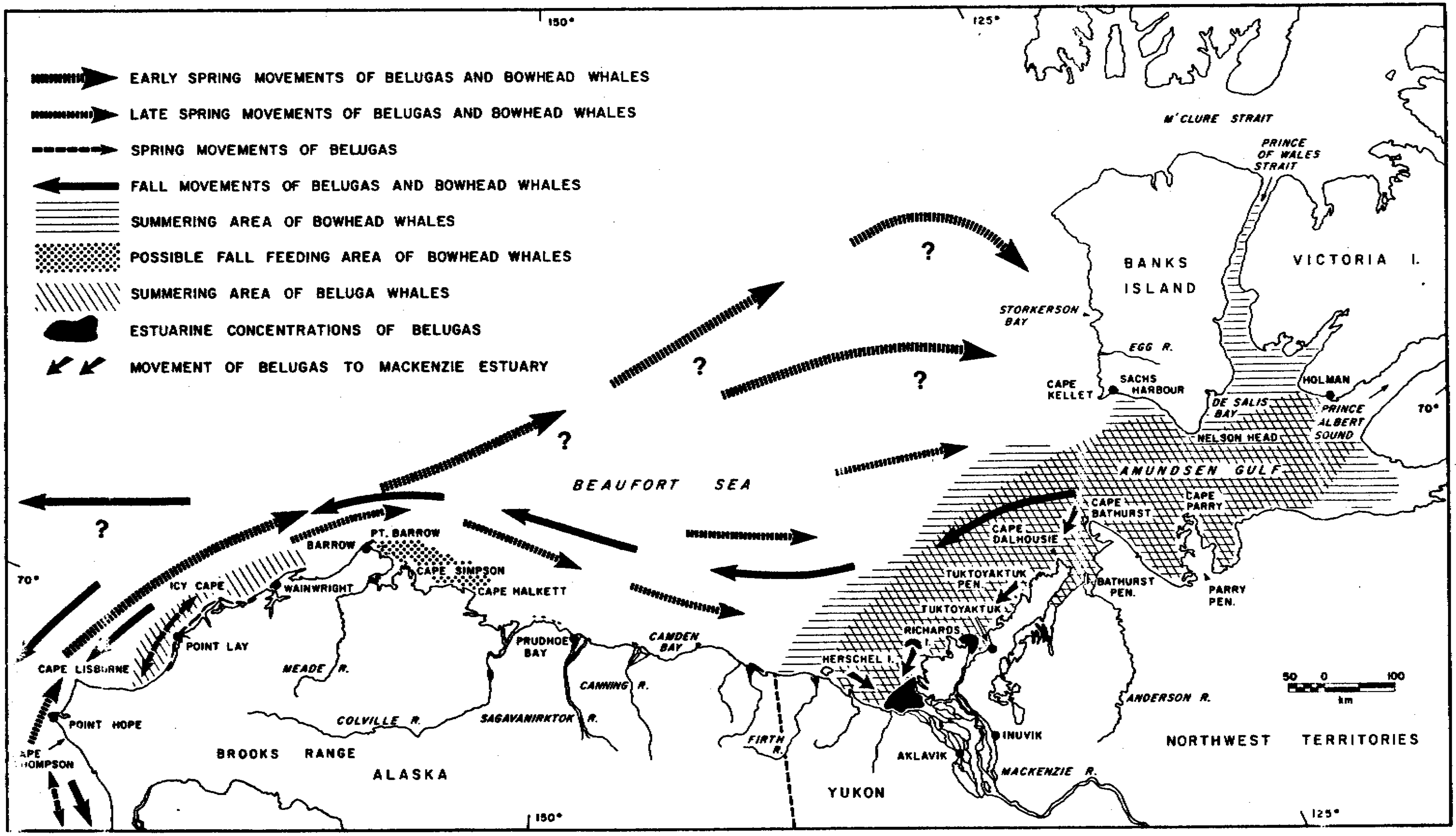


FIGURE 5-12 Summary of movements and summering areas of beluga and bowhead whales.

annual food intake by the species occurs during the two to three months they spend in the southeastern Beaufort Sea, the lack of information about distribution and behaviour in this area may be considered a significant data gap both from an impact and a management point of view.

The summer distribution of belugas is somewhat better known. They travel west along the landfast ice edge from Amundsen Gulf to the Mackenzie estuary in late June. They occupy estuarine concentration areas during most of July (Figure 5-10). They leave the estuary in August but their distribution in August and September is poorly known.

The fall migration of bowheads occurs from late August to mid October, as compared to mainly September for Belugas. There is practically no information about the major routes used by bowheads and belugas during their fall migration through and out of the Beaufort Sea and NE Chukchi Sea.

The gray whale, walrus and spotted seal are other important summer visitors to the NE Chukchi Sea. However, these species are all uncommon in the western Beaufort Sea and of the three, only the walrus has been recorded in the eastern Beaufort Sea.

Eastern Arctic (Northeast Passage/Baffin Bay/Davis Strait)

Permanent resident species of marine mammals include the ringed seal, bearded seal and polar bear. Breeding ringed seals generally occupy stable fast ice, whereas most non-breeding ringed seals and bearded seals occupy polynias, thin ice and pack ice.

A few hundred belugas winter in the "North Water" but most of the 10,000 - 12,000 animals in the Lancaster Sound population winter along the west coast of Greenland south of 70° N. These animals migrate north along the Greenland coast, cross Baffin Bay and enter Lancaster Sound in June and July. They occupy coastal estuarine areas in the central Arctic (primarily along Somerset, SW Devon and NW Baffin Islands) in late July and early August. Few belugas move west as far as western Barrow Strait. Eastward migration through Lancaster Sound occurs in September and re-traces the spring migration route.

A small population of belugas summers in Clearwater Fiord in Cumberland Sound, SE Baffin Island. This population has been reduced to about 500 animals in recent years. They are thought to winter at the east end of Hudson Strait.

About 20,000 narwhals inhabit the eastern Arctic. They are thought to winter in the southern portions of the Baffin Bay pack ice. Spring migration is not well documented but occurs along the west coast of Greenland and through the pack ice. Narwhals enter Lancaster Sound in June and July and most summer around northern Baffin Island in Eclipse Sound, Admiralty Inlet and Prince Regent Inlet; some move west to Peel Sound. Fall migration from these areas back to Baffin Bay occurs in early October.

The remnants of the eastern Arctic bowhead population winter in Davis Strait and off northern Labrador and summer in Prince Regent Inlet, Admiralty Inlet, Eclipse Sound and along the NE coast of Baffin Island.

The present status of the walrus in this area is unclear. Small numbers occur in summer in several locations but migration routes and wintering areas are poorly known.

Harp seals move north into Davis Strait and Baffin Bay after whelping off Newfoundland. Large numbers may enter the Parry Channel area in some years (150,000 seen passing Cape Hay, Bylot Island, in 1957) but fewer are present in other years (16,000 seen in 1976).

Hooded seals are uncommon in Baffin Bay and Lancaster Sound, but a whelping concentration of 30,000 to 50,000 occurs in March along the south edge of the pack ice in Davis Strait. Harbour seals occur in small numbers along the coasts of Baffin Bay and Davis Strait.

Small numbers of killer whales occur in Davis Strait and in Baffin Bay north to Lancaster Sound in summer. Several additional species of whales (blue, fin, sei, humpback, minke, sperm, pilot, northern bottlenose, white-beaked dolphin, and harbour porpoise) enter Davis Strait in summer and some move north to about 70° N along the Greenland coast. These species are not associated with ice and return south in the fall.

RESOURCE UTILIZATION

Beaufort Sea/ NE Chukchi Sea

Nine species of mammals and several species of birds and fish are harvested from the marine system by native subsistence hunters from five Alaskan and six Canadian communities in the Beaufort Sea/NE Chukchi Sea area. Marine mammals are the most important species. Spotted seals, walruses, bowhead and gray whales are taken only by Alaskan natives. Ringed and bearded seals, white whales, polar bears and arctic foxes are taken throughout the area. Table 5-1 shows the approximate yearly harvest of marine mammals in the Alaskan and Canadian portions of this region. The sale of arctic fox skins provides a large portion of the cash income for Inuit at Sachs Harbour and Holman and a lesser portion at other Canadian communities and the Alaskan communities. The sale of polar bear skins also provides cash income in Canadian communities but not in Alaska where such sales are prohibited under the Marine Mammal Act.

Table 5-1 Approximate Numbers of Marine Mammals Harvested by Inuit in the Beaufort Sea NE Chukchi Sea Area.

	Approximate Numbers Harvested Yearly	
Species	Northern Alaska	Northwestern Canada
All seals	1400	3800
Walrus	65-410	0
Bowhead whale	4-35[1]	0
White whale	20-25	210[2]
Gray whale	5	0
Polar bear	10	50
Arctic fox	no reliable data	5500-14000

1 1979 quota was 18 killed or 27 struck.

2 Includes estimated number struck but not retrieved.

People from the communities of Nuiqsut and Kaktovik in Alaska, and from Inuvik and Aklavik in the Mackenzie Delta, depend as much or more on the harvest of terrestrial mammals than on marine mammals. The species of greatest importance at other communities varies - e.g. bowhead whales at Wainwright and Barrow, white whales at Tuktoyaktuk, white whales and walruses at Point Lay. But, in the event of failure of the hunt for these species, seals provide the most dependable resource at all communities.

The areas used for hunting and trapping of marine mammals are somewhat different for each species but, overall, include most of Amundsen Gulf as well as the nearshore areas of the Beaufort and northeast Chukchi Seas. Hunting for some species extends out to distances of 70 to 80 km offshore in the latter area but most hunting occurs within about 40 km of the coast.

Eastern Arctic
(Northwest Passage/Baffin Bay)

Most hunting and trapping in the eastern Northwest Passage is carried out seasonally by people from the communities of Resolute, Arctic Bay and Pond Inlet.

In March, or earlier, Resolute Inuit begin hunting caribou on West Somerset and Russell Islands and, to a lesser extent, East Prince of Wales Island. This hunting pattern requires extended trips across about 120 km of Barrow Strait sea ice. The collapse of caribou populations on most of the Queen Elizabeth Islands has forced hunters to abandon game areas on Bathurst and Cornwallis Islands. En route, they do not miss opportunities to shoot polar bears and ringed or bearded seals. Legally, the bear hunting season extends from October 1 to May 31 and, since 1970, the annual quota for Resolute Bay residents has been 34 bears. Most polar bears are killed between February and May, after the coldest and darkest winter months have passed. Bear hunters travel by snow-machines throughout Barrow Strait and East Viscount Melville Sound, and as far as McDougall Sound, South Wellington Channel and North Peel Sound. However, most bears are killed at the Barrow Strait ice edge, especially when the ice edge stabilizes, temporarily, immediately south of Resolute village (Figure 5-13).

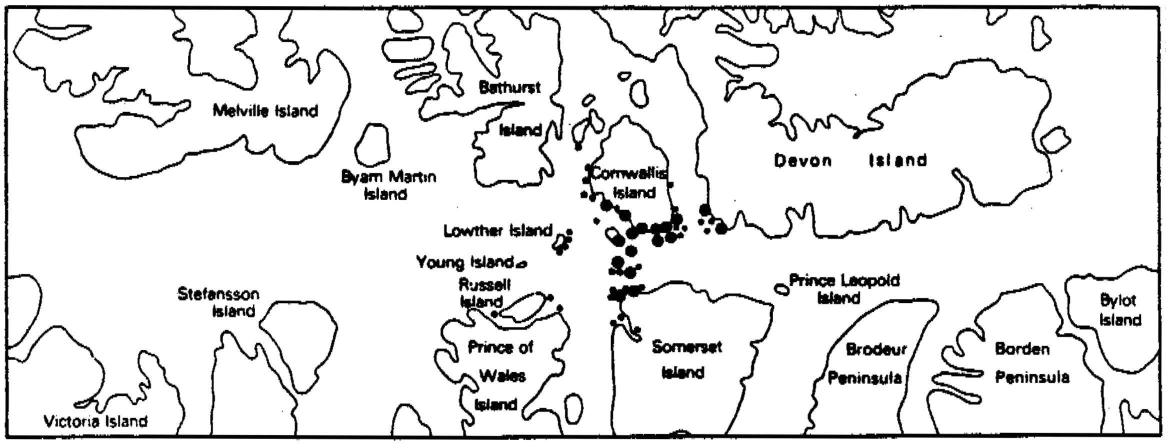


FIGURE 5-13 KNOWN LOCATIONS OF POLAR BEAR KILLS BY INUIT IN CENTRAL PARRY CHANNEL FROM 1968 TO 1976 (FROM SMILEY AND MILNE, 1979)

The seal harvest occurs on the stable, relatively flat ice near Resolute Bay in winter and spring, but this changes as ice conditions differ. As mentioned above, many seals are killed by hunters en route to Somerset Island and Wellington Channel, but seal hunting is also popular in Allen Bay (east of Resolute Bay on South Cornwallis Island) and McDougall Sound. Bearded seals are often shot when hauled-out on coastal sea ice in late May and June.

Inuit hunt white whales opportunistically near Resolute Bay, if herds happen to swim close to shore during their open water migration. Walruses are hunted in certain locales in Penny Strait, around Crozier and Baring Islands, and along south Bathurst Island. Again, walruses are sometimes killed in conjunction with sealing and whaling trips in summer.

Hunters from Arctic Bay and Pond Inlet (North Baffin Island) kill narwhals, ringed seals, and polar bears along East Parry Channel's south shore, and in adjacent inlets and fjords.

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6. ENVIRONMENTAL ISSUES AND MITIGATION MEASURES

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6 ENVIRONMENTAL ISSUES AND MITIGATION MEASURES

The fundamental purpose of this section of the report is to identify what the company perceives to be the major areas of environmental concern that are or may be associated with projected development activities. This long range overview is intended only to provide background for subsequent site specific analyses that will be carried out as components of the development become defined over a period of many years.

Discussion of the types and where possible, magnitudes of impacts which might be anticipated is limited to Dome's Beaufort interest lands, the marine route north of 60° latitude, and the immediate coastal zone. It does not address possible pipelines to southern markets, marine transportation routes south of 60°, or construction activities in southern centers.

All components and activities associated with the development scenario will have some implications with respect to environmental matters. Aside from "mere presence" considerations, most components will produce liquid effluents, gaseous emissions, solid wastes, noise, heat, etc. Some types of activities may or will be associated with two or more of the development components, whether in a construction or operational mode. For example, fuel or lubricating oil may be spilled from any facility. Similarly there could be disturbance effects resulting from aircraft support or underwater noises associated with almost every component.

Table 6-1 summarizes Domes initial view of the principal environmental issues and impacts which may be associated with the major development components.

The three most important issues to be discussed in this overview are major oil spills, industrial land use, and chronic pollution.

TABLE

SUMMARY OF ENVIRONMENTAL ISSUES AND MAJOR IMPACTS

ENVIRONMENTAL ISSUES	IMPORTANCE	GEOGRAPHICAL EXTENT	IMPACTS
1) Major Oil Spill	High	Broad	Significant impacts could be anticipated, particularly with respect to seabirds, under ice biota, shoreline and ice edge habitats, marine mammals and benthic communities. Degree of impact would vary depending upon many factors, but not expected to be permanent.
2) Industrial Land Use	Moderate	Local	Localized disturbance to terrestrial habitat, possible interference with migratory patterns, particularly mammals.
3) Chronic Pollution			
a) Drilling Fluids	Moderate	Local)	Localized smothering and disturbance to benthic and planktonic communities.
b) Produced Fluids	Low	Local)	
c) Rig Wash Water	Low	Local)	
d) BOP Control Fluids	Low	Local)	
e) Sewage	Moderate	Local)	The cumulative effects of all chronic pollution could have significant environmental repercussions if left unchecked.
f) Cooling Water	Low	Local)	
g) Ballast Water	Low	Local)	
h) Minor Oil Spills	Low	Local)	
Cumulative Chronic Pollution	High	Local)	
4) Other Issues a) Ice Breaking	Low	Broad	Minor linear effects in comparison to natural ice variations. Some disturbance to marine mammals. Possibly beneficial to feeding and nesting marine birds.
b) Presence of Artificial Structures	Low	Local	Localized implications for ice cover, water circulation, current regimes, coastal and biotic processes.
c) Effects of Dredging	Low to Moderate	Local	Temporary increase in turbidity, minor reduction in dissolved oxygen, and localized changes in vertical salinity/temperature structure. Some effect on seabirds, zooplankton, as well as localized removal and burial of bottom flora and fauna.
d) Aircraft Disturbance	Low	Local	Overflights may cause disturbance to birds, marine and terrestrial mammals.
e) Noise	Low	Local	Localized disturbance from production facilities. Vessel activity may affect the behavior of marine mammals.
f) Solid Waste	Low	Local	Localized impacts only; for example, emissions associated with incineration, and land alteration associated with landfill.
g) Air Emissions	Low	Local	Localized ice fog and possible interaction between air emissions and atmospheric conditions.
h) Gas Blowout	Low	Local	Negligible environmental impact anticipated. Human health and safety of primary concern.

MAJOR OIL SPILLS

The issue of an uncontrolled oil blowout or massive spill resulting from a tanker accident, ruptured pipeline or storage tank may be viewed as the single greatest threat to the well being of the arctic environment.

Even though the probability of a major oil spill is low, the risk must be faced and minimized through the adoption of sound design and operating practices, a continuing program of experimentation, and the updating of all preventative and contingency measures as field experience is gained.

Risk and Reducing Risk

The current exploratory drilling program in the Beaufort sea is being carried out under the authorization of an approval-in-principle granted by the Federal Government in 1974. A key condition of this approval requires the company to report its progress and problems to the Federal Cabinet on a yearly basis. All activities, but particularly the drilling operations, are closely scrutinized by federal regulatory agencies. It has been a learning process for all concerned. Although there have been some minor problems, no oil blowouts have occurred to date.

The first generation of offshore arctic drilling equipment will soon be giving way to more advanced technologies such as arctic drilling barges, supported by larger icebreakers. Lessons learned from the initial experiences will be incorporated into the second and subsequent generation drilling equipment. The advent of the new equipment may permit year round drilling in the offshore waters. This is an important consideration because it will provide much better relief well drilling capabilities, if required.

Progressing through to the early stages of production, the proper design of permanent facilities such as artificial islands, arctic production/loading atolls and caisson platforms, should further enhance capabilities to control the possible release of oil to the environment from blowouts.

The risk of pipeline and oil storage tank ruptures occurring will be reduced to the maximum extent possible by the incorporation of approved design, placement and protection features. Underwater pipelines will be located to avoid geological hazards, ice scour and other problems as identified. Offshore oil storage tanks will generally be positioned below the depth of ice scour, or may be enclosed within the platform which it serves.

The arctic class tankers to be used for transportation of the oil will be the most technologically advanced vessels operating in the world at the time, and will be designed to further reduce the possible risk of oil spills. In this regard a recent (Dome 1979) study of worldwide tanker related oil spills was carried out to determine the design, equipment and operational features that should be incorporated into Dome's proposed arctic tankers.

In addition to the preventative measures employed in tanker design and construction, the traffic controls, including shipboard, satellite and shorebased, will be the most sophisticated available. This should further assist in reducing the risks associated with tanker transportation of the oil.

In summary, the risk of a major oil spill will be minimized through the adoption of sound design and operating practices a continuing program of experimentation, and the updating of all preventative and contingency measures as field experience is gained.

Oil Spill Countermeasures

As has been mentioned the best cure for oil pollution is prevention. Good operational procedures, good housekeeping, high quality engineering, adequate equipment maintenance and testing, and regular training of personnel are the best insurance against oil spills.

In spite of these preventative measures, the risk of oil spills remains, and must be planned for. Pre-planning involves emergency preparedness through organization, machinery and manpower. In this regard during exploratory drilling in the Beaufort, oil spill contingency plans have been prepared, personnel have been trained, and a large inventory of equipment is immediately available in the region to respond to oil spills.

The most appropriate oil spill response decisions will rarely be straightforward. Decisions must take into account priorities for protection, the effectiveness of oil spill protection and clean-up techniques and the resulting damage to resources from oil or treatment methods.

The basic approach to oil spill planning is flexibility. Responses must alter as the situation changes. Factors such as weather conditions, time of year, type and quantity of oil, all affect the nature of the response required. Whatever the decision, it is imperative that the On-Scene Commander realizes the benefits and limitations of each of his options.

Oil removal or treatment is easier and preferable at sea, rather than on shore. The first line of defense is to keep the oil near the source of pollution - localize the problem. Present methods include in-situ burning, with or without fireproof booms. Methods presently being investigated include the use of underwater containment systems.

If the proposed oil spill countermeasures have not been totally effective at the source of pollution, action must be taken to fight the spill in open water. Response to oil spills at sea would include burning, mechanical recovery and chemical dispersants. Mechanical recovery systems already available in the region include containment of oil by offshore booms with recovery by mechanical skimmers. The use of chemical dispersants in arctic waters requires government approval and further investigation in order to determine the effectiveness of dispersants on fresh, weathered and emulsified oil.

If the response at the pollution source and in the open water has not been totally effective, there are recommended oil spill protection and clean-up activities for the nearshore and shoreline regions. These techniques include:

1) burning the oil offshore;

2) mechanical recovery offshore;

3) application of chemical dispersants;

4) diverting oil away from sensitive shorelines;

5) sealing sensitive lagoons and bays with booms and recovering oil with skimmers;

6) the use of deflector booms and skimmers in inlets where the current exceeds 1 knot;

7) as a last resort, the construction of temporary dams across narrow inlets to ensure oil does not pollute sensitive backshore areas.

If all previous protection methods fail, and oil does contaminate the shoreline, some clean-up techniques can be recommended.

In general, clean-up of shoreline areas is more difficult and more expensive than containment and recovery operations on water. Sometimes the best course of action is to do nothing, as attempts to remove or treat oil from some shorelines would be far more damaging or at best a waste of time and money. Shoreline clean-up methods are relatively straightforward and in most cases do not rely on sophisticated technology. Usually the most efficient method of removing oil from beaches involves small teams of laborers, shovels, buckets, portable burners and incinerators, and possibly a limited amount of large machinery (e.g., front end loaders, graders).

The most important factor for shoreline clean-up decisions is the identification of the coastal land form, beach type and shoreline processes. Once this is known for specific coastal areas, the On-Scene Commander can recommend the most appropriate clean-up method. As an example Table 6-2 reviews the clean-up techniques that are recommended for shorelines along the southern Beaufort Sea.

Response to oil spills in the arctic offshore is presently restricted to the open water season, i.e., from July through October. Some activities, however, may occur in the winter months and would include: monitoring and tracking the oil spill; the movement of machinery (on ice) to specified shoreline locations to facilitate beach clean-up; and construction of government-approved oil debris landfill sites. In the spring, oil from the blowout will migrate up through the ice to collect on the surface in melt pools. As this unweathered oil collects to a sufficient thickness in [illegible]
made to burn the oil in situ.

TABLE 6-2 SHORELINE CLEANUP TECHNIQUES APPLICABLE TO SOUTHERN BEAUFORT SEA[1]

	Manual Removal	Mechanical Removal	Burning	Hydraulic Low Pressure	Chemical[2] Dispersants	Mixing	Cropping	Sorbents[3]
Deltas Tundra Beaches	§	N/A	+	§	N/A	N/A	+	+
Gravel Beaches	§	§	+	N/A	+	+	N/A	+
Mudflats	+	N/A	+	N/A	+	N/A	N/A	+
Sand Beaches	§	§	+	N/A	+	+	N/A	N/A
Cliffs (Unconsolidated)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

§ -- Recommended
\+ -- Applicable, possibly useful
N/A -- Not applicable or not recommended

1) Adapted from EPS 1978, "the Impact and Cleanup of Oil Spills on Canadian Shorelines: A Summary". It should be noted that most of these techniques have never been tried in the Arctic.
2) Sorbents should only be used as a final touch-up during clean-up operations.
3) Use of chemical dispersants along shorelines would require government permission.

Environmental Implications

Notwithstanding all the preventive measures incorporated into the design and construction of arctic development components, and the suite of countermeasure tools which may be available to combat and reduce the magnitude of accidents, there may be major losses of oil to the environment, with subsequent, possibly significant environmental repercussions.

The following excerpts from a report published under the auspices of the Beaufort Sea Project (Blood, 1977) fairly well captures the present state of the art regarding this issue.

> "Contact between accidentally spilled oil and animal life depends upon countless factors. The most important of these are the presence of the birds and mammals in the polluted area, their numbers and activities, as well as the influence of the season's winds, currents and ice conditions.....
>
> "It is all-but impossible to forecast the damage that oil pollution may inflict on wildlife. In the first place, the 'vulnerability' of the animals must be known. A creature is vulnerable to spilled oil whenever the presence of oil and the animal happens to coincide. Birds and marine mammals which seek out specific habitats in pristine surroundings and arrive in large numbers, can be seriously jeoparized by ecological upset.
>
> These situations occur in the Canadian Arctic. Seabirds arrive suddenly and en masse in traditional summering grounds and immediately begin reproductive duties. They compress the phases of breeding, nesting and fledging into a few weeks. Winter residents

> such as the seal and polar bear converge where their food is abundant, or accessible. Each species has its own life history, distribution patterns and behaviour traits. Their vulnerability will be realized at different places and at different times; a nightmare for anyone attempting to predict the impact of an oil spill."

The report goes on to provide a seasonal account of when, where and why some bird or mammal populations may be vulnerable to oil pollution, with particular reference to the Beaufort Sea.

There are currently several research initiatives underway or being planned which should contribute significantly to a better understanding of the possible fate and effects of oil in the arctic environment. These investigations have been initiated by industry and government under the Arctic Marine Oil Spill Program (AMOP) to study;

1. Oil and Gas under Beaufort Sea Ice (1979-80)*

2. Oil on Cold Water (1979-81)

3. Oil in Arctic Nearshore Environments (1979-83)

4. Oil on Arctic Shorelines (1979-83)

5. Oil in East Coast Pack Ice (1982-83)

It is expected that these and other efforts will lead to a significant improvement in our future predictive capabilities regarding the environmental implications of major oil spills.

The following represents some of the more current thoughts on the subject of oil spills in the Beaufort environment. The material presented is extracted primarily from Beaufort Sea Project Report No. 39 (1977) and APOA Project No.

136, (1979). Neither document purports to be definitive in its statements because there remain too many unknowns. Both reports agree that the effects of an oil blowout in the Beaufort Sea could be severe to some portions of the ecosystem and to some populations, particularly sea birds. However, both suggest that none of the effects are likely to be permanent, although recovery might take as long as a decade in some cases.

The APOA report placed considerable emphasis on the importance of animal habitats. Without preservation of these locales it was felt that the survival of a population of birds, fish or sea mammals would be more threatened, since recovery from oil related mortality would be made more difficult. There was considered to be little value in the expensive rehabilitation (capture, cleaning, release) of oiled animals if oil pollution were to persist in key habitats.

On the assumption that certain key habitats could be protected by one means or another, it was concluded that animal populations could recover, in time, even from a large scale reduction in numbers, be it caused by accident or design. Table 6-3 ranks the biological sensitivity of different habitats in the Beaufort Sea.

TABLE 6-3 SENSITIVITY RANKING OF KEY ARCTIC HABITAT TYPES

Sensitivity		Element
↑	1	Habitat of Rare and/or Endangered Species
	2	Sensitive* Waterfowl Habitat (nesting, moulting, staging, feeding)
Increasing	3	Sensitive Marine Mammal habitat (calving, pupping, feeding, travel routes)
Sensitivity	4	Sensitive Fish Habitat (spawning, feeding, migrating, overwintering)
	5	Sensitive Terrestrial Mammal Habitat (feeding, local movements, summer retreat from insects)
	6	Concentrations of Marine Food Organisms (plankton/ benthos)

*"Sensitive habitat" is defined as an area thought to be essential for the survival of a significant portion of a population or species.

The habitat of rare or endangered species is thought to be most important. No species utilizing the coastal region of the Beaufort Sea has been identified in "danger of extinction". However, polar bear, bowhead whale, thick-billed murre and black guillemot are considered to be rare in the Beaufort area, and as a result, may possibly be more vulnerable to increased human activities, including oil spills. Of these species, the murre and guillemot are probably most vulnerable to an oil spill.

Sensitive waterfowl habitat is considered the second most important category in the biological rating scheme. A major spill would probably result in the contamination of offshore leads and possibly coastal bays and shorelines. Seabirds would probably be the most severely affected component of the Beaufort Sea ecosystem. Table 6-4 shows the birds in the Beaufort area which are considered to be most vulnerable to an oil spill.

Marine mammals such as seals and whales and their habitat are the next most likely candidates to be significantly affected by an oil spill. The effects of oil on these animals are poorly known. However, experiments with seals have shown that exposure to oil may cause eye irritation, minor kidney damage and possible liver lesions, especially if the seals are manhandled during cleaning. The ingestion of oil by seals has not been known to produce symptoms or behavioral changes on the part of the animals, although contamination of the seals could affect their thermoregulatory abilities especially in the case of seal pups, which lack blubber.

Possible mortality of overwintering ringed and bearded seals concentrated in the ice of the transition zone cannot be predicted. However, it has been estimated that a large fraction of the sub-adult and adolescent seal populations in the southeastern Beaufort Sea, perhaps 30% or more, could encounter oil in the event of a blowout. Bearded seals, because of their preference for open leads where oil may concentrate, are more likely to be affected, as may be whales such as the beluga and bowhead.

Reductions in the seal population, caused by oil-related stresses, would likely be reflected in subsequent decreases in the numbers of polar bears and white foxes, caused by emigration to marginal habitats elsewhere, and possibly reduced offspring survival. However, it is postulated that these populations can recover in time, if the critical leads and polynias used for feeding and breeding are not chronically polluted.

TABLE 6-4 MAJOR BIRD SPECIES VULNERABLE TO AN OIL SPILL
(ADAPTED FROM BARRY, 1976)

COMMON NAME	SCIENTIFIC NAME	VULNERABLE TIME: Migration May-June	Nesting June-Sept.	Moulting July-Aug.	Staging Aug.-Oct.
Arctic Loon	Gavia arctica	X			
red-throated loon	Gavia stella	X			
yellow-billed loon	Gavia adamsii	X			
common eider	Somateria mollissima	X	X		
king eider	Somateria spectabilia	X	X		
old squaw	Clangula hyemalis	X		X	
white-winged scoter	Melanitta deglandi			X	
surf scoter	Melanitta perspicillata			X	
greater scaup	Aythya marila			X	
black guillemot[2]	Cepphus grylle	X			
thick-billed murre[2]	Uria lomvia	X			
white-fronted goose	Anser albifrons			X	X
snow goose	Chen caerulescens		X	X	X
Pacific brant	Branta bernicla		X	X	X
Canada goose	Branta canadensis			X	
whistling swan	Olor columbianus			X	
sandhill crane	Grus canadensis			X	
shorebirds[1]			X		
glaucous gull	Larus hyperboreus	X	X		
Sabines gull	Xema sabini		X		
Arctic tern	Sterna paradisaea		X		
parasitic jaeger	Stercorarius parasiticus		X		
pomarine jaeger	Stercorarius pomarinus		X		
long-tailed jaeger	Stercorarius longicaudus		X		

1 There are 18 species of plovers and two species of phalaropes included under the heading "shorebirds"
2 The black guillemot and thick-billed murre and included in the endangered species category.

Concerns with respect to fish and fish habitat comprise the fourth element in the biological ranking system. It is generally felt that oil reaching nearshore regions, especially bays and estuarine areas, poses a greater concern to fish, food organisms and their habitat, than does oil in the offshore region. Oil reaching coastal margins could become incorporated into the sediments and marshes, to be re-released over extended periods of time (5-10 years). Through this process, possible deleterious effects of oil to the particularly significant nearshore communities could likewise continue for many years. Possible impacts could be expressed in several ways including direct mortality to fish and food organisms, the replacement of species, tainting, the concentration of hydrocarbons in the food chain, reduced breeding success, etc.

Offshore, oil trapped beneath the under-surface of ice may destroy exposed under-ice biota. The significance of the epontic life to the overall ecosystem is not well understood, although it is believed to represent an important component of the diet of some fish, seabirds and marine mammals. Oil on the water surface offshore would not be expected to have major effects upon the plankton, fish and benthos primarily due to the limited exposure they would receive and their generally ubiquitous distribution.

The effect of shoreline oil spills on the habitat of terrestrial mammals is considered to be insignificant compared to the other elements described. However, the possible effects of oil on arctic fox, wolves, grizzly bear, caribou and reindeer should not be overlooked. For example, during the peak of the summer insect season, large herds of caribou and reindeer retreat to the Beaufort Sea coast, including Richards Island and Tuktoyaktuk Peninsula. The onshore winds of the arctic coast reduce the severity of insect attacks, but more often the animals wade and swim in nearshore waters and bays seeking relief. It is probable that these large ungulates could encounter floating oil along the mainland coast and protected bays; however, the result of such encounters is unknown.

INDUSTRIAL LAND USE

Implications of Industrial Activities

The use of industrial lands will become increasingly important as the hydrocarbon reserves of the Beaufort region are developed. The Company's requirement for these industrial lands will be entirely dependent on the degree of success experienced during the exploratory program and the extent to which the reserves are developed.

This section assumes development of major petroleum reserves in the region and briefly discusses the kinds of impacts and mitigative measures which may be associated with increased land use.

To date the exploratory program has been supported by a small area of industrial land at existing shore facilities. As an example, the Dome/Canmar operations base at Tuktoyaktuk covers 6 hectares serving as a staging area, as well as providing accommodation, materials transfer and construction, repair and maintenance facilities. There is additional land use adjacent to the Tuktoyaktuk and Inuvik airports as well as some office space and apartments at Inuvik. The temporary use of land at natural harbours, navigation/communication sites, gravel pits, etc. has proceeded as needs required.

In total the amount of land required to support present company activities has been less than 10 hectares and is comparable to support facilities used in exploration programmes in Northern and Western Alaska. From a regional viewpoint the impacts of increased land use have been small and localized. Issues have been resolved or continue to be worked out by industry, government and the local population.

Assuming commercial production of reservoirs becomes justified, the preliminary development phase will follow. During this time, onshore activity will be greatly increased with perhaps a peak period of construction lasting 3 to 6 years.

Construction of additional facilities such as deep draft harbours, service bases, treatment facilities, tank farms, marine oil terminals, LNG plants, and pipelines must be carefully sequenced in order that all facilities become operational when oil and gas start flowing from production platforms. The demand for onshore facilities will vary directly with the magnitude of offshore operations.

General Mitigative Measures

Site selection of new shore facilities in support of development will have to minimize adverse environmental and social effects while satisfying industrial requirements.

Where possible, siting decisions should not foreclose other land and water uses, current or subsequent, such as wildlife sanctuaries, parks, approved IBP sites, etc.

It should be noted however, that physical and operational requirements may limit the alternatives for siting onshore facilities. For example, siting a marine terminal or deep draft harbour requires adequate water depth, safe navigation channels, maneuvering room, suitable level land and proximity to offshore rigs and production platforms. These requirements limit the coastal areas that could be used for such a facility. Once all potential alternatives are known, the final choice will depend on environmental, social and economic criteria.

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The use of land for industrial purposes will displace natural habitats causing localized disruptions to flora and fauna. The impact of these disturbances can be serious if wildlife do not have similiar habitats to relocate to, or if industrial lands destroy large tracts of important habitat. In the Beaufort region the impact of increased industrial land use can be minimized by:

1) concentrating new facilities at existing industrial sites
2) proper siting of new facilities
3) locating industrial facilities offshore

Expanding Existing Facilities

Tuktoyaktuk offers several advantages for continuing to serve as a seasonal supply base including; its central location and proximity to offshore operations, the existing harbour, shore facilities, airstrip, support services, labour force and history of successfully working within the community.

With the increased use of Tuktoyaktuk as a service base, industrial land use is proposed to expand by several fold. Facilities would most likely be located south and east of the present base on suitable level land that is well away from existing and other traditional activities (as Figure 6-1 shows).

In excess of 20 hectares of land is suitable for development in the vicinity of the present base and may be sufficient for all future needs. As more industrial land is developed, issues to be resolved within the communitity will include;

- planning to allow sufficient and suitable land for expanding community facilities
- the availability of a large, year round, inland gravel source suitable for community and industry needs.

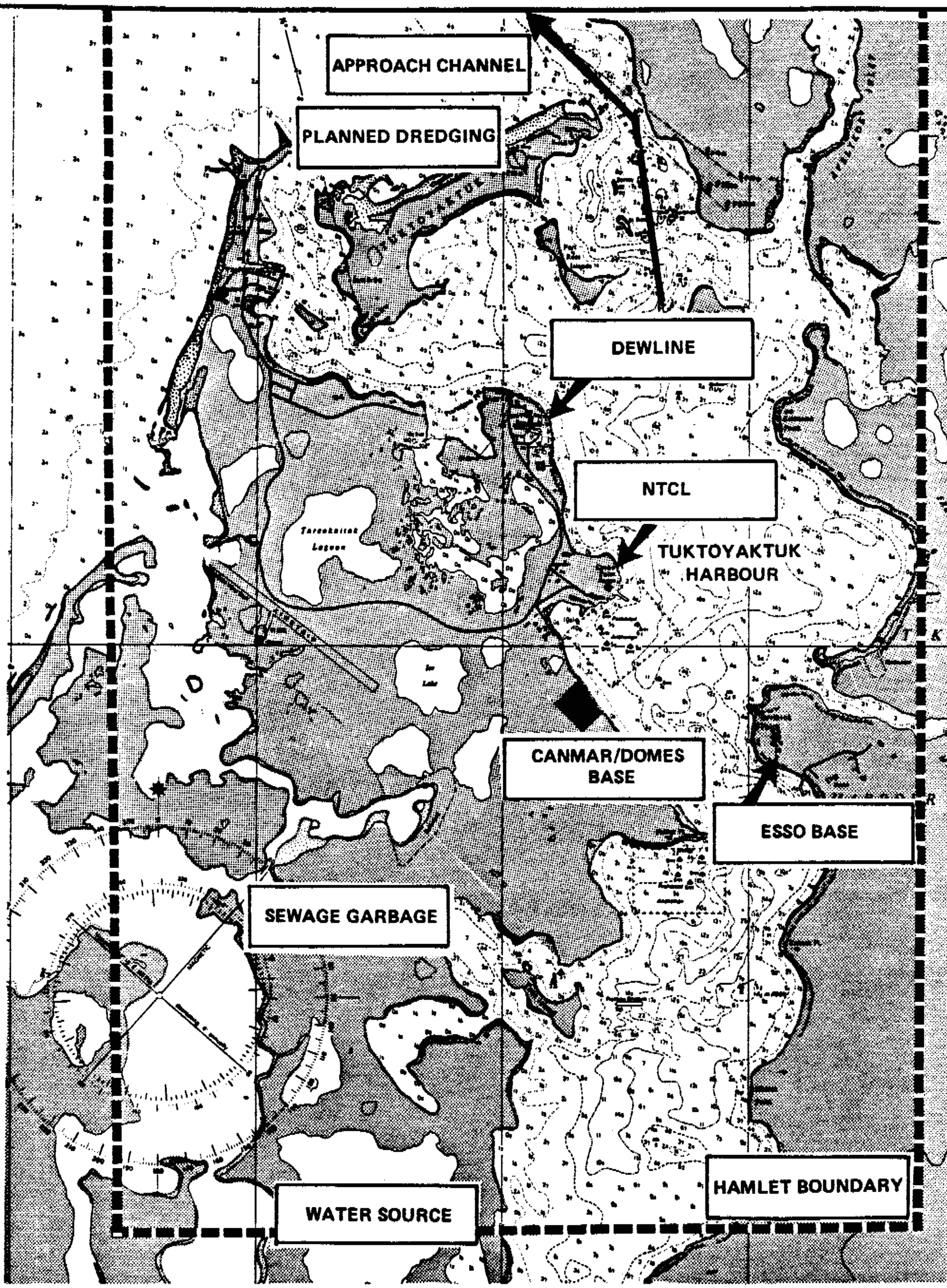


FIGURE 6 - 1

TUKTOYAKTUK AREA

In terms of future development, Inuvik appears to be the most desirable location for Beaufort region admiinstration field engineering and research, as well as regional control of operations, production and communications.

These functions, and the related staff, appear compatible with the existing Inuvik infrastructure, social and environmental setting. Inuvik's role as a regional administration center for the Government of Northwest Territories is an additional reason for locating the Company's regional administration there. Inuvik is also well situated to receive material from Hay River by barge or by road on the Dempster Highway. Housing could be made available in Inuvik to lessen the pressure of expanding housing and community services in Tuktoyaktuk.

Over the period 1980-82 Wise Bay is being developed as a fueling facility for deep draft vessels. Facilities will consist of a 50,000 barrel tankfarm, campsite and an access road to the Cape Parry Dew line strip. The impact of land use and operation of the fueling station is viewed as minor as has been discussed in a recent "Initial Environmental Evaluation". The company has applied for a leasehold interest covering seven hectares.

In the future Wise Bay remains a good candidate for a deep water port and marine terminal, particularly if oil discoveries are made in the eastern Beaufort. The surrounding land is suitable for a shore base, offshore waters are deep, and there are an airstrip and related facilities at the nearby Cape Parry Dew line station. The effect of increased land use at Wise Bay would be localized. However, further investigation is warranted prior to consideration of future expansion.

Siting Future Facilities

It is clear that expansion at Tuktoyaktuk, Inuvik and Wise Bay cannot accommodate all the facilities that may be required during the development phase. As Section 4.4 discussed, there will be a need for additional facilities such as deep draft harbours, western marine oil and gas terminals, and auxiliary requirements such as gravel pits, pipelines and access roads.

A deep draft harbour and marine terminal will be required to develop western Beaufort reserves. As in the Gulf of Alaska, onshore terminals in the Beaufort would require between 30 and 200 hectares of land, near deep water. Most of the land would be used for oil storage, with the remainder taken up by treatment facilities, pumps, pipelines, airstrip, warehousing, camp facilities, office space, safety equipment and buffer zones. The amount of land for storage would largely depend on the terrain characteristics of a specific site.

The only sites that appear to be suitable for a deep draft harbour and marine terminal in the western Beaufort are along the Yukon coast. King Point, along the Babbage Bight appears to be the best.

A wilderness park had been proposed for the Northern Yukon and 38,700 km^2 have been withdrawn prior to final determination of boundaries for such a park.

Possibly the best approach to industrial land use in this area would be the establishment of a development zone. Virtually all significant development facilities on the Yukon coast could be confined within this area, including marine terminals, deep draft harbour, a major airport and related

65 km^2 and would limit environmental and social impacts, while

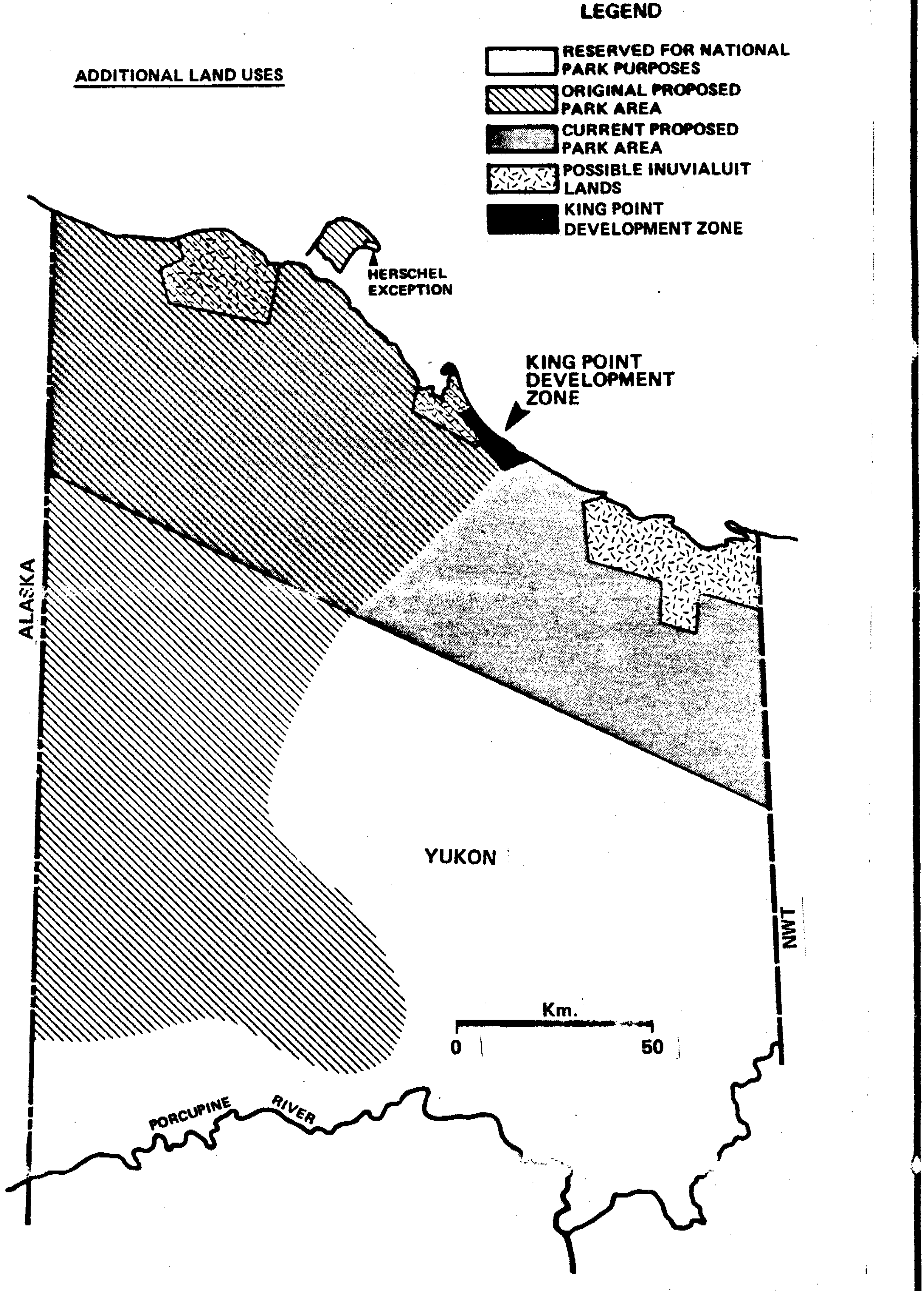
permitting flexibility of facility location, bearing in mind that good construction terrain is intermixed amongst lakes and gravel sources. The 65 km^2 area of proposed development zone represents 0.17% of the 38,700 km^2 withdrawn for wilderness park consideration. It is shown in relation to the withdrawn area in Figure 6-2. A coastal development zone in the northeastern Yukon would tend to be less important as critical habitat to the Porcupine caribou herd. Studies have indicated that the herd shows a preference for interior areas of the coastal plain for migration routes and calving locations. As well, calving on the coastal plain tends to occur west of the Babbage Bight region.

A development zone along the northern Yukon would cause localized changes in marine and terrestrial habitats. A comparatively small amount of terrestrial habitat would be lost while marine habitat would be both added and lost due to construction of protected harbours. Before the specific impacts of a development zone along the Yukon can be analyzed further investigation is warranted.

The last land use category discussed in 4.3 was auxiliary facilities such as access roads, pipelines and gravel sources. Again all these requirements would vary with the magnitude of offshore activity.

In general, onshore pipelines would be limited to corridors used for gathering and transporting offshore and onshore hydrocarbons to a marine terminal site where it would be transferred for tanker shipment south. At a later date, if required, this same gathering system could be modified as a direct overland route to southern markets. Onshore pipelines normally require 15 to 30 m rights-of-way. Where a pipeline comes onshore and product is transported for some distance inland, pumping stations would be required near the land fall

FIGURE 6 - 2


LEGEND
RESERVED FOR NATIONAL PARK PURPOSES
ORIGINAL PROPOSED PARK AREA
CURRENT PROPOSED PARK AREA
POSSIBLE INUVIALUIT LANDS
KING POINT DEVELOPMENT ZONE
ADDITIONAL LAND USES
HERSCHEL EXCEPTION
KING POINT DEVELOPMENT ZONE
ALASKA
YUKON
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PORCUPINE
RIVER

site. Land fall site requirements vary in size. However, by comparison the Forties line in the North Sea has an 8 hectare site. Onshore pipelines, land falls and access routes generally require approximately 1600 m^3 of gravel per km. To minimize land use and impact during such construction it would be important to route facilities on low ice content soils and in proximity to gravel sources while limiting construction during certain time periods. In addition to the location of hydrocarbon discoveries and physical conditions of the land all corridor alternatives would have to take into account socio-economic and environmental protection concerns.

Locating Industrial Facilities Offshore

It may be feasible to locate a major portion of facilities offshore rather than onshore. These options will have to be evaluated on a case by case basis.

Examples of potential options include:

- the Arctic Production and Loading Basin which would be a self contained facility capable of drilling, production, storage, loading, and supply base

- A dredged offshore island and harbour to fulfill the function of deep water harbour and supply base

- The use of sub-sea materials for fill and aggregate where available

CHRONIC POLLUTION

Almost all components of the development scenario generate wastes at one time or another. They may be solid wastes produced during a construction and/or installation phase; liquid wastes associated with drilling, or sewage generated by all activities; or gaseous emissions released by machinery.

Most present significant sources of pollution are already regulated and monitored. Dome's future waste management and treatment practices will continue to comply with prevailng regulatory requirements.

Following current practice, discharge and environmental monitoring programs will be undertaken by both the company and the government, in order to determine compliance with requirements and the environmental implications which may be associated with the releases. The results of these programs will determine the adequacy of the waste management practices employed at the time, and will form the basis for subsequent approaches to the problem as may be necessary.

The following is a summary of the major types of wastes which would be emitted by components of the development scenario, and a review of the general environmental implications envisaged.

The major types of wastes include:

1) Drilling Fluids, Formation Cuttings
2) Produced Water
3) B.O.P. Control Fluids
4) Sewage
5) Process Cooling Water
6) Ballast Water
7) Minor Fuel Spills
   Regulated Discharges
   Chronic Fuel Losses

Drilling Fuilds and Formation Cuttings

Drilling fluids and formation cuttings represent one of the most significant sources of waste effluent generated by Dome's proposed offshore activities. Drilling fluids (muds) are required to lubricate the drill bit and stem; carry drilled formation solids (cuttings) away from the drilling interface and up to the surface; seal the drilled hole against excessive inward or outward fluid movements; and to increase static pressure in the drilled hole to counteract formation pressures which may be experienced.

To date, all drilling wastes produced by current exploratory programs in the offshore Beaufort have been water-based and discharged directly to the sea. From data obtained at the first two Canadian Arctic offshore locations, where stringent control measures were used to limit the quantity of wastes produced, approximately 13,000 barrels (2,067 m^3) of waste, or approximately 1.5 barrels (0.24 m^3) per foot of hole was discharged.

Using 1200 as the number of holes which may be drilled by Dome up to the year 2,000, and the above figure, approximately 15.6 x 10^6 barrels (2.5 x 10^6 m^3) of water-based drilling wastes could be generated during this period. However, it should be noted that this estimate is probably high because in many situations an oil-based mud system may be employed. Under these circumstances, only washed, oil-free cuttings, representing approximately 10% of the total mix, may be discharged to the water column.

The principal environmental concerns associated with drilling fluids and formation cuttings have been the toxicity of the wastes, the effects of turbidity in the water column, the smothering of bottom life, and the possible accumulation of contaminants in sediments and organisms. Since the early 1970's these issues have been the focus of considerable research by both government and industry.

The toxicity of drilling muds is attributed to the wide variety of organic and inorganic chemical components used in the formulation of the fluids. Several hundred drilling mud components and additives are marketed, and many are being employed in current Arctic drilling programs. All those utilized have been approved for use by the regulatory agencies.

The major constituents of drilling fluids, namely barite and bentonite, are considered to be non-toxic. Many of the other additives, however, including metal chlorides, lignosulfinates, biocides, rust inhibitors, defoamers, etc., have been found to be more toxic, with 96-hour lethal response levels to fish being recorded in the range of 10 to 3000 mg/l (0.001 to 0.3% LC50). Laboratory bioassay analyses of whole muds has produced LC50 values ranging from 5 to 50%.

The primary factors influencing the lethality of drilling mud effluents to marine organisms are the potential for buffering, dilution and dispersion of the wastes. Preliminary drilling in the Beaufort Sea off artificial islands located in shallow waters (less than 5 m) often resulted in the discharge of drilling muds into restricted areas. Environmental observations undertaken in the vicinity of these discharges showed that the muds did not disperse in the absence of adequate water circulation. These observations were compounded during winter when in some areas, the effective water depth under ice was further reduced. Under these conditions, with almost no natural dispersion, there was a potential for toxic effects to occur.

Largely as a result of these observations, the government issued "Interim Guidelines for the Disposal of Waste Fluids from Petroleum Exploratory Drilling in the Arctic". The guidelines required an initial pH adjustment and a controlled dilution of the drilling muds with receiving water at a minimum ratio of 25:1 prior to discharge. Subsequently these guidelines were applied and continue to apply to Dome's deeper water drill sites.

The issue of dilution requirements for drilling muds has continued to receive considerably more attention. The most recent studies carried out by a Joint Working Group of the Arctic Petroleum Operators Association and government agencies, have shown that in offshore areas such as Cook Inlet, Tanner Bank, and offshore Louisiana, discharged muds were diluted rapidly. Dilutions of 100:1 and more have been found to be achieved within 100 metres of the discharge point. The industry now generally feels that the prudent selection of drilling fluid additives to reduce initial toxicity, and the natural dispersion and dilution characteristics of the offshore Beaufort receiving area, will ensure that direct lethal effects to marine organisms will be minimized.

With respect to other water column concerns, field monitoring at the offshore Beaufort locations, has demonstrated that pH, temperature, salinity and dissolved oxygen levels were either unaffected entirely, or generally achieved background status within 30 m from the point of discharge. The visible plume associated with the surface release of drilling muds (clay particles) has been detected to extend out to approximately 4 km, depending on the location and water movement conditions prevailing. However, suspended solids and trace metal concentrations have been generally found to reach background within a 200 m radius of the discharge point.

Sedimentation studies have indicated that most solids released settle rapidly, with the majority reaching the bottom within a 200 m radius of the discharge point. If wastes were to build up in such an area, one may anticipate that some benthic animals could be smothered or excluded because of substrate alteration.

Of possibly greater concern is the potential for contaminants, particularly heavy metals, to build up in the sediments and perhaps to become concentrated in marine organisms.

Field studies have shown threefold increases in the sediment concentration of lead, zinc and cadmium near an offshore Texas wellsite. The Tanner Bank work also reported a threefold increase in chromium, and a forty-fold increase in lead. In the nearshore Beaufort at Netserk F-40, Imperial Oil has reported elevated concentrations of mercury, lead, zinc, cadmium, arsenic and chromium in sediments mixed with drilling fluids. However, metal concentrations in the benthic animals inhabiting the area were all at background, with the exception of mercury, where values ranging from < 0.01 - 0.49 µg/gm (wet weight) were found at two stations. Dome's own work in the vicinity of several offshore Beaufort drillsites has shown slight, localized increases in bottom sediment metal values at some sites but no significant concentration of heavy metals in resident biota.

Nevertheless, recognizing that future production drilling activities will be much more concentrated, the concern of contaminant build-up in particular, will merit attention and further evaluation. Studies are currently ongoing to determine the potential for bioaccumulation of mud contaminants by organisms under laboratory conditions. As the first offshore field develops, a comprehensive monitoring program will be required in order to detect possible impacts related to the disposal of drilling wastes such that further mitigative measures, if necessary, may be employed.

Produced Water

Produced water is formation water which is extracted in combination with oil and gas from production wells. Formation water is generally anaerobic and may contain higher chloride and dissolved mineral concentrations than seawater. Upon reaching the surface the water will be extracted from the hydrocarbons by separators, most probably located on the production platform. Since the Beaufort basin fields are projected to be using water injection for pressure maintenance and to enhance oil recovery, a high percentage of produced water will be reinjected into the geological structures.

In the event produced water volumes exceed water injection requirements, the excess produced water would be processed further to ensure that oil concentrations in the water would be less than 50 mg/l prior to discharge. This would represent a chronic source of oil and mineral contamination, the significance of which would have to be evaluated if and when it occurred.

Current exploratory drilling by Dome has resulted in the accidental release of some formation water to the offshore Beaufort Sea. Follow-up investigations by the company have shown that with time the flows have generally diminished. More importantly however, the flows have been found to disperse rapidly and no increases in contaminant levels have been recorded.

If during future production drilling, it is found to be necessary to release large quantities of formation waters directly into the water column, this activity would have to be monitored closely.

Rig Washwater

Rig washwater, as the name implies, is water used to wash down drilling equipment. It would likely also include detergents approved by regulatory agencies. Washwater on all rigs will be collected through an open drain system, treated to reduce oil concentrations to acceptable limits, and discharged to the sea.

B.O.P. Control Fluids

Blow-out preventers require a hydraulic fluid to operate. This fluid is typically a mixture of hydraulic oil water and antifreeze (ethylene glycol). Bioassay testing of a B.O.P. control fluid used during the drilling of the Aquitaine-Polar Bear 0-20 well found that the fluid was lethal to rainbow trout at a 96-hour LC50 concentration of 1.3%. Moreover, ethylene glycol itself has been known to kill aquatic organisms in the range of 100 - 1,000 mg/l (0.01 - 1%).

Where blow-out preventers are mounted on the sea floor, approximately 1 m^3 of B.O.P. fluid will be discharged to the surrounding water each time it is operated. With the dilution the liquid will receive upon being released the impacts which may be incurred by the discharge are considered short term, minor, and highly site specific.

Sewage

Domestic sewage will be generated by all activities. The volume of sewage produced will increase incrementally as the actual production scenario unfolds. This document has estimated that by the year 2,000 the total number of offshore personnel employed could reach 13,500, while approximately 3,000 personnel would be required for onshore support activities. In addition, an infrastructure of presently unknown proportions will develop in the vicinity of shore bases to provide local services to the burgeoning development. For this discussion an associated population of 3,500 is assumed.

Using these figures, and the generation of sewage at a rate of 0.2 m^3/person/day, one may estimate that by the year 2,000 the total daily production of sewage would amount to 4,000 m^3 (880,000 gallons). Potential environmental concerns associated with sewage disposal in the Beaufort Sea center around possible nutrient enrichment, oxygen depletion, and the introduction of pathogens. Adequate sewage treatment, combined with appropriate site selection for discharge of the treated wastes should ensure that none of the possible concerns develop into problems. This should be followed up with effluent and environmental quality monitoring programs to confirm predictions, and/or to detect possible problems at an early stage, thereby permitting further remedial actions to be taken as necessary.

Process Cooling Water

Process cooling water is filtered seawater used as a cooling medium for regulating the temperature of industrial machinery. Process cooling water will be generated by all offshore platforms, shore bases and ships, with the most significant source being the drilling platforms. Approximately 100 m^3 (220,000 gallons) of seawater warmed to between 10 and 40°C may be discharged per day from each drilling platform as a result of cooling functions. Although not normal, cooling water may on occasion contain some oil due to chronic leakage from engines. All cooling water discharges will require routine on-line monitoring in order to detect for the possible presence of oil and to activate remedial measures.

The proliferation of oil, coal and nuclear-powered electric generating plants, with their attendant need for large volumes of cooling water, has given rise to an extensive data base dealing with thermal effects in temperate areas. Extrapolating this data base to the arctic seas, where heat is a limited commodity and most arctic organisms are living near the low end of the temperature range suitable for active life, one may predict that the introduction of some warmer water may generally be more beneficial than detrimental.

Because of the relatively small volumes of heated water which will be discharged, temperature changes to the water column will be extremely localized in aerial extent and depth. A surface discharge will result in the generation of steam fog and a localized lens of warmer water above the cold water column. The heat will dissipate rapidly, and a small ice-free area may be maintained during winter in the immediate vicinity. The subsurface discharge of treated water will produce a plume rising through the water column, thereby providing localized mixing and rapid dispersion of the heat.

Small quantities of plankton entrained in the water drawn from the sea for cooling purposes will be killed. In addition, there may be limited mortality of plankton around the immediate discharge area. Fish will likely be attracted to areas of warmer water, as may be birds such as gulls, who are relatively tolerant of human activities.

In summary the introduction of heat into an extremely cold environment could be judged to be beneficial. The main obstacles to its beneficial use in the present situation appear to be the intermittent nature of the discharges and their possible contamination with oil or other pollutants.

Ballast Water

All vessels require ballast (seawater) to maintain water tanks in icebreaker tankers will be segregated from the hydrocarbon storage tanks to ensure no contact with oil. Some ballast will be taken aboard at southern terminals while unloading the cargo. The bulk of ballast water will be pumped aboard upon reaching the ice edge on route to the Beaufort Sea. Depending upon the time of year, this would generally occur somewhere between Davis Strait and Parry Channel. Upon arrival at a given Beaufort Sea terminal, excess seawater ballast will be discharged. The temperature of the seawater would generally be near 1°C.

Concern has been expressed that the ballast water could contain "chemical pollutants" or plankton organisms brought in from southern waters. The chemical quality of ballast waters could be monitored to ensure that only "clean", approved water was brought on board. The artificial transport of temperate zone or eastern arctic plankton into the Beaufort Sea is not considered to pose a significant problem largely because the area already receives temperate and boreal plankton in parcels of water that move from the north Pacific and Atlantic oceans through the Bering Strait and around Greenland.

Minor Fuel Spills

Fuel spills could take many forms, including crude, Bunker C and diesel oil, hydraulic fluid, gasoline, kerosine, and residues. Releases to the environment could be approved/regulated discharges; chronic losses from leaking valves, machinery, etc., accidental minor spills associated with oil transfer and handling facilities.

The immediate, direct impacts of these input possibilities would be highly dependent upon the specific circumstances surrounding the release, and a host of additional factors. These would include the type, quantity, and rate of oil discharged; the location, time of the year, ambient weather and hydrographic conditions prevailing; the methods and relative success of containment, recovery and cleanup techniques employed; and the types of environment and organisms exposed.

Over the longer term, the incremental build-up of oils from all sources in the Beaufort Sea could have less obvious, perhaps at the time, undetectable negative implications. Conceivably, the so-called assimilative capacity of the Beaufort Sea could eventually be overtaxed, possibly leading to the occurrence of highly significant undesirable consequences. For this reason, and recognizing that science has not yet and may never determine the assimilative capacity of any sizeable water body with respect to oil or any other pollutant, it would be prudent to restrict oil releases to the Beaufort Sea.

For the purposes of this general discussion, the term oil will be used to describe all the varieties of oil which may be released from time to time, except as otherwise indicated.

Regulated Discharges

Regulated discharges of oil may result from drilling mud and formation cutting wastes, produced water, rig washwater, sewage, bilge water and process cooling waters. In all instances the effluents will be treated in accordance with existing regulations to ensure initial discharge concentrations of less than 50 mg/l of oil. The waste sludges generated will likewise be treated in an approved manner, probably by incineration or through on-land disposal.

Comprehensive effluent and environmental quality monitoring programs should be established to determine the immediate zone of influence of regulated oil discharges, and in a larger framework, possible changes to hydrocarbon concentrations in the Beaufort Sea generally. Information obtained should be used to evaluate the adequacy of controls in force, and to modify them, as may be appropriate.

Chronic Fuel Losses

The frequency of occurrence of chronic oil losses from leaking valves, joints, machinery, and other sources must be reduced to the extent possible. This may best be accomplished through regular inspections and maintenance of all likely problem areas. Presumably many of these chronic losses will be captured in the gathering and treatment facilities established for the regulated discharges. Nevertheless, good housekeeping practices will reduce the overall amount of oil likely to enter the receiving environment.

Accidental, minor oil spills of 50 barrels or less may result from a variety of development components or activities, including the rupture, malfunction or overflow of fuel and crude oil lines, and spillages associated with hydrocarbon transfer activities. The solutions to reduce spills will vary from one situation to another but will all be based initially on the principal of prevention.

The major causes of these spills will be due to human error, often combined with natural forces and equipment malfunctions. Intensive operator training programs and regular inspections should help to reduce this human error factor. In addition, equipment and operating procedures must be specially designed to cope with the cold, harsh climate in which they must perform. Valves and fittings must be as simple and fail-safe as possible.

Assuming that all preventive measures prove unsuccessful, and minor spills do reach the receiving environment, the relevant sections of the Canmar Oil Spill Contingency Plan will be applied. The current contingency plan was developed for all activities associated with the exploratory phase of Dome's Beaufort Sea operations. The company's present oil spill counter-measures and cleanup equipment inventory is considered to be one of the largest and most comprehensive of its kind in the country, with a total value in excess of $3 million. Nonetheless, oil spill control and cleanup technology is evolving with each new spill incident and research activity. The company is committed to active participation in these endeavors, with the intent of incorporating all appropriate technological advances into future contingency plans and counter-measures operations for the Arctic.

The environmental implications of minor spills will naturally vary with the prevailing circumstances. Spills occurring in the vicinity of shore bases would probably be expected to have potentially greater environmental repercussions than offshore spills. Sea associated birds would likely represent the most significant component directly affected. The application of appropriate counter-measures such as booms, approved dispersants, scare tactics, and others should ensure that negative impacts associated with minor spills should themselves generally remain minor. More detailed specific projections will have to be developed for each major development component as they arise.

OTHER IMPORTANT ISSUES

This section describes other kinds of concerns which may be associated with ice breaking; the presence of artificial structures; dredging activities and aircraft disturbances; the generation of noise, solid wastes and air emissions, and identifies possible measures which may be taken to mitigate these concerns.

Icebreaking

A unique aspect of the proposed plans for production of hydrocarbons from the Beaufort Sea will be the icebreaking associated with the year-round exploration, production and transportation phases of the project.

All icebreaking activities in the Beaufort Sea Development Area will be limited to areas around drilling platforms and corridors to and from harbours. Much of Dome's current lease area is located within the seasonal pack ice zone, between the permanent pack ice and the landfast ice zone which forms in winter. The seasonal pack ice is generally moving and constantly deforming, resulting in the production of broken ice, ridges, open water areas, etc. Even in mid-winter, some open water may be expected in this region.

As indicated in the scenario, the development of Dome's Beaufort interest lands would take place in an incremental manner over at least a 20-year period. The initial production will be generated from a single platform supported by ice breaking vessels and serviced by two tankers. This will be preceded by exploratory drilling, hopefully on a year-round basis using ADB's. Considering the immense natural variations in ice cover and features within the seasonal pack ice of the Beaufort Sea, Dome does not envisage any significant additional implications for the ice conditions, resulting from ice-breaking activities.

Class 10 icebreaker tankers, assisted where necessary by Class 10 icebreakers, will be used to transport hydrocarbons from the Dome interest production area to southern markets. On the basis of Company investigations, the most difficult stretches of the route will be the area of Viscount Melville Sound from northern Prince of Wales Strait to Bridport Inlet.

Tanker traffic is projected to be initiated by two tankers, building up between 10 and 20 vessels at the peak of tanker utilization. The average round trip travel time to east coast ports will range from 28-35 days, depending on conditions encountered. On this basis, any given portion of the icebound marine route would be broken once per month initially, increasing to perhaps once every 2-4 days when peak transportation is achieved.

There are a number of environmental implications that may be associated with ice breaking. The epontic algae community in and within a few metres of the icebreaker track will be disrupted by changes in light intensity, overturning of ice and physical destruction of ice. Many ice-associated amphipods and arctic cod in the same area will be crushed or exposed on overturned ice. Exposure of amphipods and cod may attract birds to the icebreaker track. If an adequate epontic algal community persists within the track, increased light levels and roughness of the ice undersurface after refreezing may enhance habitat suitability for certain amphipods and for arctic cod.

Some marine mammals, especially ringed seal pups, may be unable to avoid approaching icebreakers and will be killed or injured by collision. Others may be affected by disturbance.

The presence of "artificial leads" will probably benefit birds by providing feeding and resting habitat. Whales that enter icebreaker tracks may be trapped; however this occasionally occurs naturally. Artificial leads in the Northwest Passage area may delay the occasional inter-island movements of muskoxen and caribou.

The recent voyage of the Canmar Kigoriak AMLX-4 icebreaker through the Northwest passage offered an opportunity to make some qualitative, direct observations of possible environmental implications. With respect to the creation of artifical leads with possible subsequent negative implications for mammal entrapment, interference with migrations, etc. the following observations were made.

The Kigoriak was able to produce a clean channel in ice depths up to approximately two feet (61 cm) wide. Thereafter, relatively little ice was cleared out, and in depths of 4 feet (1.22 m) approximately 10/10 ice remained in the channel. In heavy pack ice, as was experienced in Viscount Melville Sound, it was surmised that any arctic animal, including humans, could walk over the ice left in the ship's wake within 200 m of the stern immediately after passage.

Extrapolating up to the larger icebreakers and tankers, it was assumed that a relatively clear channel could be produced in ice depths approaching 4 feet (1.22 m). However, in areas of multi-year pack ice, floes, ridging, etc., which appears to be common particularly in Viscount Melville Sound, and which is generally more than 6 feet (2 m) thick, it was projected that significant percentages of ice would remain in the wake. In addition, the integrity of the artificial lead created by icebreakers will be greatly influenced by winds, currents, and ice pressures. In the case of the Kigoriak trip, it was apparent that under any one or combination of the above circumstances, the surrounding ice pack tended to move in and seal off the lead created very quickly.

The ultimate implications which may be associated with icebreaker traffic through the Northwest Passage will undoubtedly continue to be the subject of considerable debate for sometime to come. It is an area about which facts can only be formulated as a result of experience gained. Responsible environmental monitoring programs undertaken as traffic increases will form the basis for ultimate conclusions regarding this important area of concern.

Artificial Structures

In the broad context, the definition of an artificial structure could include any of the numerous components introduced in the scenario. However, for the purposes of this section, the physical structures include offshore platforms nearshore breakwaters, docks, etc.

As discussed in the section on icebreaking, the physical presence of stationary offshore platforms will have localized implications for ice cover. The same could be stated for nearshore breakwaters and other structures impinging on the coastline. Other physical implications which may be associated with structures, and particularly shore-based facilities, might include local alterations in water circulation, current regimes, sediment transport, and coastal erosion processes. The actual degree of impact will be dependent upon numerous site specific circumstances which will have to be examined in detail as a particular plan for a given area are formalized.

From a marine biological point of view, effects of the physical presence of artificial structures are expected to be primarily beneficial to marine life in the Beaufort Sea. Solid substrates should increase habitat diversity in this predominantly soft-bottomed area. Structures may be expected to be colonized by attached fauna, macrophytic algae, and eventually by resident populations of algae-associated fish. Colonization should take place by recruitment from the plankton, and by immigration of mobile invertebrates and fish from nearby areas. The location and specific physical characteristics of an artificial structure will probably influence the resulting biotic community, as may the quantities and characteristics of effluents discharged in the proximity of the facility. Site-specific field examinations will be required in order to determine the degree of colonization which may occur and the possible physical and biological ramifications.

Except for limited mortality of birds (especially migrating water birds) by collision with structures, the effects of the physical presence of artificial structures on birds and mammals will be insignificant. During winter, assuming that offshore structures are in contact with the moving ice field, polar bears and foxes may be attracted to the operations areas. Proper garbage disposal should ensure that potential problems will be minimized.

Dredging

During the course of development, there will be a continuing major requirement for dredging. The main categories of dredging operations undertaken will include:

1. Dredging to excavate glory holes as required for drilling from floating platforms in less than 54 m of water depth.
2. Dredging to provide materials used in the construction of artificial islands and foundation pads or berms for offshore platforms; and ballast for caisson platforms.
3. Dredging to provide ice-scour protection as required for production trees, manifold templates, pipelines, subsea storage and other possible seafloor systems.
4. Dredging to develop and maintain harbours of appropriate depth and configurations to accommodate future marine fleet requirements.

Estimates of the amount of material dredged for each purpose will vary depending upon site characteristics, needs and other factors (Table 6-6).

TABLE 6-5

Estimated Dredged Material Quantities per Facility

Type of Facility	Estimated Dredged Material per Facility (million m^3)
1) Glory hole	.04 - .05
2) Ballast for Caisson	.70 - .80
3) Pads/berms for Caissons	.76 - 3.8
4) Pipelines	.06 m^3 per Km
5) New Harbour	2 - 6
6) Artificial Island	6 - 15
7) Arctic Production and Loading Atoll	50 - 100

The types and sizes of dredging equipment employed will also vary and could include cutter suction, clamshell, dragline, bucket and/or trailing suction hopper dredges. In addition, under water plows, backhoes, and even underwater bulldozers could be considered for excavating trenches for pipelines, production trees, flowlines and other smaller or linear components.

As a result of Dome's 1979 dredging program in McKinley Bay and past dredging projects in the area a number of physical, chemical and biological impacts can be predicted. Table 6-7 reviews the potential effects.

Experience in the Beaufort has indicated that site specific mitigative measures can be developed and employed for dredging projects in order that negative environmental impacts may be minimized. Concurrent monitoring programs will be required to assess actual operating impacts. The results should be used to modify the specific operation under review, and/or to assist in improving the effectiveness of subsequent mitigative measures.

TABLE 6 - 6

SUMMARY OF POTENTIAL PHYSICAL, CHEMICAL AND BIOLOGICAL IMPACTS

RELATED TO DREDGING IN THE BEAUFORT REGION

PHYSICAL CHEMICAL IMPACTS

- thicker ice and delayed localized ice break-up in spring
- excavations near shore causing localized erosion and/or deposition
- increase in suspended materials, turbidity, and sedimentation rates downstream of dredge
- localized short term reductions in dissolved oxygen (1-2 mg/litre)
- localized changes in vertical salinity/temperature structure
- bottom contours and sediments altered by dredging and deposition of materials

BIOLOGICAL IMPACTS

- whale movements may be affected by vessel traffic
- sounds from operating dredges and associated vessels may disturb whales
- localized alterations in phytoplankton species composition diversity, and productivity due to marked reductions in light intensity within the plume.
- localized, temporary removal and burial of bottom flora and fauna
- permanent depth and salinity changes may affect numbers and species composition of marine animals.

Aircraft Disturbance

Aircraft overflights can disturb birds and marine mammals but are not known to affect other marine organisms. Reactions to aircraft will depend on the species, stage of the life cycle, type of aircraft and its altitude and location.

During the nesting season, geese and arctic terns may flush when aircraft are as high as 300 m above ground level and as far as 2.4 km laterally. However, some duck species do not respond overtly even when aircraft fly overhead at only 40 m above ground level. Observations of cliff-nesting seabirds suggest that safety considerations would usually keep aircraft far enough away from major colonies to prevent severe disturbance. When birds are flushed from their nests, the eggs or young can be dislodged, or exposed to predators or to the elements.

Brood-rearing geese have abandoned feeding areas overflown daily by helicopters, but brood-rearing ducks did not abandon a lake subjected to disturbance by fixed-wing aircraft. Moulting ducks without broods did abandon the same lake but ducks moulting on the sea apparently were disturbed only temporarily by aircraft.

Migrating and staging snow geese are particularly sensitive to aircraft disturbance and flush at distances as great as 3.2 km. Eiders also flush at long distances from aircraft but the reactions of other migrating waterfowl are quite variable. The reactions of spring-migrating waterbirds using offshore leads are not known, but occasional disturbance is unlikely to cause these birds to abandon the few ice-free areas available in spring.

Since sound does not transfer well from air to water, the marine mammals most sensitive to aircraft disturbance are polar bears and those pinnipeds that spend time on land or on the ice. White whales may also be disturbed when in shallow water.

Walruses can be injured or killed when stampeded, but one study found that walruses escaped from land to water only when aircraft were closer than 1.3 km. Disturbance has been implicated in the permanent abandonment of terrestrial haul-out sites by walruses and spotted seals, but this may not have resulted from aircraft disturbance per se.

Ringed seals remain hauled out on the ice for long periods during their epidermal moult in spring. They usually dive in response to an aircraft approaching at low altitude. Polar bears usually flee from low-flying aircraft but occasionally react aggressively.

Disturbance can be minimized by adherence to altitude guidelines and routing aircraft away from areas used by sensitive species. Altitude and routing criteria cannot be set for all relevant situations based on presently available data, but baseline, experimental and monitoring studies should provide the additional information needed.

Noise

Sounds will be generated from all activities whether located onshore or offshore. In the vicinity of shore bases, sounds and activity in general may result in the exclusion of many of the mammals and birds normally frequenting the area. The appropriate application of site selection criteria should ensure that most areas heavily utilized by birds and mammals will be avoided, in the siting of new shore based facilities.

Offshore, sounds will be generated by drilling and production machinery, dredging, ships, aircraft and seismic activities. Above water the environmental implications of these sounds are anticipated to be limited and localized. They may even serve to attract certain predatory animals such as polar bears, which would be undesirable from a human safety point of view.

Underwater sounds may affect the behaviour and movements of marine mammals, particularly whales. Marine mammals make a wide variety of sounds. Some sounds are used for communication, and the odontocete whales (e.g., beluga, narwhal) produce sounds for purposes of echolocation. Marine mammals probably use other natural sounds to provide information about their environment. In order to be detected, the intensity of a sound must be above the ambient noise level, which depends on wind, ice conditions and any artificially-produced noise that may be present. Even if marine mammals can detect the sounds that are important to them, they may still be disturbed by human-induced noise. Potential effects of underwater noise are not as spatially restricted as many other kinds of impacts, since water transmits sound (especially low-frequency sound) efficiently, and since noise will be produced by ships as well as production facilities.

Beluga whales appear to be especially sensitive to sonic disturbance. Human activities (not necessarily noise alone) appear to disrupt their normal movements and may deny them the use of traditionally-used nearshore areas, with unknown r effects on the population. Bowhead whales are also suspected to be highly sensitive to sound.

The noise generated from facilities onshore, offshore, and under water are restricted to small areas and would therefore not affect the normal activity of wildlife. However, because underwater sounds from vessels may affect movements of marine mammals, vessels may be restricted in space and time to ensure normal behavior of marine mammals.

Solid Wastes

Solid wastes, whether scrap metal, other non-combustibles, or combustibles will be produced by all activities envisaged by Dome.

Estimates of the amount of solid wastes which may be generated have been derived from typical quantities produced at current northern construction camps. On this basis it has been determined that approximately 860 kg/day may be produced in association with each offshore platform. The application of appropriate solid waste disposal practices should ensure that undesirable environmental and/or aesthetic problems do not arise. Of particular concern will be the possible attraction of bears, foxes and other scavengers to garbage disposal areas.

The most likely methods of waste disposal to be employed will be incineration and landfill. Emissions associated with incineration, and drainage associated with landfill operations will likewise have to conform with applicable regulatory requirements.

Air Emissions

Air emissions will result from many components of the development scenario. The primary emissions will originate from internal combustion engine exhausts. Typically, they would include carbon monoxide, carbon dioxide, water vapour, smoke, odour, particulates, and oxides of nitrogen and sulfur. Other main sources of gaseous emissions would include those associated with the flaring of gas and the incineration of garbage.

The primary concerns associated with air emissions will be the formation of ice fog, particularly under very cold temperatures with inversions and light wind. A further area of possible concern will be the interaction between fog and pollutants. Concerns regarding atmosphere emissions should be greater in onshore locales than offshore at the drilling platforms. Nonetheless, the application of appropriate, government approved emission controls, plus regular monitoring of the waste gases and receiving atmosphere should ensure that possible environmental implications remain highly localized if they occur at all.

Gas Blowout

In addition to the possible major oil spill, offshore drilling for oil brings with it the risk of a natural gas blowout. Gas could be released in combination with crude oil and/or with other light liquid hydrocarbons. PetroCanada, in their initial environmental assessment of the proposed Baffin Bay drilling program cited the following with regard to this issue.

"The principal hazards to the marine environment resulting from a gas blowout would involve toxicity from hydrocarbons or hydrosulfates, damage to benthos from redistrbution of sedimentary material and from the effects of increased turbidity in the water column. Light liquid hydrocarbons, especially light aromatics, such as toluene, benzene and xylene, represent the more toxic petroleum components. In the immediate vicinity of a blowout one can expect an increase in dissolved hydrocarbon levels, especially methane, and in suspended sediment. In deep water wells it is doubtful that the redistribution of sediment or increase in turbidity would have an appreciable effect on the marine environment as benthic communities would be very limited at that depth. Further, increased turbidity could be expected to decrease phytoplanktion productivity (due to decreased penetration of light) only in shallow waters. Such an effect, if it did occur, may be offset by enhanced nutrient additions through turbulent mixing in the water.

The potential for biological impacts from a gas blowout might be increased should the gas be accompanied by significant quantities of hydrogen sulfide (H_2S) (especially an under-ice blowout). Although detailed studies on the introduction of this type of gas to the marine environment from a blowout are not available, one could expect significant toxicity to marine organisms, possible including marine mammals, where high dissolved concentrations of this highly toxic gas occurred. However, significant quantities of H_2S have not been found in Beaüfort Sea gas to date nor is such expected in the future.

In a study of drilling operations in the North Sea Johnston (1977) considered that the uncontrolled escape of natural gas from the sea bed would generate local concentrations of 3×10^3 mgdm^{-3} at 100 m depths, but that local accumulations would be quickly dispersed to small concentrations. Based on short-term toxicological investigations of the chemical toxicity of natural gas he estimated that the likely range for plankton toxic effects would range from 50-500 mg dm^{-3}, and that, at sub-lethal concentrations, components of the hydrocarbons would be readily metabolized by microbes. As such, the biological impact on fishery resources of a gas sub-sea blowout would be confined to localized damage to plankton. Local marine conditions would probably strongly deter fishes from entering the immediate area. This would include the possible impacts associated with sulfurous materials which would probably also cause local avoidance of fishes and mammals. As such, Johnston (1977) considered that no significant losses were likely to result from a gas blowout to fisheries in the North Sea.

Above the water surface a gas blowout may or may not be burning. If combustion was not occurring, the gas products would be released directly to the atmosphere minus any hydrates formed in the water. With inefficient or no combustion, emissions would consist of carbon dioxide, water, nitrogen, and possibly sulfur dioxides. The greatest concern at this time would be for the safety of personnel assigned to bring the gas blowout under control.

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